

https://dspace.org/

Effect of the environment change from REFIT to REBID programmes by the South African government on the economic viability of solar PV projects

Seveni, Lovemore

2015-05-08
http://hdl.handle.net/10539/17687

Downloaded from a DSpace repository. https://dspace.org/

EFFECT OF THE ENVIRONMENT CHANGE FROM REFIT TO REBID PROGRAMMES BY THE SOUTH AFRICAN GOVERNMENT ON THE ECONOMIC VIABILITY OF SOLAR PV PROJECTS

Lovemore Seveni

A research report submitted to the Faculty of Engineering and Built Environment, University of the Witwatersrand, Johannesburg in partial fulfilment of the requirements for the degree of Master of Science in Engineering.

Johannesburg, 2014

Table of Contents

Declaration iv
Abstract v
Acknowledgments vi
List of Figures vii
List of Tables viii
List of Acronyms ix
1. THE RESEARCH OVERVIEW 1
1.1 Introduction 1
1.2 Problem Statement 2
1.3 Research Questions 4
1.4 Knowledge to be gained 4
1.5 Research Methodology 5
1.6 Research report structure 6
2 THE RESEARCH PROBLEM 8
2.1 Introduction 8
2.2 Novelty 8
2.3 Research Hypothesis 9
2.4 The Concept of Levelised Cost of Electricity (LCOE) in Solar PV [3] 9
2.4.1 Parameters that determine the LCOE 12
2.4.2 Setbacks of the LCOE in PV 15
2.5 Conclusion 16
3 THE SOLAR PV TECHNOLOGY 17
3.1 Introduction 17
3.1.1 PV Technologies [12] 18
3.1.2 Other Components of a PV System [31] 20
3.2 Advantages of Solar PV Technologies 21
3.3 Disadvantages of Solar PV Technologies 22
3.4 Global trends in the deployment of Solar PV 23
3.4.1 The past decade 23
3.4.1 The recent past [48] 23
3.4.2 The future 25
4 OVERVIEW OF THE SOLAR PV MARKET IN SOUTH AFRICA 26

4.1 Introduction to Solar irradiation [9] 26
4.2 Measurement of Solar irradiation [9] 27
4.3 Solar irradiation levels 27
4.4 GHI levels – South Africa context 28
4.5 The South African Renewable Energy Market [14, 51] 30
4.5.1 The REFITs Phase I & II [22, 23, 37, 53] 31
4.5.2 Promulgation of the IRP2010 33
4.5.3 The REFIT Review [51] 33
4.5.4 The change from REFIT to REBID Process 35
4.6 Conclusion 38
5 BARRIERS AND SUPPORT SCHEMES TO THE DEVELOPMENT OF THE RENEWABLE ENERGY MARKETS 39
5.1 Introduction 39
5.2 Barriers to renewable energy development 39
5.2.1 Costs and pricing 39
5.2.3 Legal and Regulatory 40
5.2.4 Technical barriers [34] 41
5.2.5 Market Performance 41
5.2.6 Social Barriers [28] 42
5.3 Overview of renewable energy support schemes 42
5.3.1 Consistent rules and policies 43
5.3.2 Reduction in administrative lead times for approval 44
5.3.3 Simplify and adjust support schemes 44
5.3.4 Clear rules of ownership and control of RES facilities 44
5.3.5 Feed-In Tariffs Mechanisms 45
5.3.6 Renewable Portfolio Standards (RPS)/Quota system 46
5.3.7 Competitive bidding 47
5.3.8 Investment Tax Credits (ITC) 48
5.3.9 Production Tax Credit (PTC) 48
5.3.10 Clean Renewable Energy Bonds (CREB) 48
5.3.11 Accelerated depreciation 49
5.3.12 Capacity payment tariff 49
5.3.13 Buy down capital cost 49
5.3.14 Carbon credits 49

5.3.15 Other Tax Incentives 50
6.4.1 Germany (8, 12) 51
6.4.2 Italy [8, 12] 52
6.4.3 USA [8, 12,33] 52
6.4.4 Japan [8, 12] 53
6.4.5 China [8, 12,30] 53
6.4.6 Spain [4, 8,12] 54
6.4.7 France [8, 12] 54
6.4.8 Belgium 55
6.4.9 Australia [2, 47] 55
6.4.10 Czech Republic 56
6.5 Conclusions on PV support schemes in the top ten countries 56
7. ANALYSIS OF THE ENVIRONMENT CHANGE ON THE VIABILITY OF SOLAR PV PROJECTS UNDER REBID VERSUS UNDER REFIT 58
7.1 Overview 58
7.2 Solar PV qualification criteria under the REBID 59
7.2.1 Bid Price 59
7.2.2 Other criteria 59
7.3 Trends in the Solar PV REBID Prices 60
7.4 Solar PV REBID Prices versus Projected REFIT Rates 61
7.5 Solar PV REBID Prices versus International benchmark prices for PV 63
7.5.1 Approach to benchmark comparisons 63
7.6 Benchmarks and Forecasts for Solar PV LCOE 65
7.6.1 Benchmark Studies 65
7.6.2 LCOE Calculation Assumptions Adopted for the South African PV Market 69
7.7 Results of the Solar PV LCOE Calculation 72
7.7.1 Analysis of Results 73
7.7.2 Accuracy of Results 74
7.8 Discussion of Results 74
8. CONCLUSIONS 76
8.1 Recommendations 77
References 79

Declaration

I declare that this research project is my own unaided work. It is being submitted for the Degree of Master of Science in Engineering to the University of the Witwatersrand, Johannesburg. It has not been submitted before for any degree or examination to any other university.

_____

Lovemore Seveni

_____Day of _____Year _____

Abstract

South Africa is amongst the world's top emitters of GHG but this is set to change as the government has taken steps to address the dependence on fossil fuels. The first step was when a Renewable Energy White Paper (REWP) was published in November 2003 intended to give much needed thrust to renewable energy. Based on the REWP, the National Energy Regulator of South Africa (NERSA) in 2009 announced Renewable Feed-In Tariffs (REFITs) for various technologies including solar PV that was designed to attract investors. However, in 2011, before the first REFIT projects were implemented or approved for implementation, the Department of Energy (DoE) announced that the procurement of new generation capacity, in this case renewable energy, was to be procured through a competitive bidding process in order to reduce the price of supplying renewable energy. The programme is now termed "Renewable Energy Bidding Programme (REBID)". This change was not well received by project developers who had been attracted by the REFITs in the first place. The research report presents an analysis of the two methods of procuring solar PV to determine if the South African made the right decision by abandoning the REFIT model in favour of the REBID model. A theoretical evaluation with established solar PV markets and benchmarks is carried out, as well as a calculation of the cost of producing electricity using an Excel model. These are compared with the average REBID prices as announced by the DoE. The analysis done in this report concludes that the South African government took the right decision of abandoning the REFIT model in favour of the REBID model. It is further concluded that the REBID model adopted is well designed and will ensure that solar PV projects are viable in South Africa.

Acknowledgments

I would to like thank everyone who inspired and encouraged me to complete my research project.

To the Almighty God, thank you for the life and strength that kept me going throughout the period of preparing this work. .

To my supervisor, Dr John van Coller, thank you for all your guidance, vision and initiative as well as your patience from the inception to the end of this project work.

To my co-worker and fellow research mate, Tamai Hore, thank you for sharing the stressful moments and information and creating a spirit of fear of failure amongst ourselves throughout the research project.

To my partner and kids, Trish Ashirai and Joshua Nqobile, thanks for your love and encouragement and patience as I sacrificed some of your dad time working on this project.

To my dear parents, Daniel and Lillian Seveni, your desire to empower me with education will always be cherished. Thank you for your love, support and patience.

List of Figures

Figure 1: Photovoltaic Effect [12] 17
Figure 2: Cumulative PV Installed Capacity Globally [48] 23
Figure 3: Share of PV Installations per region [48] 24
Figure 4: Annual Sum of GHI for South Africa (average 1994-2012) [50] 29
Figure 5: Technology Allocations as per Ministerial Determination 37
Figure 6: Share of Preferred Bidders by Technology Phase 1 37
Figure 7: Share of Preferred Bidders Capacity by Technology Phase II 38
Figure 8: Map of Support Schemes in Europe [12] 57
Figure 9: Average Solar Bidding Prices for the REBID Windows 60
Figure 10: Solar PV REFIT Tariffs, Review and Projections 61
Figure 11: Comparison of REFIT Review Projections and average REBID Tariffs 62
Figure 12: Average Module Price Decline by year in $/Watt [43] 63
Figure 13: Typical Cost Components of Solar PV Installed [34] 64
Figure 14: Comparison of Chinese LCOE Projections with average REBID Prices 65
Figure 15: Comparison of North Carolina LCOE Projections with average REBID Prices 66
Figure 16: Comparison of the US EIA 2018 Solar PV LCOE Forecast with average REBID Prices 67
Figure 17: Comparison of the Lazard Solar PV LCOE Analysis with the average REBID Prices 68
Figure 18: LCOE vs. Loan Term 73
Figure 19: Calculated LCOE vs. average REBID Prices 73

List of Tables

Table 1: Comparison of installed solar PV capacity and mean GHI [48] 30
Table 2: REFIT PHASE 1[37]..... 31
Table 3: REFIT PHASE II [53]..... 31
Table 4: Financial Assumptions for REFIT Phase I & II [37, 53] 32
Table 5: Proposed REFIT Review Tariffs [51] 34
Table 6: REFIT Review Financial Assumptions[51] 34
Table 7: Solar PV REBID Window Average Price Drops 61
Table 8: Summary of Calculated LCOE Results..... 72

List of Acronyms

Acronyms	
AC	Alternating Current
AEO	Annual Energy Outlook
a-Si	Armophous Silicon
BOS	Balance-of- System
CAD	Canadian Dollar
CDM	Clean Development Mechanism
CdTe	Cadmium Telluride
CIGS	Copper, Indium, Gallium, (di) selenide/ (di)sulphide
CIS	Copper, Indium, (di)selenide/(di)sulphide (CIS).
CPI	Consumer Price Index
CREB	Clean Renewable Energy Bonds
CSP	Concentrating Solar Power
DC	Direct Current
DoE	Department of Energy
DSSC	Dye-Sensitised Solar Cells
EIA	Energy Information Agency
EPBT	Energy Pay Back Time
ERA	Electricity Regulation Act
FIT	Feed-In Tariff
GHG	Green-House Gases
GHI	Global Horizontal Irradiation
GWh	Giga Watt-hour
IEA-PVPS	Energy Information Agency - PhotoVoltaic Power Systems
IEP	Integrated Energy Plan
IPP	Independent Power Producers
IRP	Integrated Resources Plan
IRR	Internal Rate of Return
ITC	Investment Tax Credits
kW	kilowatt
kWh	kilowatt-hour
LCD	Liquid Crystal Display
LCOE	Levelised Cost of Electricity
Mtoe	Metric Tonne Oil Equivalent
MW	Megawatt
MWh	Megawatt-hour
NERSA	National Energy Regulator of South Africa

NFFO	Non-Fossil Fuel Obligation
NPV	Net Present Value
NREL	National Renewable Energy Laboratory
O&M	Operations and Maintenance
OPV	Organic Photovoltaics
PFMA	Public Finance Management Act
PPA	Power Purchase Agreement
PTC	Production Tax Credit
PV	Photovoltaic
R&D	Research and Development
REBID	Renewable Energy Bidding
REC	Renewable Energy Credits
REFIT	Renewable Energy Feed-In Tariff
REIPPPP	Renewable Energy Independent Power Producers' Procurement Programme
RES	Renewable Energy Sources
REWP	Renewable Energy White Paper
RFP	Request for Proposal
ROI	Return On Investment
RPS	Renewable Portifolio Standards
TOU	Time-of-Use
TRECS	Tradeable Renewable Energy Certificates
UNFCC	United Nations Framework on Climate Change
UV	Ultra-violet

1. THE RESEARCH OVERVIEW

1.1 Introduction

The advent of major industrialisation in the globe has led to unprecedented levels of Green House Gas (GHG) emissions that are responsible for the deterioration of the ozone layer. Depletion of the ozone layer has been identified as the major cause of the frequency and magnitude of natural disasters as well as marked increase in the temperature of the earth. A large proportion of these GHG emissions are as a result of generation of electricity especially by countries like South Africa which is heavily dependent on coal for the generation of 95% of its electricity requirements. The electricity sector contributes over 60% of the GHG emissions in the energy sector. These adverse climatic conditions has led world leaders to negotiate to have legally binding agreements on GHG emissions reductions such as the Kyoto Protocol that was adopted by the United Nations Framework on Climate Change (UNFCC) in 1997 and entered into force in 2005. South Africa, as a signatory to the treaty, is also expected to have reduced its combined GHG emissions by at least 5 % compared to the 1990 levels over the period 2008-2012.

To achieve these targets, the South African government through the then Department of Minerals and Energy (now Department of Energy), set the tone for the development of renewable energy by publishing the Renewable Energy White Paper (REWP) in November 2003. The policy document was intended to give much needed thrust to renewable energy; a policy that envisaged a range of measures to bring about integration of renewable energies into the mainstream energy economy. To achieve this aim the SA Government set its target at 10 000 GWh (0.8 Mtoe) renewable energy contribution to final energy consumption by 2013, to be produced mainly from biomass, wind, solar and small-scale hydro. The renewable energy would be utilised for power generation and non-electric technologies such as solar water heating and bio-fuels. This is approximately 4% (1667 MW) of the projected electricity demand for 2013 (41539 MW). This is in addition to the estimated existing (in 2000) renewable energy contribution of 115 278 GWh/annum (mainly from fuel wood and waste). The REWP also committed the country to the development of a practical implementation plan to achieve the targets set. A Renewable Energy summit was held in March 2009 and came out with a resolution that the review envisaged in the REWP 2003 would be taken by the end of 2009/10, with a view to publish it by end of 2011 but this did not happen [27].

