

ห้องสมุดงานวิจัย สำนักงานคณะกรรมการวิจัยแห่งชาติ



E42119

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)

February 2012

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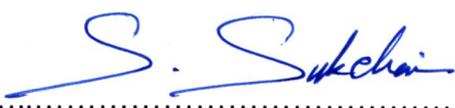
JOACHIM KRUEGER

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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

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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 $\text{SOLAR A} = 4$ would describe a non-profit, but balanced project like a pilot or demonstration plant. If $\text{SOLAR A} > 5$, 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 €/t 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 extent 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 down 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 CO₂ 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.

LIST OF CONTENTS

Chapter	Page
I INTRODUCTION.....	1
Rationale for the study.....	1
Purpose of the study.....	2
Significance of the study.....	2
Scope of the study.....	3
II REVIEW OF RELATED LITERATURE AND RESEARCH.....	5
Types of solar thermal power plants.....	5
World CSP outlook.....	10
Europe CSP outlook.....	13
Southeast Asia CSP outlook.....	16
General statements on CSP worldwide.....	17
Advantages and disadvantages of solar thermal power plants.....	19
Critical parameters for economical use.....	20
III RESEARCH METHODOLOGY.....	28
Equation Models.....	30
Existing Cost Analysing Models.....	31
IEA model for calculating LCOE.....	32
Economic Assumptions.....	32
NREL cost model.....	34
Ecostart.....	39
Economics of concentrating solar power.....	43
Potential for reduction in Operation and Maintenance (O&M) Costs	46

LIST OF CONTENTS (CONT.)

Chapter	Page
IV RESULTS AND DISCUSSION.....	48
Kaiser-Guttman-Criteria.....	48
Factor Discussion.....	48
Selected Criteria.....	50
Case studies.....	68
Conclusion and general model.....	90
V CONCLUSION AND RECOMMENDATION.....	92
Conclusion	94
REFERENCES.....	97
BIOGRAPHY.....	102

LIST OF TABLES

Table	Page
1 Key results from DLR analysis.....	12
2 Multi factor analysis to identify the factors value; own calculation and Kroening.....	49
3 Climate criteria Validation.....	59
4 Electricity Power Size.....	61
5 Price per kW installed in Household.....	61
6 Price per kW installed in Individual.....	62
7 Price per kW installed in Very small.....	62
8 Price per kW installed in Small.....	63
9 Price per kW installed in Large.....	63
10 Solar-electrical efficiency.....	65
11 Solar feed-in tariff binding period.....	67

LIST OF FIGURES

Figure	Page
1 Schematic representation of parabolic dish technology.....	6
2 Schematic representation of central receiver technology.....	7
3 Schematic representation of trough technology.....	8
4 Schematic representation of linear concentrating Fresnel technology.....	9
5 Second stage reflector and absorber.....	9
6 ESTIA-Greenpeace preview for CSP global development.....	10
7 Key results from Greenpeace-ESTIA scenario 2002 to 2020.....	11
8 Key results from DLR analysis in graphic detail.....	12
9 CSP Industry's global focus; Market study 2007; EER.....	13
10 Electricity generation in the Mediterranean until 2050 and CSP potential.....	14
11 Electricity cost in the Mediterranean until 2050 for CSP and other RE...	15
12 IEA preview for small scale CSP process heat station development in Europe.....	16
13 Electricity supply network for Europe, Northern Africa, Near East and Arabia.....	18
14 Location suitability and economical potential for solar thermal power Plants.....	22
15 Feed-in Tariff details of different countries around the world.....	25
16 Flow chart Methodology to develop economical model.....	29
17 Results for a 30 MWe solar only STPP with no hybrid or storage systems.....	33
18 Integrated Performance Model of NREL.....	34
19 Reference 30 MWe SEGS Plant.....	35
20 Near-Term 50 MWe trough Plant.....	36

LIST OF FIGURES (CONT.)

Figure	Page
21 Impact of plant size on cost of electricity.....	37
22 Effect of thermal storage on cost of energy.....	38
23 LEC and sensitivity analysis.....	40
24 Methodology for the cost studies.....	40
25 Comparison between electricity costs for the major CSP technologies....	42
26 Sargent & Lundy LCOE reduction in mid and long term for tower and trough technologies.....	43
27 Cost of electricity for the existing and future trough power plants.....	44
28 Cost perspectives of CSP until 2020.....	45
29 O&M costs and electrical output at Kramer Junction during the years 1992 to 1998.....	47
30 Concentrating solar power resource Potential Map.....	54
31 Concentrating solar power plant Potential Map.....	55
32 Average yearly global radiation (MJ/m ² -day).....	56
33 Simplified Sankey-diagram about radiation impact validation.....	58
34 Feed-in regulations in different countries around the world.....	66
35 The comparison of solar global irradiation from three data sources.....	71
36 The comparison of solar global irradiation between Chonburi / Thailand and Almeria / Spain.....	71
37 The efficiency of solar parabolic trough Solarlite SL4600.....	73
38 The financial results after using.....	77
39 The financial details in a EBIT business plan.....	78
40 The cash flow is behaving positively from the very beginning of the project.....	78

LIST OF FIGURES (CONT.)

Figure		Page
41	The use of ORC machines in different renewable applications.....	80
42	Sankey diagram of the solar energy use.....	80
43	The detailed LCOE calculation shows higher specific investment per kWe installed as the power block includes numerous installations like in large scale power plants. In addition to that, the project is situated on an island and therefore demands higher transportation costs.....	83
44	The business plan.....	84
45	The cash flow is negative in the depreciation period. An extension of this period may bring the cash flow back into positive values.....	85
46	The project shows lower specific investment per kWe installed as scale effects take place. The efficiency of the turbine also has a positive impact on sizing and economic data.....	88
47	The business plan over 25 years.....	89
48	The cash flow is positive from the beginning. After 12 years of payback time for the loan it increases drastically.....	89
49	SOLAR A values of several, different solar projects in Thailand and Europe.....	91
50	The development of solar thermal power plant pricing.....	94

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