ECONOMIC SUITABILITY OF SMALL SCALE SOLAR THERMAL POWER PLANTS

JOACHIM KRUEGER

A Thesis Submitted to the Graduate School of Naresuan University
in Partial Fulfillment of the Requirements
for the Doctor of Philosophy Degree in
Renewable Energy (International Program)
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This thesis entitled "Economic Suitability of Small Scale Solar Thermal Power Plants" submitted by Joachim Krueger in partial fulfillment of the requirements for the Doctor of Philosophy Degree in Renewable Energy (International Program) is hereby approved.

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ABSTRACT

The use of solar power as energy source for the general needs becomes more and more important as the climate change demands immediate actions and know-how transfers of suitable technologies. One suitable technology that allows decentralized structures and can be operated by technician is the concentrated solar thermal power plant (CSP). This technology combined with biomass technology allows full, uninterrupted operation for energy supply for different needs in communities, and industries. The technology was developed in the early 20th century and brought to operation in Spain and the U.S. at the late 80th of that century. The proven concept led to the installation of larger quantities in the last years, mainly in Europe and the US. A downscaled design for electricity production in rural areas is a possible solution, where the direct sun radiation permits. In Thailand such a technology has been implemented during the studies for this work and shows the performance of the technology under tropical conditions. This type of technology can be used by industry as well, as its size permits to supply co-generation for production capacities, which need electricity and process heat at the same time.

The purpose of this work is to develop a tool that allows general decision makers to find out, if solar energies can be recommend for their hemisphere under defined conditions. The conditions are discussed, defined and brought into an equation. Mayor parameters are identified and discussed. These drivers brought into the equation are Climate, Investment, Technical Character and Public Impact. To validate the drivers, actual numbers have been developed, which are discussed and defined in this work. These numbers are brought into a range, which can be updated according to future developments. They allow to adopt the equation to various conditions. These values of the drivers are combined with factors for each parameter to find a realistic indicator. The factors are defined in accordance with the Kaiser-Gutman-Criteria and discussed with common assumptions. The equation is resulting in an indicator for solar attractiveness, which allows to identify, if the technology can be used and is viable for the questioned conditions. The equation consists of:

Solar attractiveness = climate + investment + technical character + public impacts

The SOLAR A equation is validated by analyzing existing or planned projects. Positive and negative examples are shown.The developed factors are suitable and show the reality of today solar technology. The factor catalogues as well as the classification need to be surveyed and accepted by a broader audit, but they can be used as a basis to identify on short term basis a value of a project. The results shown in the validation studies of several projects in comparison with commonly used LCOE calculations, come to the result that the SOLAR A figure needs to be higher than 4. A project with SOLAR A = 4 would describe a non-profit, but balanced project like a pilot or demonstration plant. If SOLAR A > 5, commercial status of the projects is reached. It might still be necessary to support the technology in those projects by using feed-in-tariff systems as a public impact.

The economical use of appropriate solar thermal technology in Thailand is possible. The case studies and the SOLAR A equation show in comparison, if the right criteria are met, economical valuable projects can be done even under limited conditions. The validation study for a 5 MW plant in Thailand is technically and economically viable. The IRR is reaching a value of 15.3 %, while the ROE of 14.4 % is a sufficient result as well. The simple payback period of 7.28 years is acceptable.

The LCOE analysis result and business plan prove that the result of the SOLAR A equation is correct as the value higher than 4. The results shown in the validation studies of several projects in comparison with commonly used LCOE calculations, come to the result that the SOLAR A figure needs to be higher than 4. A project with SOLAR A = 4 would describe a non-profit, but balanced project like a pilot or demonstration plant. If SOLAR A > 5, commercial status of the projects is reached. It might still be necessary to support the technology in those projects by using feed-in-tariff systems as a public impact. While the second validation study of a project in south-east Thailand is not profitable and showing a SOLAR A value of 2.95 and the IRR is reaching a value of 4.3 % only, while the LCOE is reaching 17 THB. This result proves that the SOLAR A equation is correct and that this project should not be put into reality as the economic reasons are insufficient. The third project in Spain is showing a SOLAR A value higher than 7 and is therefore technically and economically viable. The IRR is reaching a value of 21.5 % and the LCOE of 6.3 €Ct is comparable to actual production costs of fossil energy and therefore showing grid parity. The LCOE calculations and the SOLAR A equation give the explanation, why this type of technology is used to a large extend in Spain and other countries.

Investment costs for solar thermal power plants are still high and need to be subsidized by state supporting systems, but in future the cost will come down and allow suitable prices for electricity production. Small scale systems need higher financial support as their electricity production cost may reach 0.46 Euro per kWh. At sites with good direct solar irradiation conditions and 5 MW size of the turbines minimum, the price per kWh may drop from 0.11 to 0.19 Euro today to 0.05 to 0.08 Euro in 2020. The investment costs will reduce, but also have to come done in the near future to allow this technology to become mainstream like other green technologies are already. The price of 3,620 €/kW installed today has to drop to 2,600 €/kW in 2015 and 1,900 €/kW in 2020.

The protection of the climate can be supported with the described technology in terms of the CO_2 savings achieved as well as the ecological balances of the used parts which are worthy amounts. Such an equation tool can assist to make the first decisions for renewable energies in countries, where energy production still has to be converted into renewable.

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ABBREVIATIONS

Bar	=	Unit for pressure
°C	=	Unit for degree Celsius
CL	=	Climate
CSP	=	Concentrated Solar Power
DLR	=	Deutsches Institut für Luft- und Raumfahrt eV (German Aerospace Agency; Germany)
DNI	=	Direct nominal irradiation
DSCR	=	Debt service coverage ratio
El	=	Electric
€	=	EURO (currency)
€ct	=	Eurocent (currency)
GW	=	Gigawatt
GWh	=	Gigawatthour
I	=	Investment
IRR	=	Internal rate of return
kW	=	Kilowatt
kWh	=	Kilowatthour
LEC	=	Levelized electricity costs (ECOSTRART; US)
LCOE	=	Levelized costs of electricity (EU)
m	=	Meter
m^2	=	Squaremeter
m^3	=	Cubicmeter
mm	=	Millimeter
MW	=	Megawatt
NPV	=	Net present value
NREL	=	National renewable energy laboratory (USA)
O+M	=	Operation and maintenance
O&MIP	=	Operation and maintenance improvement program
ORC	=	Organic rankine cycle

ABBREVIATIONS (CONT.)

P	=	Power
PI	=	Public impact
PV	=	Photovoltaics
Q	=	Quantity
ROE	=	Return rate on equity
SEGS	=	Solar electricity generating system
SOLAR A	=	Solar Attractiveness
TC	=	Technical character
Th	=	Thermal
THB	=	Thai Baht (currency)
TW	=	Terrawatt