Based on the White Paper, the National Energy Regulator of South Africa (NERSA) in 2009 announced Renewable Energy Feed-In Tariffs (FITs) for various technologies including solar PV that were designed such that they are high enough to interest investors. Indeed high levels of interest were shown by developers of Renewable Energy Sources (RES) from all over the world and investments in research started to be undertaken which meant that there was a great deal of investor confidence in the FITs. It was designed as a temporary mechanism that would further drive the cost reductions and economies of scales in the development of RES especially solar PV. NERSA itself was flooded with applications from potential investors in all the technologies included and discussed later in the document.

However in 2011, before the first projects were implemented or approved for implementation, concerns were raised about the tariffs being a burden on consumers especially the significant high population of unemployed and poor South Africans who required this basic commodity at an affordable rate. In light of this, the Department of Energy (DoE) through a Ministerial Determination as allowed for by ''the Act'', Electricity Regulation Act (Act 4 of 2006) Section 34(1), stipulated that the procurement of new generation capacity in this case renewable energy was to be procured through a competitive bidding process in order to reduce the price of supplying renewable energy. The programme had come to be termed the ''Renewable Energy Bidding'' (REBiD). Simply put, the company with the lowest production costs will be able to ask for the lowest price and will finally get the order. The project developer enters a contract which guarantees that the electricity will be bought over a defined period of time (power purchase agreement).

1.2 Problem Statement

In a bid to achieve the initial target set by the government in its White paper on Renewable Energy in 2003 of having 10000GWh of the electricity generated in South Africa coming from RES, the National Energy Regulator announced Renewable Feed-In Tariffs (REFIT) in two phases namely REFIT Phase I and II in March 2009 and, after receiving comments from the public, October 2009 respectively. The technologies covered under these FITs were:

Phase I – Onshore wind, small hydro, landfill gas and concentrating solar trough with 6 hours storage and;

Phase II – Concentrating solar power (CSP) trough without storage, large scale grid connected PV (≥1MW), biomass solid, biogas and CSP (Tower) with 6 hours storage.

This project will however focus on large scale grid connected photovoltaic (PV) with a capacity greater than 1MW which was announced under Phase II with a feed-in tariff of R3.94/kWh. This approach was in line with the approach adopted by many other emerging markets to promote renewable energy and generated substantial interest from the local and international community.

However, no projects were executed under this regime as the Minister of Energy according to Section 34(1) of the Electricity Regulation Act, 2006 (Act No. 4 of 2006) issued a determination regarding the Independent Power Producers (IPP) Procurement programme under which renewable energy would be procured. The method of procurement was through a competitive bidding process with ceiling price/price caps per technology which were not the same as the ones promulgated under the FIT regime.

The National Energy Regulator of South Africa (NERSA) subsequently concurred on its meeting of the 07th July 2011 with the Ministers determination as required by ERA (Act No. 4 of 2006).

The price cap for power generated from solar PV was set at R2.85/kWh for the first and second RFPs, while it was set at R1.40/kWh for the third round onwards. Potential bidders are expected to bid either at or below the ceiling price.

In light of the above developments, this project seeks to explore the impact this change of policy is likely to have on the development of solar PV projects in South Africa. It seeks to determine whether and how investor confidence and bankability of solar PV projects is likely to be affected by this change in approach.

Benchmark studies of developed solar PV markets will be conducted especially in mature markets.

The concept of the levelised cost of electricity will be used to compare the two approaches as well as current trends in solar PV costs from international markets.

1.3 Research Questions

The research work seeks to address the following questions:

1. Why did the South African government opt for a bidding process instead of a guaranteed fixed price (REFITs) for procuring renewable energy?

2. What has been the approach of other developed nations to enhance the development of solar PV as part of their generation portfolios? What levels of success were achieved overseas studies regarding REFIT vs. REBID to measure the level of success especially the economic aspects of PV?

3. What are the likely effects on investors of the change from the REFIT to the REBID programme with regard to solar PV projects? Is there a guarantee that the selected projects will be delivered as planned by the qualifying bids potential winners?

4. What are the risk factors related to funding for the projects e.g. banks are responsive to the introduction of a bidding process versus a feed-in tariff regime in a new market where the project risks are higher risk?

5. What are the merits and demerits of procuring solar PV through a feed-in tariff versus a competitive bidding process?

1.4 Knowledge to be gained

The generation of electricity from solar is not an entirely new concept on the African continent and the world at large. Various applications have used solar energy as a source of power such as in robots, orbital satellites, telecommunications equipment located in remote locations and off-grid domestic/commercial sites especially in remote areas where it is not economical to run power lines. However, the introduction of large-scale solar PV plants is fairly new in the African market in general and Sub-Saharan Africa in particular [16].

The recommendations and conclusions of this analysis are expected to assist in the selection of the right approach in the introduction of solar PV in emerging markets

especially on the African continent. An informed approach to the promotion of solar PV will ensure that there is an orderly development of the industry, which will contribute to the development of the host countries economically and environmentally such as the creation of jobs and better living standards for the host country.

The outcomes will assist policy makers, regulators and prospective solar PV developers intending to promote the introduction of solar PV on how to successfully introduce RES in general and solar PV in particular, by avoiding pitfalls that have resulted in projects failing to take off. Governments will formulate polices, regulators will provide the appropriate regulatory framework that will not stifle projects. The aspects covered in this report will include regulatory aspects, economics of solar PV as well as environmental issues.

1.5 Research Methodology

The report will assess the attractiveness of solar PV projects in South Africa based on the solar irradiation levels, comparing these to other locations in the world that have successfully built and integrated solar PV at utility scale. The report will also explore the concept of solar PV power generation, covering the solar PV technologies that are currently available on the market. Emerging technologies are also briefly looked at taking into account costs and efficiencies.

An overview of various support schemes for renewable energy technologies specifically solar PV in other countries will be shared and evaluated against their success. Other non-incentive based schemes that have been used during the introduction of renewable energy technologies will also be discussed.

The advantages and disadvantages of each scheme will be discussed in detail. A closer analysis of the REFIT scheme versus the REBID scheme in general will be done especially how the cost and performance of such projects would fare under the two schemes in the South African context.

The viability of the actual solar PV projects based on bid prices that are awarded to the successful bidders versus the initially proposed FITs, together with the review that was done a year after their announcement will be analysed in order to determine the likely

effect such changes would have on project executabilty. Conclusions on the South African competitive bidding process versus the feed-in process for solar PV will be explored in detail.

1.6 Research report structure

The research report comprises of eight chapters that describe the different components of the research which will culminate in the conclusions of the report. The chapters are organised as follows:

Chapter 1: This chapter gives an introduction to the research work, defines the problem and then presents the proposed research methodology.

Chapter 2: This chapter gives an overview and an introduction to the research problem at hand. It also covers the rationale for embarking on the research work and its novelty. It further discusses the concept of the levelised cost of electricity (LCOE) as a methodology to determine the viability of generation projects including solar PV.

Chapter 3: This chapter covers the solar PV power generation, its history and developments over time across the globe. It will also cover the rationale for using it as a preferred power generation technology, the various technologies that are available on the market as well as other emerging technologies will also be covered. Past, present and possible future trends in global solar PV installations are also covered including costs and penetration.

Chapter 4: This chapter will focus on the solar resource availability in the South African market as well as its route to the introduction of renewable energy technologies in general and solar PV in particular. It will cover the policies, mechanisms and regulations that were put in place to promote the solar PV market by government and its various organs. The processes and rationale for introducing the REFIT will be covered as well as the introduction of the REBID and the reasoning thereof. Key aspects of both policies will be discussed as well.

Chapter 5: This chapter discusses the barriers that have been determined as deterrents to the development of RES in general and solar PV in particular. These barriers represent the international experience and will differ from location to location. In addition, some

support schemes designed to address the barriers are discussed and how they assist in ensuring that RES projects are actually built and operated.

Chapter 6: This chapter covers the various policies that were adopted by the top ten markets in terms of installed solar PV capacity up to 2012. It briefly explores the journeys taken by each of the countries and how they got it right, including legislative and regulatory decisions. These countries are mainly in Europe which is the current continental leader in terms of PV installed capacity. It also looks at how the different policies managed, or failed to stimulate the development of solar PV.

Chapter 7: This chapter will analyse the impact of the policy change from REFIT to REBID on the viability of solar PV projects in South Africa. The Energy Regulator's decision to revise the REFIT after the first year will also be discussed and comparisons with the REBID and benchmarks from other jurisdictions. A levelised cost calculation for solar PV will be done for the South African market to assess the viability of solar PV projects. The comparison will also assess the financial assumptions that are used. The impact of learning curves of solar PV modules on the overall cost will be taken into account during the assessments.

Chapter 8: Lastly, the conclusions are presented and the proposed recommendations regarding the best approach during the introduction of solar PV in emerging markets such as South Africa.

2. THE RESEARCH PROBLEM

2.1 Introduction

The South African government has pledged to reduce its total annual GHG emissions by 4% below its business-as-usual level by 2020.

In this regard, The Energy Regulator, NERSA, published REFITs in 2009 which were well received by the industry as they offered a guaranteed tariff for a period of 20 years which would be escalated by the Consumer Price Index (CPI) and revised annually for the first five years, and once every three years thereafter.

However, in 2011 the SA government launched a different incentive instrument to realise this objective by introducing the Renewable Energy Independent Power Producer Procurement Programme (REIPPPP) whereby the lowest bidder is awarded a long term Power Purchase Agreement which should be less or equal to the cap set for a particular technology. This has come to be known as the Renewable Energy Bidding Programme (REBID) which is currently underway with Round 1 and 2 already having closed and reached financial close.

What has been significant with the REBID is that the bidding price has reduced by almost 28.5% (weighted average) from round 1 to 2 due to increased competition as bidders clamour to get the contracts. Solar PV projects were affected by the competition and registered significant drops in the bidding prices between the first and second rounds of the REBID as will be discussed later.

2.2 Novelty

The research seeks to analyse the two incentive schemes that have been introduced at utility scale in the South African renewable market, namely REFIT and REBID with respect to solar PV technology. The intention is to assess the impact on the viability of the projects that was introduced by change of scheme from the REFIT to the REBID. The work seeks to explore the balance between developer's need to acquire contracts versus the actual costs and returns from solar PV projects. This will culminate in recommendations on whether the decision to adopt REBID over REFIT would affect the

development of the solar PV projects. The assessment is novel and to the best knowledge of the author, no work has ever been done to analyse the two different approaches, bearing in mind that most of the plants are yet to be commissioned.

2.3 Research Hypothesis

There is no doubt that solar energy will play a vital role in ensuring that South Africa reduces its GHG emissions as well as diversifying its energy mix. However, solar PV (together with other renewable energy technologies) is still more expensive than conventional sources such as coal. To reap the benefits associated with solar energy, it is necessary to have support mechanisms in the initial stages of its development. There are various mechanisms that have been used around the world with varying degrees of success of stimulation of the solar PV markets. South Africa had initially opted for the route of FIT but this was changed to the REBID model.

It is hypothesised that solar PV deployment and growth in South Africa is likely to be successfully delivered if a policy of FITs is pursued rather than REBID. The latter system is more likely to attract numerous and lowly priced bids which might not materialise in actual built projects being delivered. The report seeks to prove that a solar PV incentive scheme based on the REBID is not a well suited economic model for an emerging market such as South Africa as developers will seek to acquire contracts at all cost, with a lower likelihood of successful project implementation and delivery. The economic analysis and resultant comparison will be based on the levelised cost of generating electricity from solar PV. The concept allows comparisons to be made between the cost and performance of different technologies, as well as comparing similar technologies that are developed in different conditions such as different levels of solar irradiation.

2.4 The Concept of Levelised Cost of Electricity (LCOE) in Solar PV [3]

Although sunlight is free, capturing its rays to generate electricity is a capital intensive undertaking with high upfront costs but low operational costs [31]. To determine how much is required to capture the sun's energy, the concept of LCOE will be used in this

report. The LCOE can be thought of as the price at which electricity must be sold in order to break even, over the lifetime of the technology [53].

The levelised cost is often cited as a convenient summary/measure of the overall competitiveness of generating technologies. Decisions on whether to invest in a particular technology are not only based on the upfront capital costs of the technology as this would not give a fair comparison, but rather on the life cycle cost and a reasonable payback of investment into consideration [46]. Without accurate information on the relative costs and benefits of various renewable energy technologies, governments are not able to arrive at an accurate assessment of which renewable energy is most appropriate for its circumstances [57]. Although the economic feasibility of any project, including own generation projects, is typically evaluated using metrics such as Return On Investment (ROI) and Internal Rate of Return, the LCOE is the most commonly used toll to determine the competitiveness of a project for policy makers and project developers alike [25]. Project developers, as is the case with any project, would expect a reasonable investment return and this normally determines the level of investor stimulation. [40]

Typically different generation technologies have very different investment costs and life spans making it difficult to compare. However, the LCOE enables these to be compared on a similar basis which is normally quoted in cost per kWh cost such as Rand/kWh [12].The costs cover the investment, construction and operation of the generation plant over an assumed life and duty cycle. The operational costs include fuel and replacement of equipment during the life of the plant. It remains the most transparent consensus measurement of generating costs and is widely used for comparing costs of different power generation technologies.

