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Techno-Economic Assessment of Concentrated Solar and Photovoltaic Power Plants in Brazil

G. S. Torres (UnB), T. A. P. de Oliveira (UnB), A. de L. Ferreira Filho (UnB), F. C. Melo (UnB), E. G. Domingues (IFG)

e-mails: gstorres.ene@gmail.com; tulio.apo612@gmail.com; leles@ene.unb.br; fernando.melo@ene.unb.br; prof.eldergd@gmail.com

Abstract

This study proposes a methodology to assess the techno-economic viability of the implementation of 100 MW solar plants in Brazil, simulated by the System Advisor Model (SAM) software. The solar systems' techno-economic viability is evaluated through the analysis of the annual energy generated, as well as the economic viability indicators, such as the Net Present Value, the Internal Rate of Return, the Discounted Payback and the Levelized Cost of Energy. The results point out that the current economic unfeasibility of CSP systems on Brazil can be overcome with proper incentives to sensible parameters.

Introduction

- Hydroelectric plants constitute about **62**% of the installed power in Brazil. Solar power could improve the diversification of the electric network, taking advantage of **the high solar irradiance levels** on Brazilian territory.
- Large scale plants still encounter many barriers, mainly due to **high costs** and **lack of incentives.**
- Concentrated Solar Power (CSP) systems can generate energy through long periods, causing less environmental impact, **but it is still an incipient technology in Brazil**.
- Four CSP technologies are contemplated by this study: Solar Tower (**ST**), Parabolic Trough Collector (**PTC**), Linear Fresnel Reflector (**LFR**), and Dish Stirling systems (**DS**). Both technical and economic performances are compared to a Photovoltaic (**PV**) plant of the same size.
- A cash flow analysis is employed to evaluate the feasibility of each project, and multiple economic indicators are utilized to compare the performances of the solar systems.

Methodology

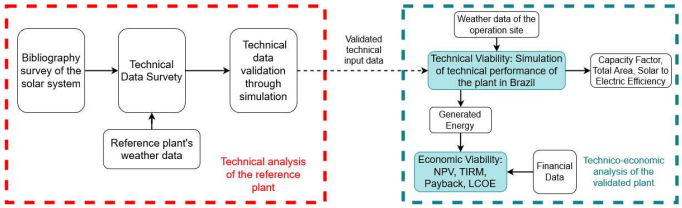

Fig 1. Flowchart of the developed methodology

- Net Present Value: $$NPV = \sum_{n=0}^{t} \frac{C_n}{(1+i)^n}$$
- Levelized Cost of Energy: $$LCOE = \frac{I_0 + \sum_{n=1}^{t} \frac{A_n}{(1+i)^n}}{\sum_{n=1}^{t} \frac{E_n}{(1+i)^n}}$$
- Modified Internal Rate of Return: $$MIRR = \left(\frac{\sum_{n=0}^{t} PCF_n (1+R_r)^{t-n}}{\sum_{n=0}^{t} \frac{|NCF_n|}{(1+R_f)^n}} \right)^{\frac{1}{t}} - 1$$

Results

A. CSP and PV technical and economic performances

Table I - Overview of the technical performance of each of the simulated power plants

	ST	PTC	LFR	DS	PV
Energy produced at year 1 (GWh)	**372.66**	333.39	305.74	185.20	231.88
Capacity Factor (%)	**42.50**	37.80	34.90	21.10	26.50
SEE (%)	16.30	16.56	18.23	**27.48**	17.84
Electrical efficiency (%)	87.86	84.60	91.23	**95.80**	X
Performance Ratio (%)	X	X	X	X	77.4
Total land area (acres)	1613.99	881.00	416.00	**221.99**	364.57

- The **ST** plant has **the best technical performance**, but requires **a large area**;
- DS plants have **better efficiency**, due to their tracking system's characteristics, but still **can't generate much power.**
- **PTC** plant produces about **9%** more energy than the **LFR** plant, but occupies almost **twice the space** of the latter.

Table II - Economic indicators results for the base case

	ST	PTC	LFR	DS	PV
NPV (million USD)	-377.36	-340.26	-321.38	-212.23	**604.87**
MIRR (%)	4.52	4.55	4.43	4.06	**9.65**
Payback (years)	>30	>30	>30	>30	**11.09**
LCOE(%)	0.150	0.152	0.155	0.163	**0.041**

- The energy is sold at electricity auctions, which are carried out by the Chamber of Electric Energy Commercialization (CCEE).
- The **PV system** was the only one to achieve **economic viability**, with overall good results for all indicators.
- Investment at CSP technologies **would not be advised** in this case.

B. Sensitivity Analysis

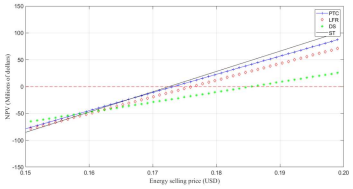

Fig 2. NPV sensitivity to the variation of the energy selling price

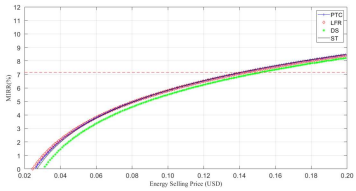

Fig 3. MIRR sensitivity to the variation of the energy selling price

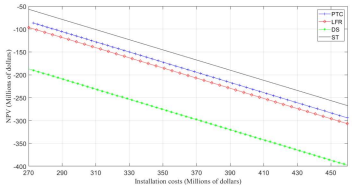

Fig 4. NPV sensitivity to the variation of the installation costs

C. Optimistic Scenario

- Cost reduction of 50% for all CSP technologies.
- Average energy price of USD 88,57 dollars/kWh.
- Reduction of 50% on the electricity transmission tariff.

Table III - Economic indicators results for the optimistic case

	ST	PTC	LFR	DS
NPV (million USD)	**136.95**	114.95	101.65	53.06
MIRR (%)	**8.75**	8.66	8.58	8.53
Payback (years)	**13.43**	13.94	14.40	14.66
LCOE(%)	**0.056**	0.057	0.058	0.059

Conclusions

- The energy results show a **promising future** for the concentrating solar technology in the Brazilian market, specially in terms of **technical performance.**
- CSP technology **is not economically viable in Brazil**, mainly due to the **import dependence**, which elevate the costs considerably.
- Both the sensitivity analysis and optimistic scenario point out that the economic indicators are very sensible to **installation costs** and **auction prices.** With **proper incentives** focused on these parameters, CSP plants could turn to be **very lucrative.**
- **ST** plant is currently the **most attractive CSP technology. PTC** and **LFR** plants have very good performance, considering that both occupy significantly less space.