For utility scale PV projects such as the one under discussion, there is normally third party ownership financing and the project recovers its costs through electricity sales. The LCOE in this case will be the cost per unit of energy that when multiplied by the total energy produced by the plant over its life and discounted to the base analysis year, is equivalent to the net present value if the project required revenues over the project given a set of financial assumptions. While the LCOE is a convenient summary of the competitiveness of a particular technology, actual plant investment decisions are affected by the specific technological and regional characteristics of the project. [46]

The LCOE is a target (i.e. it's a calculated value) rather than the actual that might be generated from the actual project. This is summarised in the word formula and mathematical formulae as shown below in equation (1) and equation (2) respectively.

$$LCOE = \frac{Total\ Life\ Cycle\ Cost}{Total\ Lifetime\ Energy\ Production} \quad (1)$$

$$LCOE = \frac{\sum_{t-0}^{T} \frac{C_t}{(1+r)^t}}{\sum_{t-0}^{T} \frac{E_t}{(1+r)^t}} \quad (2)$$

Where E_t is the energy produced by the project in year t, calculated based on solar radiation and other climate data, T is the project life in years, C_t is the required project revenue due to the electricity sales in year t and r is the discount rate [27]. The system energy production is a key factor in the calculation of the LCOE and is calculated by determining the annual production over the life of the plant, which is then discounted, based on a derived discount rate.

For solar PV, this equation can be disaggregated to include the system degradation rate and system residual value of the panels at the end of the life cycle. The system degradation rate relates to the reduction in output of the solar PV panels due to wear of system components in time, while the system residual value is the present value of the end of life asset which is deducted from the total life cycle cost in the LCOE calculation [42,53].

Solar PV degradation is an important factor as it translates directly into less power being produced and therefore reduces the future cash flows for the project. This will increase the risk involved in taking up such projects and thus higher expected returns by developers. The median degradation rate obtained from various literature and recorded over years of research shows a value of 0.5% per annum for both silicon based technologies as well as thin film.

The LCOE formula that caters for the degradation of the solar PV panels is shown in equation (3) below.

$$LCOE = \frac{\sum_{t-0}^{T} \frac{I_t + O_t + M_t + F_t}{(1+r)^t}}{\sum_{t-0}^{T} \frac{E_t}{(1+r)^t}} = \frac{\sum_{t-0}^{T} \frac{I_t + O_t + M_t + F_t}{(1+r)^t}}{\sum_{t-0}^{T} \frac{S_t(1-d)^t}{(1+r)^t}} \quad (3)$$

Where C_t is disaggregated to give the cost components of the revenue requirements (C_t = It + O_t +M_t+ F_t). It is the initial investment/cost of the system including construction and installation, O_t and M_t represents the operation and maintenance costs respectively and F_t is the interest expenditures for year t. S_t is the yearly rated energy for t. The additional term d represents the degradation rate.

2.4.1 Parameters that determine the LCOE

It is important to remember that the LCOE is an evaluation of the levelised life cycle costs and may differ substantially from the price of energy that can be established under a Power Purchase Agreement (PPA) as they may include different contract or incentive durations, accelerated depreciation, financing structures and in some case time-of-use (TOU) production tariffs [42]. The LCOE formula can be modified to include financial considerations such as taxes, subsidies and other complexities.

The key inputs to calculating the levelised cost for solar PV includes the following:

i. Installed system cost of the plant

This is the initial investment in a PV system and the costs include total project cost plus the cost of construction financing. This cost is driven by cost of the panels, inverters, switchgear, transformers, land related costs, grid integration costs and any upgrades that may need to be done onto the existing system [3].

ii. Fixed and variable operation and maintenance costs (O&M) [42]

O&M costs for a PV plant is fairly straightforward as there are no moving parts (for fixed systems) and no cooling systems. O&M for a utility scale PV plant can range from $10/kW/year to $30/kW/year due to the differences in scope offered under a particular O&M contract [25]. These are added to the total life cycle cost and include activities such as inverter maintenance, panel cleaning, site monitoring and clearing, insurance, financial reporting and field repairs.

iii. Local solar resource and climate

The amount of electricity that can be generated from a particular solar PV panel depends on the local solar resource and climate of the specific location. This will be covered in detail under the solar PV technology descriptions in the next chapter.

However, a location with high insolation levels will naturally yield more solar energy than one with lower insolation levels amongst other factors. In some instances a place with high wind levels or snow may result in high operation and maintenance costs which will ultimately affect the LCOE [12].

iv. Financing costs

The Weighted Average Cost of Capital (WACC), also referred to as the discount rate, is normally used to determine the Net Present Value (NPV) of the PV power generation project (or any other project for that matter).

However, variations can occur on the WACC due to factors like type of project owner, the nature and stability of the regulatory regimes and the regional/national differences in the cost of capital [25]. It plays an important part in the LCOE of projects such as solar PV which are capital intensive and represents the return on capital invested in a project [57]. Project developers all over the world are interested in knowing how much return will they get after investing their funds.

In the South African context, the solar PV market is still in its infancy and therefore lenders are likely to factor a higher risk factor than in developed markets that are more mature and experienced [12]. The higher risk premium will affect the final cost of generating electricity.

v. PV panel orientation

This is the direction in which the panels are mounted. They could be flat or tilted in a certain direction and also whether they are fixed or track the sun as it moves through the sky. Tracking systems typically cost more due to the maintenance requirements of the moving parts but the energy yield is also higher in a given location. The tracking can also be single-axis tracking (tracks the sun from east to west only), or dual axis which tracks the movement of the sun in 4 different directions [42].

vi. System lifetime

The lifespan of the system also affects the LCOE as the amount of energy generated will depend on the life span of the panels. A longer system life will result in lower LCOE.

vii. Taxation

These can be tax breaks and/or incentives that might be offered to potential developers in order to stimulate the solar PV industry development. They will affect the final LCOE required by the developer by reducing the costs component ad consequently the overall LCOE.

viii. Policies

These relate to polices that may be introduced to stimulate development of solar PV projects. Project developers normally respond to favourable policies and certainty. Risk associated with policy can lead to higher financing costs for developers.

ix. System capacity factor

This is a key driver of solar energy economics and is a function of the insolation at the project site, the PV system performance (relating to high temperature), system electrical efficiencies, as well as the availability of the plant to generate power [3]. As the capacity factor declines, the required installed system price must also substantially decline to maintain system economics [42]. The higher the capacity factor, the more efficient is the solar plant. Solar cells typically have a capacity factor of 18 % [43].

These parameters differ from one technology to the other e.g. with renewable energy technologies having zero fuel costs while for technologies such as gas or coal, the cost of fuel is a key factor in the value of the levelised cost. Therefore, the sensitivity of the levelised cost to a certain parameter is different for different technologies. It is also important to note that the availability of incentives (including tax and credit incentives) to support a particular technology has an impact on the final levelised cost.

For renewable energy technologies such as solar PV the capacity factor varies by the level of solar irradiation in a particular location as well as the time of the day. The capacity

factor will normally be a simple average of the capacity factor for site and can vary significantly by region. Sites with higher irradiation levels would typically have lower levelised costs than sites with a poor irradiation level. For comparison of different countries, and in some instances provinces, variations can be introduced by local labour market costs together with grid integration/connection costs (albeit at plant level and normally excludes system costs such as the impact on the grid as a whole) [31].

As previously stated, the LCOE is generally calculated based on a set of technical and financial assumptions. Economies of scale play an important role on the value of LCOE for a particular technology e.g. utility scale solar PV plants are cheaper than smaller distributed end-use residential and commercial applications. The focus of this report will be on the former, which are plants greater than 1 MW in size.

2.4.2 Setbacks of the LCOE in PV

Although the method is widely used in determining the LCOE of generation technologies including solar, it is highly dependent on the assumptions that are made and input into the model. [25]. For the same system capital costs and initial energy generated, the LCOE can vary by a factor of two or more. It is therefore important to align assumptions when comparing LCOE calculations and power plant energy pricing.

Even at comparable LCOE with conventional technologies, there is a value that is attached to a particular technology which depends on the nature of demand, the network itself, the generation mix and the despatch rules. These factors are likely to place a higher value to the conventional generation that is rapidly dispatchable especially in electrical systems with infrequent periods of very high demand, as compared to solar which is generally variable and only somewhat predictable in an industry where supply should precisely meet demand at all times [25].

As South Africa ventures into this new era of renewables, including solar PV, many decisions will be taken by developers and regulators based on the LCOE calculation which assists in the evaluation of renewable energy projects for development of policy by governments and project developers alike.

It is important to emphasise the impact of assumptions (financial and technical) that go into the calculation. Research also seems to indicate that there is a potential danger in having a single number for LCOE and it is better to have distribution of numbers [53].

2.5 Conclusion

The LCOE will therefore be used in this report as a basis for analysing the cost of solar PV in the South African market and how that impacts the viability of solar PV projects that have been awarded successful bidder status by the Department of Energy. The same method was also used to come up with FITs that were announced by the NERSA in 2009 and thus the comparison will be on a similar basis. The calculated solar PV will be compared with the REFIT projects and the actual average bidding prices under the REBID to evaluate the effect of the environment change on the viability of the solar PV projects. The rapid growth of the installed capacity of solar PV means that data can easily be outdated thus overestimating or underestimating the appropriate LCOE [57]. This can create a barrier for the development of solar PV and any other renewable energy technology for that matter.

3. THE SOLAR PV TECHNOLOGY

3.1 Introduction

Photovoltaic (PV) technology is a means of converting the energy from the sun directly into electricity. The basic building block of solar PV is a semiconductor material, which converts the energy from the sun to electricity through a process commonly known as the 'photovoltaic effect' [12]. There are varieties of semiconductor materials that can be used for PVs and these will be discussed in the next section [37]. Light falling onto the solar cell creates an electric field across the layers of the semiconductor material causing electrical energy to flow. The photovoltaic effect is illustrated in the simplified figure below.

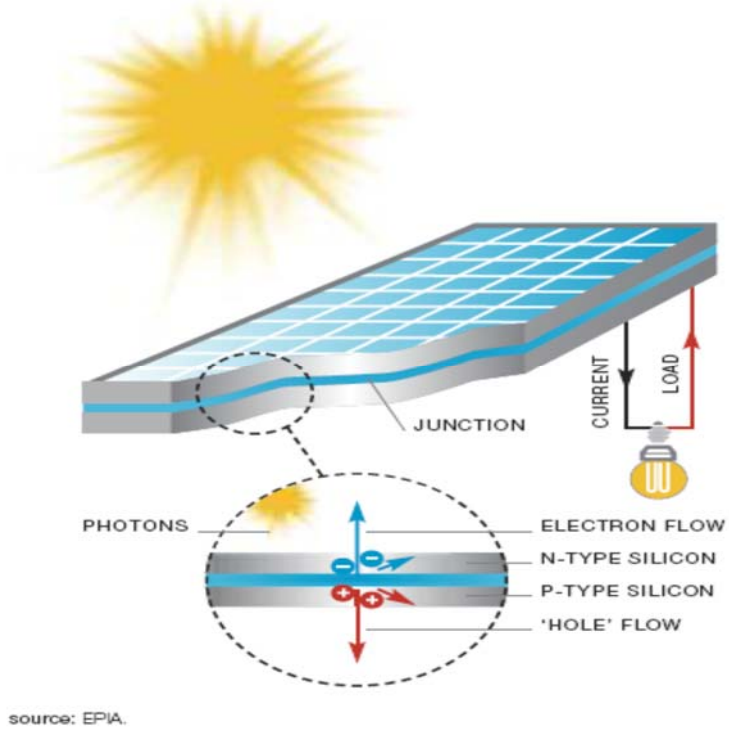


Figure 1: Photovoltaic Effect [12]

The sun's energy 'knocks' electrons out of a molecular lattice leaving a free electron and hole pair that drift in an electric field to separate contacts which give out a Direct Current (DC) electricity [31].

Solar PV is not a new technology and has been used for several years mostly in off-grid applications such as telecommunication towers and satellites. In South Africa, solar PV assembly plants were labour intensive and satisfied the small market. This has however

changed as there are now mechanised processes with plants that are capable of assembling panels for the growing grid connected systems [35]. The technology is, however, now gaining significant usage in grid connected levels at utility scale mainly due to decreasing costs which renders the electricity generated from solar PV competitive. There has therefore been rapid deployment of PV as the cost of the cell decreased over the years. The most commonly used material in the manufacture of solar PV cells is crystalline silicon and this comprises about 80% of the PV market. In addition, silicon is the second most abundant element in the Earth's crust after oxygen.

Together with other renewable energy technologies, PV deployment at utility scale is expected to continue growing and consequently reducing the overall LCOE to levels that are comparable to conventional technologies. The focus of this report will be on on-grid systems in which batteries are not required (as is the case with off-grid systems). In on-grid systems, the utility grid acts as the storage medium [21].

3.1.1 PV Technologies [12]

There are basically three types of PV technology that are available namely first, second and third generation based on the maturity of each technology. These are briefly looked at below:

(a) First generation – this generation is the silicon crystalline technology in which the cells for this technology are made from thin slices (wafers) that are cut from a single block of silicon. It is a very mature technology with the largest market share (over 80%). Depending on how the crystalline is made, several types of crystalline cells are made. The types of crystalline cells are

- Mono-crystalline (mc-Si);
- poly or multi-crystalline (p-Si); and
- ribbon and sheet-defined film growth (ribbon/sheet c-Si).

The technology has the advantage of higher conversion efficiencies due to the single crystalline used in the production of the cells. Typical cell efficiencies are in the 14-22% range while the module efficiencies are in the 12-19% range.

(b) Second generation – this represents the thin film technologies in which thin layers of photosensitive material are deposited onto a low-cost backing such as glass, stainless steel, fibreglass or plastic. The semiconductor layers are about 100 times thinner than the c-Si cells. The substrate with the deposited material is then cut by laser into multiple thin cells. It is common practice for the thin film modules to be enclosed between two layers of glass, without a frame like the silicon crystalline technologies. Some of the commercially available thin film technologies are as below:

- Amorphous silicon (a-Si)
- Multi-junction thin silicon film (a-Si/μc-Si)
- Cadmium Telluride (CdTe)
- Copper, Indium, Gallium, (di) selenide/ (di)sulphide (CIGS) and copper, indium, (di)selenide/(di)sulphide (CIS).

The main advantage of this technology is the low cost although their efficiencies are much lower than those of the crystalline silicon discussed above. The manufacturing processes for the thin film technologies are much more complex and less standardised than other types of cells thus increasing the cost. Their efficiencies are in the 7-12% range with CIGS and CIS offering the highest efficiencies. In terms of raw material availability, indium is used extensively in the Liquid Crystal Display (LCD) industry and this tends to drive the price of indium to high levels. The technology is struggling to compete with c-Si as they are less durable and, in the case of Cadmium, it is toxic [57].

(c) Third generation technologies – these technologies have recently surfaced onto the solar PV market and are still under continuous development. These technologies include the following:

- fully organic PV (OPV); and
- hybrid dye-sensitised solar cells(DSSC)

OPV technology is moving towards full commercial production with efficiencies in the region of 4% and 6% for small and large areas respectively. DSSC is much more advanced and is becoming available commercially especially in low power applications with efficiencies around 4%. The low efficiencies are the major challenge with these

technologies while they are suitable for consumer applications due to their flexibility and the ability to operate in dim or variable light conditions.

In all the cases, it is apparent that the efficiency of the solar cell is generally higher than the module efficiency. This is primarily because cells are not directly adjacent to each other and the gaps between them do not produce energy [37].

Although the cost per module for the different PV technologies described above are very different, the complete system costs are not very different and are expected to converge in the long run [45].

3.1.2 Other Components of a PV System [31]

In addition to the PV modules discussed above, the complete PV system comprises two other elements that enable it to deliver power to the grid.

The additional subsystems are the power electronics and the Balance of System (BOS) and are briefly explained below:

a) Power electronics- the main component of the power electronics is the inverter. As discussed earlier, the power output of the solar PV modules is DC. However, most of the grid systems and appliances utilise Alternating Current (AC). The inverter converts the DC electricity into AC electricity, which will be fed into the grid through step up transformers. The inverter and the step up transformer are normally combined into an integrated device that is called an inverter. The most dominant type of inverter is the string inverter (also known as a central inverter) with an estimated market share of 90% and an efficiency of about 98%. The other type of inverter is the micro inverter that is built into each solar panel [36].

b) Balance-of-System (BOS) – the BOS comprises of the non-module components of the PV system which move the produced energy. The components include support structures, mounting hardware, wiring, monitoring equipment, shipping, and land (aka 'hard' BOS). The soft BOS are the system design and engineering elements, permitting, site acquisition, installations, financing, contracting, interconnection and inspection as well as operation and maintenance.

3.2 Advantages of Solar PV Technologies

Some of the advantages are outlined below:

a) Solar power is an abundant form of energy which is renewable and is found everywhere in the world.

b) Solar PV is a versatile technology as it comes in various sizes (modular) and can be made for various sites further reducing costs due to close proximity to the demand. PV systems can be easily installed with a short lead time which means that power can be integrated earlier into the grid [39]. They can also be designed to have low visual impact.

c) Unit costs for solar PV have reduced drastically due to continuous technological improvements, massive deployment and increased efficiencies. This trend is likely to continue into the near future. For example, for solar PV the installed system price has decreased by 22% with each doubling of installed capacity. In some European countries with high retail electricity prices, solar PV will reach grid parity in 2015.

d) Average efficiencies of all solar modules have improved over the years. It is expected that by 2020 a target of 23% for crystalline modules will be reached lowering prices further.

e) There is no burning of fuel as the energy comes from the sun. This introduces social benefits such as the reduction of carbon dioxide that is emitted into the atmosphere. It is therefore part of the solution to combating climate change due to Greenhouse Gases (GHG). Solar PV has a carbon dioxide emission level of 21-65 g/kWh as compared to an average thermal power plant which produces about 900 g/kWh [1].

f) The introduction of solar PV leads to creation of jobs through the upstream industries from mining of silicon and in the production of the PV modules. In addition, local jobs are also created during the construction and maintenance of the plant. This also leads to industry development as well as business generation.

g) Each solar PV module lasts for at least 25 years. As discussed previously under section 2.4 of this document, the longer the plant life, the lower the resultant LCOE as more electricity is generated over the life of the plant.

h) The systems used in a solar PV can be salvaged, recycled, and reused at the end of their life.

i) The plants are much easier to install and do not require significant amounts of maintenance and shutdowns as compared to conventional technologies such as coal-fired power stations.

j) Solar PV introduces security of supply as well as diverse power sources in a country or region. This is relevant for South Africa as over 90% of its electricity is generated from coal [12].

k) In some instances, PV can contribute to reduction of grid losses (transmission and distribution) in cases where it is deployed near the place of consumption. This creates an added value to PV through a saving in costs that would have otherwise been incurred. In addition, upgrades onto an existing transmission/distribution system can be deferred in cases where the PV system output corresponds with the utility's peak demand period [21]

l) Solar PV also has a low Energy Payback Time (EPBT). This is the amount of time a PV system requires to operate to compensate for the energy that was used in its manufacture. The EPBT is much lower in sites that have high irradiation levels e.g. in northern Europe the EPBT is about 2.5 years while in the south it is about 1.5 years [36].

3.3 Disadvantages of Solar PV Technologies

While there are many advantages associated with solar PV, there are several disadvantages that will be discussed in this section. These include:

a) PV has traditionally had the highest LCOE as compared to other renewables. Therefore as PV markets expand, solar PV has disproportionately increased the FIT policy related costs relative to other technologies [10, 39].

b) Solar PV, like other RES, is intermittent and thus not firm. The output of solar PV cannot be accurately predicted as in conventional plants and depends on whether

the sun shines or not, which poses a challenge to power system operators in terms of scheduling [19].

c) As a result of the intermittency, solar PV decreases system reliability and stability due to the fluctuations of the output [2].

3.4 Global trends in the deployment of Solar PV

3.4.1 The past decade

The installed capacity of solar PV technology at the moment is limited (about 0.1% of the overall global generation). This is mainly due to the high investment cost. However, this trend is changing as there has been an annual growth rate of more than 40% since 2000 and with prospects for further growth going into the future [45]. The growth has been driven mainly by technology improvements and economies of scale. It has been proven to be commercially viable and reliable with significant growth potential in the whole world including South Africa.

3.4.1 The recent past [48]

The global PV market has registered massive growth for more than a decade moving from only 0.1 MW in 1992 to 96.5 GW in the year 2012. Figure 2 shows the cumulative installed PV capacity globally. IEA-PVPS Reporting Countries are countries that report to the IEA's Photovoltaic Systems Programme.

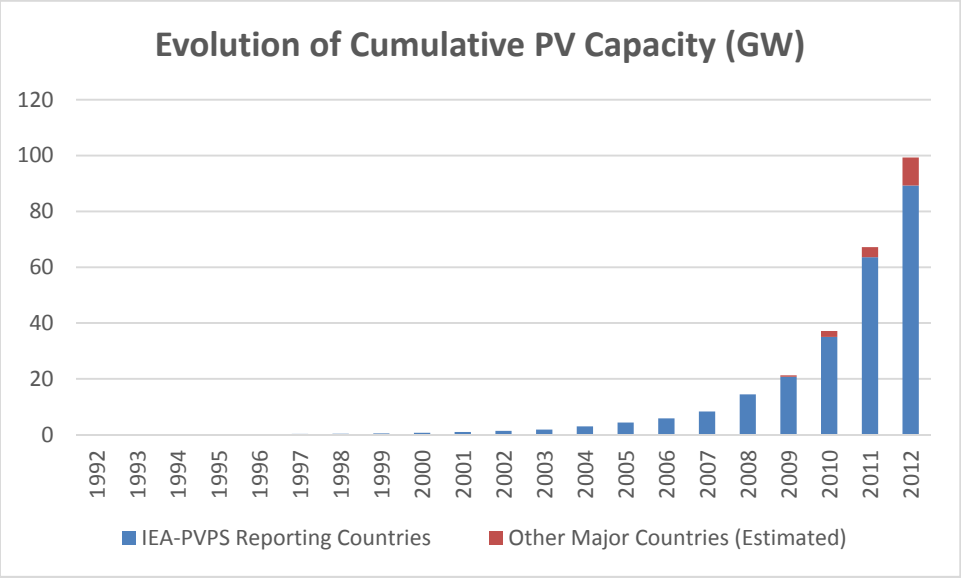


Figure 2: Cumulative PV Installed Capacity Globally [48]

The solar PV growth has been sustained but stabilised. In terms of installed capacity, there was at least 28.4 GW of new solar PV capacity that was installed last year which is comparable to the 2011 levels. Europe's domination of the market was significantly reduced from 22 GW to 16.9 GW but still dominated the market by having a 59% share of the PV market. As expected, Asian markets dominated with the highest growth of over 66% with China being second in terms of total installed capacity in the year 2012. More importantly, thirteen countries now have at least 1 GW of installed capacity while nine countries installed close to 1 GW in 2012.

The growth in the annual solar PV installations was mainly driven by European markets with five countries (Germany, China, Italy, USA and Japan) contributing about 70% of all the installations that were recorded in 2012. The other countries that added significant amounts of solar PV capacity were France, the UK, Greece, India and Australia, which all added plus/minus 1 GW of PV capacity. These ten countries together contributed about 88% of the world market but this is set to change as shown by the significant role played by China and India and other countries such as South Africa whose contributions are yet to be captured in these reports. The following graph shows the total installed capacities per region over the period in 2012.

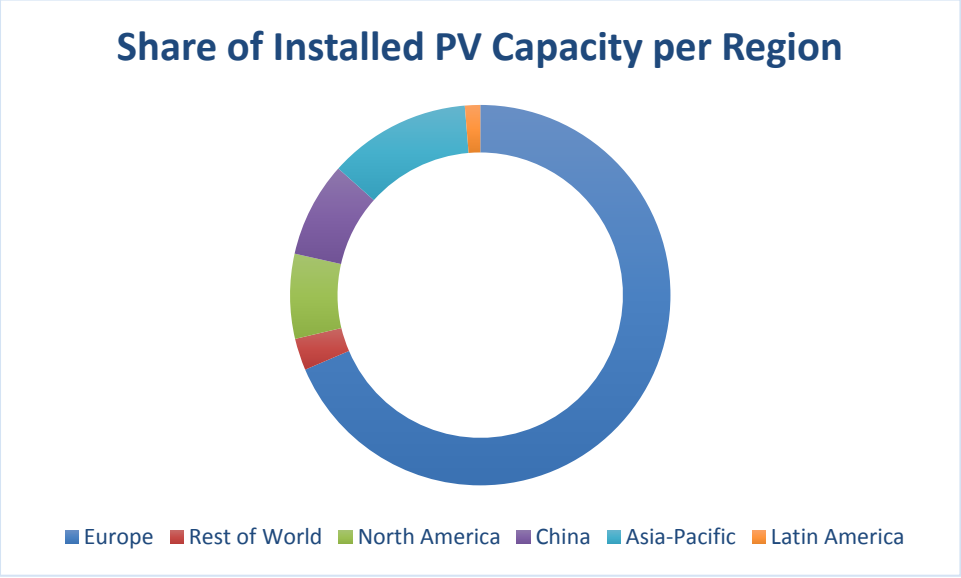


Figure 3: Share of PV Installations per region [48]

PV has already become a major player in contributing to the electricity sector worldwide and there is a huge potential in previously undeveloped markets as can be seen from the

above graph. The Middle East and Africa are following the trend as well as South Africa as can be seen from the above graph.

At least 110 TWh of electricity will be produced by the plants that are in service representing about 0.5% of the global electricity demand. European markets are slowing down (mainly due to the global recession) after years of vigorous growth and in their place will be the Asian markets, followed by the Middle East and Africa markets going into the future [48].

3.4.2 The future

The deployment of solar PV has been growing so rapidly that the projections made in 2011 for the period 2010-15 are now out of date given the new installations done in 2011 and 2012 [57]. The rapid deployment of solar PV is expected to continue pushing down prices with the possibility of reaching grid parity in some countries with high retail electricity prices and high insolation levels, as early as 2020 for commercial and residential PV systems. For utility scale plants, solar PV will be expected to compete with the wholesale electricity costs in some countries by the year 2020.

The future segment of growth for PV is in the on-grid market as compared to off-grid standalone applications. The major driver of forecasted growth of the PV industry is seen to be driven in part by policy incentives. The IEA roadmap also envisages the growth of PV throughout the OECD countries as well as Asia, followed later by Latin America and Africa, while China and India will remain important influences in the solar PV market in decades to come [45]. The IEA roadmap estimates that by 2050, solar PV will contribute around 11% of global electricity production and in the process avoiding 2.3 Gigatonnes of CO_2 emission per annum [45].

4 OVERVIEW OF THE SOLAR PV MARKET IN SOUTH AFRICA

4.1 Introduction to solar irradiation [9]

This section covers the basics of solar radiation levels and its importance to solar energy production, as well as the history and developments of renewable energy sources in general, and solar PV in particular . In addition, an overview of the REFIT and REBID programmes is given.

The sun is the earth's major energy source and radiates from a distance of 150 million kilometres, reaching the atmosphere at about 1360 W/m^2. The radiation reaching the atmosphere covers the spectrum from ultraviolet, through visible and to near infrared. The solar radiation emanating from the sun travels through the atmosphere and is scattered, diffused and absorbed by gases, water vapour, particles and clouds. (9) Light is scattered differently depending on its wavelength and three components are distinguished at the earth's surface as follows:

a) Direct irradiation – these are solar rays that travel from the sun in a straight line and were not absorbed or scattered by the atmosphere.

b) Diffuse irradiation – these are solar rays that have been diffused by the atmosphere and clouds and reach the earth's surface from all directions.

c) Global solar irradiation (Global Horizontal Irradiation (GHI) – this is the sum of the direct and diffuse radiation irradiating at a horizontal surface.

As discussed previously, the quantity of electrical energy produced by solar PV plants depends on the amount of irradiation at a particular site. An optimum site for siting a solar PV plant can only be determined by ensuring that accurate information on a proposed site for solar PV generation plant is available.

Measurements of the irradiation at a particular site enable the prediction of the system output under a variety of sky conditions and seasons. Errors on the amount of solar at a particular site can significantly affect the viability of a project especially for large utility scale PV plants which are the focus of this report.

4.2 Measurement of solar irradiation [9]

Satellite based technology is one of the methods used to measure the GHI. However, it is common practice to perform measurements on the actual site where a solar PV plant is to be constructed. The site specific measurements are then used in combination with satellite data to come up with an acceptable level of the GHI. Measurement of the global irradiance is done using horizontally mounted pyranometers, which are radiometers designed to measure the solar energy received from the entire hemisphere in the 300 to 3000 nm UV to infra-red radiation. It is ideal for measuring available energy for use in solar energy applications but can also be used in other agricultural applications such as plant growth, thermal convection and evapotranspiration.

Solar panels are normally installed to obtain the maximum amount of radiation from the sun. It is also recommended that another pyranometer which is at the angle of the proposed solar panels so that the 'tilted' global radiation can be measured to enable system efficiency monitoring [15].

4.3 Solar irradiation levels

Solar PV systems operate in the presence of direct and/or diffuse solar irradiation. The irradiation is normally expressed as kWh/m^2/year - which is the amount of electrical energy generated by a solar PV system per square meter of panel per year [57]. This is the main data input in the calculation of the potential annual energy production.

It is important to note that the majority of the countries with high levels of solar PV installations are in Europe, where the level of solar irradiation, measured as the Global Horizontal Irradiation (GHI) is much lower, averaging 1200 kWh/m^2/year, than in countries in Africa and the Middle East. South Africa is endowed with excellent solar resources which are well above the levels in Europe and other Asian markets.

Siting of PV plants in high irradiation level areas is therefore a key consideration that affects the final LCOE for that plant. However, normally high irradiation levels result in high module temperatures which reduces the efficiency of the modules resulting in reduced output energy. Since different solar PV technologies have different temperature coefficients, those that have lower coefficients produce higher energy [13].

Typically, the level of irradiation varies with seasons. The measure used to obtain the solar irradiation of a particular site is therefore based on an average of the solar irradiation at a particular site over a number of years (typically 10 years).

Lenders normally request data measured on site preferably by an independent entity in order to minimise their risk. They normally specify P-50 data (the irradiation level exceeded 50% of the time). The data used to obtain the level of irradiation would normally be historically data that is measured at a site over a number of years (e.g. 10 years). A combination of measured site data over a shorter period of time is normally accepted if it is used in combination with satellite based solar irradiation data that is obtained over a number of years.

A few years back, satellite based data alone would not satisfy project developers and funders due to the magnitude of error that is associated with such measurements. However, the recent development of databases by companies such as SolarGIS with high resolution solar radiation and meteorological data with global coverage provides more accurate project feasibility analysis. The typical uncertainty of GHI annual summaries obtained through SolarGIS satellite-to-irradiance models is lower than ± 3.5% with a probability of occurrence of 80% [15].

4.4 GHI levels – South Africa context

There is enormous potential for solar PV development in South Africa due to its climate as will be seen in the following sections. Even during the cold months when there is cloud cover, it still has 24% of the world's best winter sunshine and one of the best annual irradiation as will be seen in the following sections. As alluded to earlier under the LCOE discussions, it is important to consider the proposed project site's solar resource, as well as the optimal orientation and tilt of the solar collector. The optimal angle for the best yield is when the solar panels are at an angle equal to the angle of latitude.

For South Africa, the angle is about 30 degrees. Inclusion of a tracker in the PV system would increase the measured GHI at a given location compared with a fixed system [57]. Below is an example of a solar irradiation map for South Africa, produced by SolarGIS, which shows the GHI Index within the borders of South Africa.

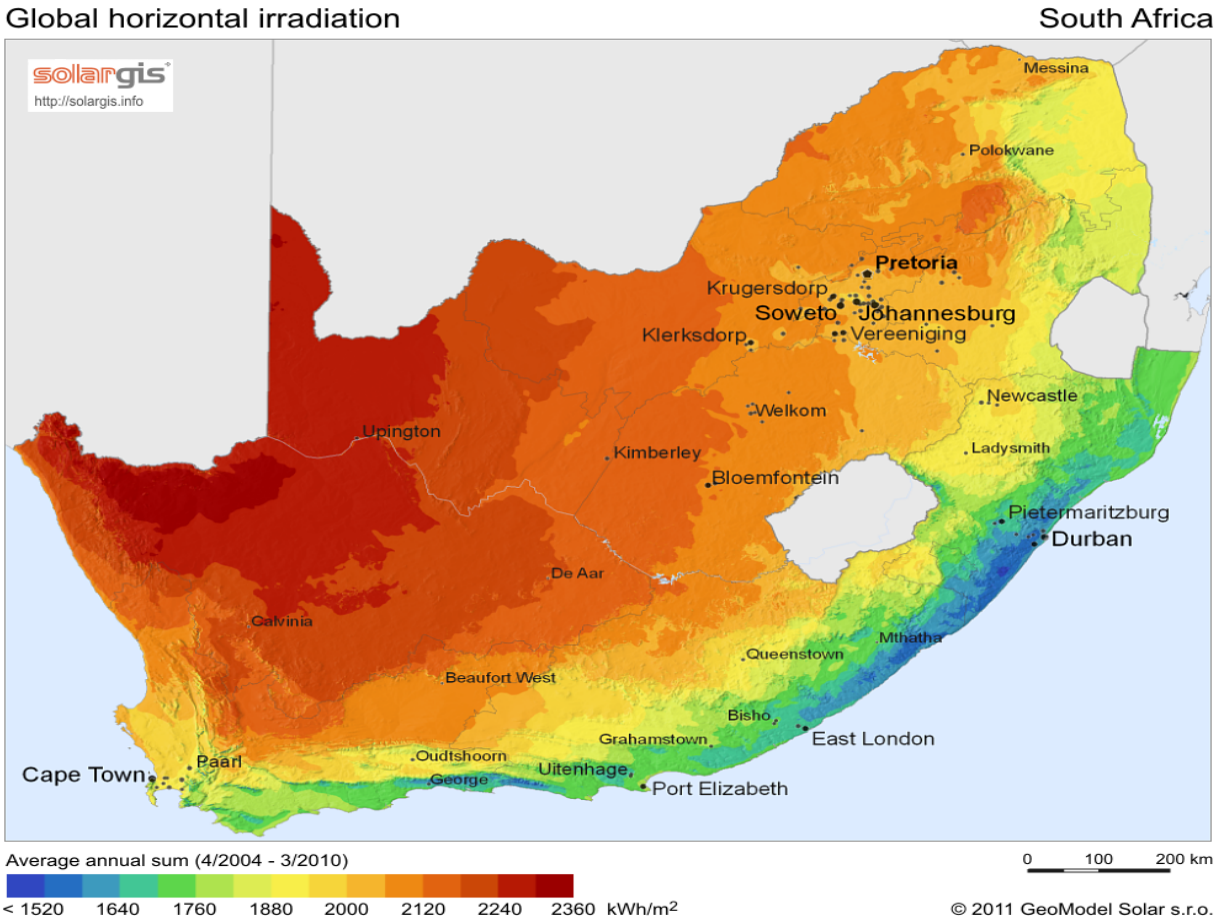


Figure 4: Annual Sum of GHI for South Africa (average 1994-2012) [50]

The map shows the distribution of the GHI values for the country which range from <1000 kWh/m^2/year in coastal areas stretching from the Western Cape to the KwaZulu-Natal coastline, to the very high levels of >2200 kWh/m^2/year that are in the Northern Cape Province. Naturally, potential developers for solar PV projects will be attracted to the high irradiation zones shown on the GHI index map.

It would also be useful to compare the mean GHI indexes for the top ten countries that have installed large amounts of solar PV generation.

The following table shows the mean annual GHI potential per country in kWh/m^2/year, against the amounts of installed solar PV.

Table 1: Comparison of installed solar PV capacity and mean GHI [48]

Country	Cumulative Installed Solar PV Capacity in MW (2012)	Mean GHI ($kWh/m^2/year$)
Germany	32 411	1200
Italy	16 250	1500
USA	7 221	1500
Japan	7 000	900
China	7 000	1500
Spain	5 100	1800
France	4 003	1400
Belgium	2 567	1000
Australia	2 400	2000
Czech Republic	2 085	1000

4.5 The South African Renewable Energy Market [14, 51]

The South African electricity market is currently dominated by Eskom which is a vertically integrated state-owned company. The major fuel source for the power stations is coal, with the majority of the plants situated in Mpumalanga where there are vast coal resources. Other non-coal fuel plants include nuclear, gas, pumped storage, conventional hydro and a wind farm. The total installed capacity of these plants is 44 084 MW and make up about 95% of the country's electricity requirements [20]

Although South Africa is endowed with some of the best resources for wind, biomass and solar, the current level of renewable energy generation is less than 2% [28]. However, this is set to change as there have been some significant developments which has seen the development of policies to create an enabling environment for the development of renewable energy. This was in part driven by the commitment South Africa agreed to during the Kyoto Protocol.

As discussed earlier, the first steps were taken when the South African government published a Renewable Energy White Paper in November 2003. The policy document envisaged a range of measures to bring about the integration of renewable energies. The SA Government set its target at 10 000 GWh/year (0.8 Mtoe) renewable energy by 2013, to be produced mainly from biomass, wind, solar and small-scale hydro. In June 2007, the Energy Regulator, in terms of the Electricity Regulation Act, 2006 (Act No. 4 of 2006)

(''the Act'') commissioned a study of the REFITS to support renewable energy technologies.

4.5.1 The REFITs Phase I & II [22, 23, 37, 53]

The National Energy Regulator of South Africa (NERSA) in March 2009 announced the first phase of the Renewable Feed-In Tariffs, namely onshore wind, small hydro, landfill gas and concentrated solar without storage. The FITs were calculated on the basis of the levelised costs of the different technologies under a set of financial assumptions. The technologies and tariffs were as shown in the table below:

Table 2: REFIT PHASE 1[37]

Technology	Unit	REFIT
Wind	R/kWh	1.25
Small Hyro	R/kWh	0.94
Landfill Gas	R/kWh	0.90
Concentrated Solar	R/kWh	2.10

Following the successful announcement of the above technologies and comments received from stakeholders, the Energy Regulator requested that the guidelines also cater for other technologies such as solar PV. In October 2009, following another study of technologies that could be developed in the South African market, the Energy Regulator further announced the second phase of the REFIT as which included concentrating solar power (CSP) trough without storage, large scale grid connected PV(≥1MW), biomass solid, biogas and CSP (Tower) with 6 hours storage. The applicable FITs are as shown in table 4-3 below.

Table 3: REFIT PHASE II [53]

Technology	Unit	REFIT
Concentrated Solar Power (CSP) trough without storage	R/kWh	3.14
Large scale grid connected PV systems (≥1MW)	R/kWh	3.94
Biomass solid	R/kWh	1.18
Biogas	R/kWh	0.96
CSP Tower with storage of 6 hrs per day	R/kWh	2.31

As can be seen from the above table, solar PV had a levelised cost of R3.94/kWh for large grid connected plants. The tariff was highly attractive for developers especially considering the irradiation levels in South Africa.

The FITs were designed such that they are high enough to interest investors. Indeed high levels of interest were shown by developers of RES from all over the world and investments in research started to be undertaken which meant that there was a great deal of investor security in the FITs. It was designed as a temporary mechanism that would further drive the cost reductions and economies of scales in the development of RES especially solar PV. The NERSA was flooded with applications from potential investors in all the technologies.

This project will however focus on large scale grid connected photovoltaic (PV) with a capacity greater than 1MW which was announced under Phase II with a feed-in tariff of R3.94/kWh. As discussed earlier, the LCOE can vary widely with the assumptions that are adopted in its calculations. Under the two phases that were announced by NERSA, the following financial assumptions were used to arrive at the WACC that was used in the calculation of the LCOE for solar PV and other renewables. Solar PV had an assumed load factor of 16%.

Table 4: Financial Assumptions for REFIT Phase I & II [37, 53]

Financial Parameter	Unit	Value
Debt	%	70.00
Equity	%	30.00
Nominal cost of debt	%	14.90
Inflation	%	8.00
Real cost of debt before tax	%	6.39
Tax rate	%	28.00
Real return on equity after tax	%	17.00
Real Weighted Average Cost of Capital (WACC)	**%**	**12.00**

Therefore, a WACC of 12% was used to arrive at the solar PV FIT of R3.94/kWh. The approach taken by the Energy Regulator was in line with the approach adopted by many other emerging markets to promote renewable energy and generated substantial interest from the local and international community.

4.5.2 Promulgation of the IRP2010

This positive sentiment was further boosted by the promulgation in May 2011 of the policy adjusted Integrated Resources Plan (IRP) 2010 which outlined the planned generation mix of the country from 2010 to 2030 which had renewable energy technologies featuring strongly at a total of 17 800MW representing 42% of the overall planned generation capacity. Power from photovoltaic is expected to have a contribution of 8 400MW which is a significant portion of the planned generation from renewable energy sources. The IRP2010 is well overdue for revision but this was halted pending the finalisation of the Integrated Energy Plan (IEP), of which the IRP is only a subset. Once the IEP has been finalised, the IRP which is only for electricity, will be revised in line with the IEP. The IEP drafting process has been finalised and stakeholder comments and public hearings will be conducted in due course.

4.5.3 The REFIT Review [51]

It is also important to note that the announced REFITs were not fixed for the duration of the PPA. The Energy Regulator in its decision of March 2009 when approving the REFITs deliberately included a clause that allowed to "review REFITs every year for the first five-year period of implementation and every three years thereafter and the resulting tariffs will apply only to new projects". This clause was included to cater for the changing environments such as the financial parameters that were used in arriving at such tariffs, as well as to cater for improvements that lowered capital costs of the technologies such as solar PV.

Solar PV has particularly high 22% decrease in the capital costs for every doubling of installed capacity [23]. In line with that decision, a consultation paper was again issued in March 2011 to solicit comments from stakeholders regarding the revisions. No project developers were able to benefit from the first round of the announced REFITs. The change in the financial parameters from 2009 to 2011 resulted in the reduction of the REFITs which was received with shock from the industry based on the comments that were received. The revised tariffs were as shown in the following table. Although the table covers all the technologies approved under REFIT Phase I and II, this report will focus on solar PV.

Table 5: Proposed REFIT Review Tariffs [51]

YEAR	REFIT 2009	REFIT 2011	REFIT 2012	REFIT 2013	PERCENTAGE CHANGE 2011/2009
TECHNOLOGY	**R/kWh**	**R/kWh**	**R/kWh**	**R/kWh**	%
Wind ≥ 1MW	1.25	0.938	0.945	0.952	-24.9
Landfill gas ≥ 1MW	0.90	0.539	0.550	0.582	-40.1
Small hydro ≥ 1MW	0.94	0.671	0.675	0.680	-28.6
CSP trough ≥ 1MW with 6hrs storage	2.10	1.836	1.845	1.854	-12.6
CSP trough ≥ 1MW without storage	3.14	1.938	1.953	1.967	-38.3
CSP Central Receiver (Tower) ≥ 1MW with TES 6hrs	2.31	1.399	1.408	1.417	-39.4
Photovoltaic ≥ 1MW ground mounted	3.94	2.311	2.325	2.338	-41.3
Biomass solid ≥ 1MW (direct combustion)	1.18	1.060	1.084	1.108	-10.1
Biogas ≥ 1MW	0.96	0.837	0.862	0.887	-12.9

There were significant reductions that were witnessed during the revision of the REFITs ranging from 10 to over 40% which were not favourably received by the industry as there were no projects that had benefited from the higher tariffs initially announced in 2009. It is important to note that as real time project data was not readily available at the time of review, cost reductions due to improvements in technology such as solar PV were not included and were to be included in subsequent reviews. This will be further explored in the analysis chapter but the financial assumptions changed as shown in the following table.

Table 6: REFIT Review Financial Assumptions [51]

Financial Parameter	Unit	2009	2011
Debt	%	70.00	70.00
Equity	%	30.00	30.00
Nominal cost of debt	%	14.90	9.93
Inflation	%	8.00	6.00
Real cost of debt before tax	%	6.39	3.71
Tax rate	%	28.00	28.00
Real return on equity after tax	%	17.00	17.00
Real Weighted Average Cost of Capital (WACC)	**%**	**12.00**	**9.80**

The change in the financial assumptions resulted in the WACC decreasing from 12% to 9.8%, thus reducing the overall LCOE for solar PV and other technologies. These reviews did not reach approval stage as there were developments that came up on the policy side which were guided by the Public Finance Management Act (PFMA) which found the REFITs unconstitutional [28]. The REFITs were therefore never implemented in South Africa and were replaced by a bidding process which has been termed ‘’REBID’’ and will be discussed in the next section in detail.

4.5.4 The change from REFIT to REBID Process

As stated in the previous sections, no renewable energy projects benefitted from the REFITs due to the concerns highlighted. A significant portion of South African society is already unable to afford the current tariffs being charged for this basic commodity as well as compliance with legislation governing procurement of services or goods as stipulated by the PFMA. If the power to be generated by the renewable energy independent power producers was not subject to the provision of the aforementioned legislation, this would have been tantamount to flouting the constitution.

In light of this, the Department of Energy (DoE) through a Ministerial Determination as allowed for by 'the Act', Electricity Regulation Act (Act 4 of 2006) Section 34(1), stipulated that the procurement of new generation capacity in this case renewable energy was to be procured through a competitive bidding process in order to benefit from competition which was likely to reduce the price of supplying renewable energy. The company with the lowest production costs will be able to ask for the lowest price and will finally get the order. The project developer enters a contract which guarantees that the electricity will be bought over a defined period of time (PPA).

The Minister of Energy according to Section 34(1) of the Electricity Regulation Act, 2006 (Act No.4 of 2006) issued a determination regarding the Independent Power Producers (IPP) Procurement programme under which renewable energy will be procured through a competitive bidding process with ceiling price/price caps per technology which were not too different from the ones promulgated under the FIT regime.

The National Energy Regulator of South Africa (Nersa) subsequently concurred on its meeting of the 07th July 2011 with the Ministers determination as required by ERA (Act No. 4 of 2006). The price cap for power generated from solar PV was set at R2.85/kWh for the first round of bidding and potential bidders were expected to bid either at or below the ceiling price.

In this regard, the Department of Energy (DoE) released a structured Request For Proposals (RFP) tender on the 3rd August 2011 for 3725 MW of renewable energy capacity comprising 1850 MW of onshore wind, 1450 MW of solar photovoltaic capacity, 200 MW of Concentrating Solar Power (CSP), 75 MW of small hydro capacity, 25 MW of landfill gas and 12.5 MW apiece of biomass and biogas capacity.

There are five bidding windows when potential bidders can submit their bids to provide power to the grid. The first bidding window closed on 4 November 2011 while the second window closed in March 2012. The third window was expected to close in the latter half of 2012 but this did not materialise as challenges were met regarding reaching financial close. The third window eventually closed more than a year later than expected and at the time of writing, the announcement of the preferred bidders was on 29 October 2013. This effectively pushed back the fourth and fifth windows to dates that are yet to be announced.

Subsequently, the Minister of Energy of energy issued another determination for a further 3200 MW of renewable energy to be procured. The allocations and the preferred bidders for solar PV as per the Ministerial Determination and bidding rounds one and two are as shown in the following charts. As can be seen from the chart, solar PV featured strongly with an allocation of 1450 MW.

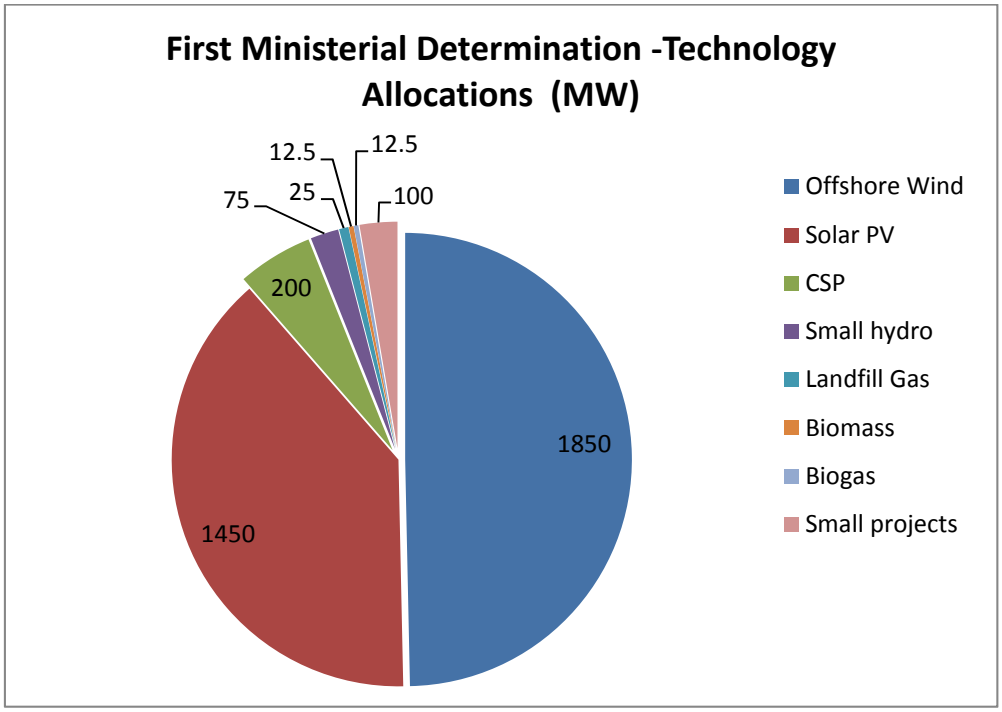


Figure 5: Technology Allocations as per Ministerial Determination

The following charts show the capacities per technology that has been taken up by the preferred bidders for the first and second bidding windows.

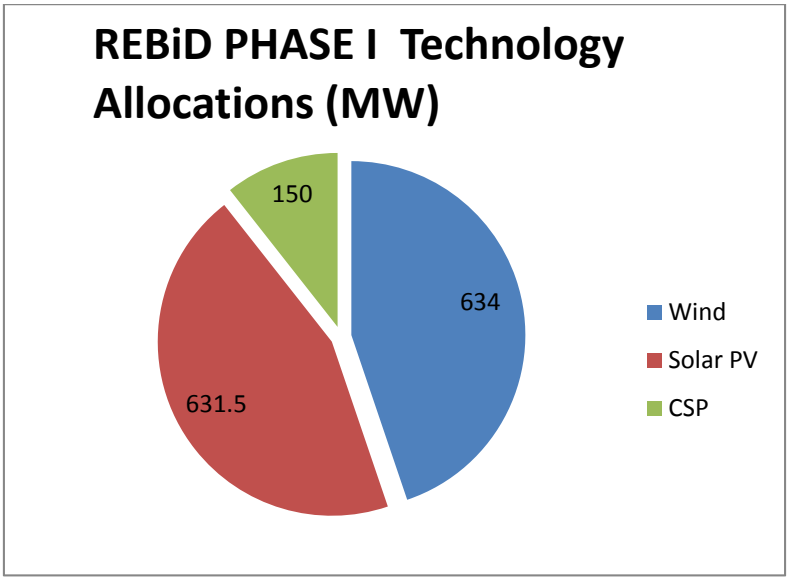


Figure 6: Share of Preferred Bidders by Technology Phase 1

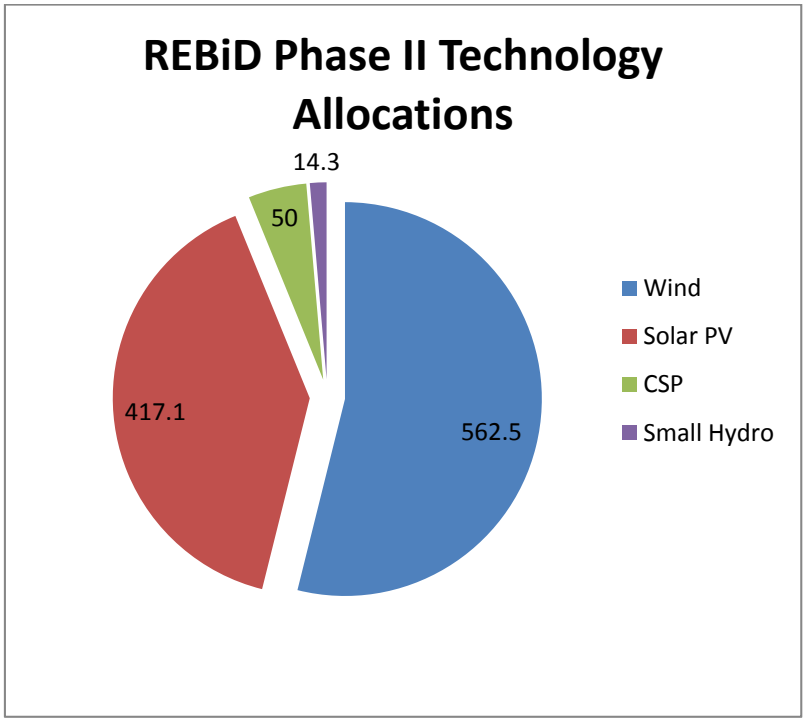


Figure 7: Share of Preferred Bidders Capacity by Technology Phase II

4.6 Conclusions

Although the REFIT model was never implemented in South Africa, it managed to create huge interest which gave way to the development of the REBID process which was meant to achieve the same purpose of ensuring investment in the renewable energy sector. The REFIT model had been based on international trends which tend to favour this approach. However, to align the processes with the SA government legislation, a REBID model was adopted with caps on technology and price.

The South African market is expected to become a major renewable energy player in the global arena if these projects are actually put onto the ground and commence production as scheduled.

5 BARRIERS AND SUPPORT SCHEMES TO THE DEVELOPMENT OF THE RENEWABLE ENERGY MARKETS

5.1 Introduction

It was discussed in the previous chapters that the rate of deployment of solar PV has increased dramatically over the past few years. Since solar PV is still relatively expensive as compared to other conventional forms of generation, the major driver for the unprecedented growth in the solar PV market has been attributed to policies that have sought to narrow the gap between the high cost and the increased deployment of solar PV. This section first looks at the barriers that hinder, or stifle the development of solar PV and other RES. It also then explores the various types of support schemes that are used to promote solar PV in particular, and renewable energy sources in general. It will seek to explore the commonalities that have driven the leading markets in PV technology.

5.2 Barriers to renewable energy development

Barriers are conditions that prevent investment from occurring and put the RES at an economic, regulatory or legal disadvantage relative to other sources of energy. These include subsides that are given to conventional sources of energy. These barriers unfairly discriminate against the RES, and typically vary from region to region and are thus situation-specific but can be classified into costs and pricing, legal, social and regulatory and market performance. The next section summarises these parameters and how they impede the renewable energy markets, including solar PV.

5.2.1 Costs and pricing

Typically higher investment costs are required for renewable energy than for the same capacity of conventional sources of energy. Capital markets will demand higher premiums in lending rates for financing as more capital is risked upfront in the construction of a renewable energy plant as well as high taxes and import duties for material such as solar cells or modules.

Although the upfront per unit costs for solar PV are higher than conventional technologies like coal-fired powers stations, this does not normally take into account public subsidies that are given to the latter. As alluded to earlier, a fair comparison can only be done on the basis of total lifecycle costs which include initial capital outlay, future fuel costs, future O&M costs, decommissioning costs and equipment lifetime.

Future uncertainties of fuel prices are not taken into account and governments are not willing to remove subsidises for these traditional technologies for political reasons. Public subsidies for fossil fuels can include direct budgetary transfers, tax incentives, liability insurance and guarantees to mitigate project financing as is the case with Eskom and the South African government. These subsides tend to lower the fuel prices for traditional sources of power and tilt the balance against renewables such as solar PV [17]. For political reasons, the approach has been not to remove subsides from traditional sources but rather increasing subsidies for renewable energy technologies.

The locational advantage of renewable energy that is normally fed close to load centres is not taken into account. Utilities only pay for the wholesale energy price without considering the transmission or distribution losses that would have been incurred through bringing power from remote places to the load centres.

The environmental impact of fossil fuels is usually not factored into the price of fuel such as the societal costs in terms of health budgets and lost production, decline in forests and fisheries and infrastructure decay due to acid rain, which are as a result of emissions from conventional sources. These are normally difficult to evaluate and can vary widely depending on the assumptions that are made. Investors do not normally factor these costs in their overall decisions when choosing between renewables and conventional sources [28].

5.2.3 Legal and Regulatory

The lack of a legal framework for IPPs hinders the development of renewable energy players as most countries still have vertically integrated monopoly utilities which control the whole value chain of power generation, transmission and distribution. The IPPs might negotiate PPAs with the monopoly on an individual basis making it difficult for developers to plan on how to finance a project on known and consistent rules. It is

therefore vital that the regulatory authority levels the playing field by introducing rules that achieves that. The absence of such rules can be a strong barrier to RES development. In South Africa, interest in RES was aroused during the introduction of the regulatory rules and guidelines for renewable energy projects.

Monopolies may also hinder transmission or distribution access by charging high prices for such connection projects or have inconsistent utility connection requirements which raise transaction costs. Challenges can also be faced to obtain way-leave for transmission or distribution lines to be used to evacuate power from the plant to the connection point.

Project developers in many jurisdictions have cited the huge number of approvals that are required for such projects such as licences, environmental authorisations and are obtained from different uncoordinated government agencies. The lack of coordination can lead to the same information being requested from a potential developer by different agencies and this creates frustration for developers and can be a serious hurdle to development of RES projects.

5.2.4 Technical barriers [34]

Some sites are not suitable for solar regardless of the incentive that is offered. The unsuitability of a given site could be due to the site being unable to accommodate the equipment and too much shading. Grid access can also present a barrier to the development of a solar project.

As alluded to earlier, the orientation of the solar modules is important in determining the output energy. If the site cannot accommodate the modules at the optimal tilt, then the performance of the modules can be severely degraded making the project uneconomical to execute.

5.2.5 Market Performance

In some instances, project developers are faced with challenges of obtaining project finance or available loan terms are not long enough relative to the equipment or investment lifetime. Uncertainty regarding the off taker's commitment to the PPA with the developer can lead to difficulty in obtaining finance or they charge high risk premiums on an already high capital investment that is required for projects such as solar PV plants.

A technology might be proven and cost effective but it can be still treated as risky if there is little experience with it in a new region or market as the South African one. The perception of the greater technical risk as compared to conventional sources will also arise and place stringent requirements on technology selection or resource assessment.

As is the case with South Africa and other emerging markets for RES, the lack of skills and understanding of the technology and information may increase perceived risk and block decisions that are in favour of renewables.

The above factors differ from region to region but have to be addressed in order to stimulate the development of renewable energy technologies in general and solar PV technology in particular.

5.2.6 Social Barriers [28]

These barriers relate to the possibility of rejection by local authorities or affected communities as there can be differences in view to such developments at the different levels of administration. Projects like solar PV require large tracts of land which might create competition or encroach onto land with cultural/traditional value.

Community acceptance and buy in is therefore essential at an early stage. In the South African context where unemployment is very high, such projects would be expected to address local joblessness in the respective communities. The next section will explore polices that can be adopted to promote renewable energy.

5.3 Overview of renewable energy support schemes

Well designed and implemented policies can act as a powerful and cost-effective catalyst to drive the growth of renewable energy and need to be appropriately tailored to specific local conditions.

The key issue that support schemes should address is to create certainty for the investors in the renewable energy market [52]. This means that investors need to be convinced that the policies that are on paper will in fact be implemented and adhered to.

Experience has shown that policies that are explicitly designed to promote renewable energy or other policies that indirectly influence incentives and barriers have a significant

impact on the rate of uptake of such RES technologies especially solar PV [17]. Solar PV has, and will continue to benefit from vast deployment with huge benefits of employment and growth of industries. It has the greatest potential of technological advancement and hence overall system LCOE reductions. To enhance this further growth, there is need for support schemes which should have the following general criteria [1]:

- Investor security – any support scheme that poses a risk/s to the investor is bound to fail.
- Simplicity of implementation – the scheme should not be complicated. A complicated scheme is likely to have higher costs that may have to be borne by the investor.
- Copy – it is critical to look at those countries that have implemented the support schemes and succeeded, then simply copy, taking into account local conditions.

These policies are designed to reduce one or more barriers that impede development of technologies. Energy policies must reflect reliable, objective, and up-to-date facts and figures on the cost, performance and the potential of RES [2].

In most instances, the incentives are designed to address cost-related barriers which are as a result of the perceived risks that come with RES but are not limited to these as there are other types of barriers as discussed earlier. There are also other approaches which are critical in supporting the development of solar PV such as regulatory and institutional barriers which can either promote or hinder development of RES [17].

The next section gives an overview of typical promotion approaches that have been adopted in various countries. Later, an analysis of which polices have spurred development of solar PV in the countries with the highest levels of penetration of this technology will be done. The first part will deal with best practices at policy or regulatory level, while the second part will look at the financial mechanisms.

5.3.1 Consistent rules and policies

Inconsistent rules and policies increase costs for developers and can lead to higher risk and regulatory uncertainty [2]. If rules are often changed, this increases the cost of doing

business for solar PV technology or other RES in terms of time spent reviewing the rules as well as the different designs and equipment that may be required as a result of the change in rules. Countries that aspire to be leaders in RES should therefore have clearly thought through policies and rules, which involve the potential developers and funders at the earliest level where possible. Policy makers should therefore assess their administrative procedures so that they are transparent, simple, cost-effective, linear in approvals and proportional to the effort for the owner.

5.3.2 Reduction in administrative lead times for approval

The policy makers in a developing market should ensure that the lead time to obtain approvals by developers is reasonable, since longer lead approval times lead to lower returns for the developer. This will make the project unattractive to undertake especially for small PV projects.

5.3.3 Simplify and adjust support schemes

Once the administrative process has been simplified in the case of FIT regimes, there should be an adaption mechanism to the changing circumstances of the technology e.g. reduced PV module costs should result in a reduction of the overall LCOE and project costs. If this is not done, the developers will register windfall profits and create an unsustainable market which is likely to crash.

It is important to note that in the REFIT introduced by NERSA, the FITs were to be reviewed annually for the first five years and three years thereafter for new entrants to cater for changing circumstances and adjust financial assumptions [12].

5.3.4 Clear rules of ownership and control of RES facilities

Monopolistic utilities would normally require some form of ownership and control the RES facilities in order for them to meet their obligations of providing safe and reliable power. It is important to set policies of facility ownership with clear rules on the ownership and control of the RES plants. For an example, utilities can take over control

of the alternative energy plants during an emergency in order to restore reliability and ensure safe operation of the grid.

5.3.5 Feed-In Tariffs Mechanisms

(a) Feed-In Tariffs

This is one form of pricing that provides a fixed payment for renewable energy generated by a RES plant such as a PV plant. As discussed earlier, the Energy Regulator in South Africa had adopted this type of incentive policy in 2009. A fixed price is paid for every unit of electricity generated by the RES and usually above the market price. It is usually temporary in nature and is used to develop the competitiveness that will result from economies of scale.

The renewable energy developer is also provided with guaranteed offtake by the utility. It can be financed from a subsidy or the utility can pass through the costs to the consumers and be specific for a particular technology.

This type of incentive has the advantage of predictability and consistency in the markets and has thus been responsible for most additional capacity that has been witnessed especially for solar PV.

Due to the lower perceived risk, developers can easily obtain project finance at lower rates and thus reduces the overall cost of electricity to consumers. This policy has the ability of encouraging the growth of small and medium scale power producers. However, there are also setbacks related to the FITs that have been experienced over the years. These include the difficulty in setting the true LCOE as most of the project costs vary by regions and may not be known, resulting in overpayments to developers and high electricity prices for the consumers.

It is thus difficult to pass the benefits of increased technological efficiency to customers and benefits accrue to the plant owner who may be able to access higher rates of return. This poses a huge challenge at a regulator perspective as there is a need to protect consumers from high prices.

The FIT system has evolved over the years as experience grew and it can be used in combination with other mechanisms to ensure that windfall profits are not realised at the expense of consumers [1, 2,6,58].

(b) Premium Feed-In Tariffs

This works similar to the FITs discussed above as the investor is still guaranteed a certain price for every unit of electricity generated. However, in this version, investors receive a premium above the regular market price. The FIT thus varies with the market prices as demand and supply vary [1]. All the other facets are similar to the one where a fixed price is offered to the investor.

5.3.6 Renewable Portfolio Standards (RPS)/Quota system

Under this type of policy, there is a mandated capacity of renewable energy sources or mandated percentage of total generation that must come from renewable energy. There can be penalties for not reaching the targets set through the obligation, which can be met by actual generation or through purchases from third parties that generate renewable energy.

There are typically two types of the RPS namely capacity based standards (set a fixed amount of capacity by a given date) and generation based standards in which a given percentage must come from renewable. Although the quota is imposed, the price is set through competition between the different project developers and also among the different technologies. It is also thought to provide certainty regarding future market share of RES (although this is not true in practice) and is perceived as more compatible with open or traditional electricity markets. However, there are a number of downsides to this policy such as higher risk and low rewards for equipment and project developers thus slowing innovation [1].

The RPS system also tends to favour larger centralised plants which are normally located in only the areas that have the best resources. Competition for the best sites is also likely to face public opposition and opportunities such as job creation and economic development will be missed.

Best practices for RPS often increase targets slowly to establish stability and encourage investment, as well as not specifying a particular technology or percentage from particular RES. RPS should also set the minimum target as long as it is economically viable to generate. Lastly, since there are no incentives to install more capacity than what is mandated under the quota, this sets an upper limit for development of the plants.

The RPS can be used with Tradable Renewable Energy Certificates (TRECs) where the portfolio standard or target is met with some form of certified renewable energy that is purchased or traded, or with a competitive bidding mechanism. An electricity producer who produces above its target can sell the excess to other third party that wants to meet its targets. TRECs can create a market for renewable energy and improve the revenue that is central to the development of RES.

5.3.7 Competitive bidding

In this type of policy, power producers bid on a fixed quantity of renewable energy with the lowest bidder winning the contract. [17]. It enables the marginal costs of all the producers to be identified. This type of policy is the one that is currently running in South Africa as discussed earlier, with a variation that a price cap is also included. Competitive solicitations specify a target or share of generation and allow potential developers to submit their bids. As is the case with the South African government, the aim is to increase renewable energy penetration, while ensuring that the costs that are passed onto the consumer are minimised as much as possible.

The major setback for this type of policy is that developers tend to bid below the cost of producing the energy in order to obtain contracts. The developers are likely to make unrealistic bids fearing losing contracts to low quality bids which may never be built. As will be discussed in detail later, the United Kingdom (UK) used this type of policy (as well as France) and although bid prices declined rapidly, some of the projects did not translate into projects on the ground [19, 59].

The policy adopted in the UK was termed the Non-Fossil Fuel Obligation (NFFO) originally designed for financing extra costs of nuclear but extended to renewable energy technologies. A bidding process was introduced where the lowest bidders would get the contracts. Although the NFFO registered a significant number of bids with reductions in each bidding round (five in total), it was considered a huge failure as delivery of actual projects by the winners did not happen [24, 55, 56].

It is therefore imperative that stringent criteria are applied for prequalifying bids to ensure the quality of bids is at the same level. In cases where there is no price cap, it is possible to receive bids that are higher than expected or the market price, thus leading to

higher prices to consumers. It also has a major setback in that it shuts out smaller investors as the transaction costs for tendering are usually high with considerable planning costs required [1].

5.3.8 Investment Tax Credits (ITC)

Investment tax credits allow investors to reduce their tax liability and gain all the benefits in the first few years of the investments. These credits reduce the overall costs and risk associated with investment in RES including solar PV which are usually very high at the beginning. Investment tax credits however, are not linked to the energy generated but to the installed capacity and thus do not stimulate investment. There is no incentive for the plant to produce power and is especially not suitable for utility scale plants but rather for household level plants e.g. solar water heating systems [52].

5.3.9 Production Tax Credit (PTC)

This type of tax credit links the amount of tax credit that a generator receives to the amount of generation output that is produced by that plant. PTCs are capable of stimulating investment, reducing uncertainty, capital costs as well as incentivizing the developer to actually run the plant to produce energy with limited downtime. From a regulator perspective, the PTC encourages investment in reliable equipment that will be capable of producing the maximum energy. This has been mostly adopted in the USA.

5.3.10 Clean Renewable Energy Bonds (CREB)

Under this type of policy, the developer gets the equivalent of an interest free loan to finance energy projects for a limited term. The developer obtains the benefits upfront unlike in PTCs above where the tax credits are drawn when the plant is financed and producing power. CREBs are issued by the utility or government and those bondholders will receive a tax credit that is in lieu of the developer paying interest to the bondholder. The developer pays back equal amounts to cover the principal amount owed to the bondholder for the term of the bond commencing from the year of issuance. They are capable of assisting the financing of renewable energy by reducing the financing costs

and the overall LCOE. Typically CREB issuers must spend 95% of the proceeds within five years for that project or they lose the right to receive any tax credits [2].

5.3.11 Accelerated depreciation

This scheme works like the investment tax credit as it allows developers to receive their tax benefits much earlier. The developer can recover the investments in RES facilities by depreciating them over say 5 years instead of the usual 15 to 20 years. It greatly reduces the risk associated with RES projects and can stimulate their development. They suffer the same disadvantage in that they do not offer the developer an incentive to produce more power. It is important that the projects are correctly incentivised to maximise both capacity and minimize costs. Technical standards and certification can be included to ensure that capacity factors are not deliberately reduced as is the case of Germany.

5.3.12 Capacity payment tariff

The capacity payment tariff is paid to developers for providing firm power and support that they give to the grid during peak times. The tariff is paid to encourage the RES generators to provide power at peak periods in return for additional revenue. It is the role of the regulator to ensure that utilities do not seek to change tariffs in such a way that negates the benefits to be gained by the RES developer.

5.3.13 Buy down capital cost

In a buy down capital program, money is collected for every kilowatt-hour of energy generated and this collected amount is used to subsidise the purchase of renewable energy systems. It is normally used for small residential renewable energy systems especially solar PV. The program is not normally suitable for utility scale projects.

5.3.14 Carbon credits

The Clean Development Mechanism (CDM) is a mechanism that was formulated under the Kyoto Protocol to assist countries to meet their target GHG emissions. The CDM is aimed at encouraging technology transfer between the developed and developing nations and create additional revenues for RES plants. Developed nations can buy Carbon Emission Reduction (CER) credits from the generator of renewable energy. It is meant to attract foreign capital investment in RES as well as encourage and permit participation of both private and public sectors in sustainable projects. There are several challenges that

developers site in the working of the CDM which include the long lifespan of the projects versus the Kyoto's commitment period, and the registration and legal costs which may outweigh the CERs credits to be obtained. This has been addressed by allowing projects to be combined so as to reduce overall transaction costs.

5.3.15 Other Tax Incentives

There are various tax incentives that can be used to lower the overall cost of renewable energy. These include property tax incentives, income tax exemptions on sales of renewable energy and equipment and exemptions from import taxes on equipment or components.

The various forms of incentives given to RES is evidence of the fact that in their inception stage, they cannot compete with conventional sources of power and require some form of support in order to do so.

6 ASSESSMENT OF POLICIES ADOPTED BY THE LEADING SOLAR PV MARKETS GLOBALLY

This chapter seeks to explore the policies that were adopted by the best performing markets in the solar PV sector. In particular, the section will discuss the best markets based on the installed solar PV capacity to date, and how they evolved to be the best in class.

The aim of the exercise is to determine if there are any conclusions that can be drawn regarding the development of a successful PV market vis-a-vis the policies adopted at the onset of the market, or wherever relatively higher installations of solar PV were registered. The countries that have the highest installed capacity of solar PV as at 2011 are discussed in detail below, together with a brief history where applicable [5].

6.4.1 Germany (8, 12)

Germany is the global leader in PV system deployment in the world. The rapid growth in PV was mainly due to the Renewable Energy Act that resulted in the introduction of FITs which offered developers a guaranteed selling FIT price over a 20 year period.

There was also a parallel 100,000 Roofs Programme which increased the share of roof-top PV installations to grow exponentially due to the incentives offered. Utilities would buy the power at the higher FIT price and pass the additional costs to all the customers. This resulted in the financial burden due to the high solar PV energy price being felt much less.

The Germany system now includes a corridor mechanism that automatically reduces the tariff each year based on the level of market performance of the previous year. The adjustment can either be up or down and depends on whether the threshold was exceeded. The amount of adjustment is set to equal the percentage the threshold was exceeded or was not met [12].

In essence, the FIT programme was instrumental in the phenomenal growth registered in the Germany solar PV market as well as stimulating growth and efficiency in the solar PV market.

6.4.2 Italy [8, 12]

Italy is endowed with high levels of sunshine and has a mixture of net-metering and a well-segmented FIT. It registered significant success in PV when it initiated its first PV support scheme by introducing the PV Roofs Program in 2000. This was further enhanced by the introduction of the FITs in the year 2005. PV was granted a guaranteed price over a 20 year period with a special emphasis on Building Integrated PV (BIPV) which resulted in rooftops accounting for about 57% of the total installed capacity in 2008. Italy also introduced performance targets for quality of service provided which determined the level of incentive paid. Again the success of Italy was premised on incentives and specifically the FITs that were introduced in 2005. The Italian government recently introduced a third Energy Bill that reduces the FITs in phases with a cap of 3000 MW. This policies on net metering and FITs adopted by the Italian government has driven the PV market to be one of the countries with the highest levels of installed PV [12].

6.4.3 USA [8, 12,33]

The USA had not aggressively focussed on the development of solar PV despite the huge potential. However, the financial crisis in 2008 exerted pressure on state governments to introduce subsidies in order to create economic growth premised on the development of cleaner and more diverse energy sources including solar PV. This is in addition to the fact that the USA is an attractive market due to a high electricity demand, available land for such projects as well as its isolation from other countries [33].

The policies are generally at State level due to the USA's government structure and vast land base. This has led to vast differences between the levels of installed capacities in the different States. Between September 2008 and September 2009, about 40 new solar incentives were created in 19 States and incentive levels were reduced in 10 States. The breakdown of the 40 new incentives was as follows:

- 14 production incentives other than FIT
- 11 FIT
- 14 renewable energy credits (RECs) purchase programmes

By the end of 2009 about 30 States had adopted RPS with about 17 specifying the amount of solar PV that should be provided. A law was passed to allow utilities to purchase the electricity through FITs to be eligible for credits under the RPS. The USA thus registered huge growth in PV development due to the above policies.

6.4.4 Japan [8, 12]

Japan initiated a subsidy programme to purchase surplus PV power in 2009 through changes that were done to the Promotion of the Use of Non-Fossil Energy Sources and Effective Use of Fossil Energy Source Materials by Energy Suppliers Act as well as enactment of legislation that obliges electricity utilities to purchase surplus PV power from developers. This purchase system was not an absolute FIT as utilities were only obligated to purchase excess PV power generated. The Ministry of Economy, Trade and Industry allocates the budgets for PV market revitalisation, subsidies for the installation of PV systems and technology development amongst other measures. The incentives paid for are reviewed annually and all electricity consumers contribute towards the renewable energy costs [12]. The Japanese system has thus revised its targets upwards from 14 GW to 28 GW due to the interest generated by the incentives that were put in place by the government.

6.4.5 China [8, 12,30]

Although China is the world leader in manufacturing PV modules, producing over 40% of the world's global PV production in 2009, it still has a relatively small installed PV capacity. China's polices and strategies in support of PV operate at national, provincial and local government levels. Central government sets the national targets which provincial and local authorities are given space to strategise to meet those national targets. The Renewable Energy Law that was passed in February 2005 was the first law passed in support of RES and obligated utility companies to purchase renewable energy produced at the regular market price, while the developers received favourable tax cuts and banking loans to finance their facilities. This law did not create much interest as it lacked specifics that developers are worried about thus increasing their risk. In late 2009 the national Energy Authority raised the target for solar PV from 1.8 GW to 20 GW by 2020, with 5

GW to be installed by 2015. China has already surpassed this target as it has already installed about 7 GW. Some regional initiatives have introduced FITs (e.g. the Jiangsu province which is the hub of PV manufacturing resource base, as well as Zhejiang) to attract investors with the costs being shared amongst the consumers in that region. The lack of a national driven FIT has stunted the development of PV to the levels that would match its production capacity which is mainly for export.

6.4.6 Spain [4, 8,12]

Spain was the world leader in 2008. The Spanish incentive system offered a mixed payment for investors in PV. A fixed price could be offered for the sale of the PV generated energy, or a premium was paid over the regular market price at which conventional electricity was sold.

The prices were determined on an annual basis on the regular price of energy at the time. This approach is similar to the two FITs systems discussed earlier. In the Spanish case, this meant that the PV developer can choose the system that would benefit them the most based on their specific project. This also influenced the installation of large ground-mounted systems especially in 2008 when Spain installed about 45% of all newly installed PV in the world during that year. Spain later switched to a FIT system in order to manage the growth in the PV industry.

Problems arose due to the fact that while developers were paid the high FIT tariffs by the utilities, the costs associated with this were not recovered by the utility form the customers as was the case with Germany. Control caps were also introduced in 2009 which limited PV to 500MW per year.

The most disastrous move was the retroactive introduction of a Royal decree that affected existing plants which led to project cancellations and putting at stake the viability of many investments. Despite these challenges, Spain witnessed a huge amount of growth in the installed capacity of PV due to its feed-in policies (fixed or premium).

6.4.7 France [8, 12]

France has one of the most attractive FITs for ground mounted systems that are located in the north with a correction coefficient that depends on the local irradiation levels. This was as a result of the review of the FITs which was done in January as well as in September 2010. In addition, there are multiple tariffs for BIPV systems whose tariffs are

amongst the highest in the world. The major setback for the French schemes is the administrative and grid connection burdens which somewhat slowed down the PV growth in France.

6.4.8 Belgium

Although Belgium is an unlikely player in the PV market, it has managed to grow its PV market significantly thanks to its green certificate support scheme in each of its three territories. The three regions implement different versions of the green certificate system with the Flanders region implementing a fixed price, while with the Wallonia region the value of the certificates fluctuates based on supply and demand. There has been a decrease of the level of support since 2009 and in the Wallonia region the subsidy had to be withdrawn to curb the unsustainable growth of PV. The reductions were in line with international PV module prices reductions. In the Belgian system, utilities were obliged to produce enough green energy themselves or purchase certificates from such producers through green certificates. The proportion of green energy was increased at a rate of 1% every year.

6.4.9 Australia [2, 47]

Australia passed the Renewable Energy Act to add 9500 GWh of renewable energy per year. The PV market in Australia has been growing steadily due to the support which is through the Mandatory Renewable Energy Target scheme which was meant to create trade and surrender RECs and more recently the Large Scale Feed in Tariff Scheme which provides the Australian Capital Territory to grant feed in tariffs entitlements up to 210 MW of generation capacity. There are also other mechanisms such as the Research and Development (R&D) tax incentive scheme. Activities conducted as part of RE development may be eligible for the scheme which offers a 45% refundable tax offset for eligible entities with a turnover of less than AUD20 million, as well as a non-refundable 40% tax offset for all other entities [49]. There have been however, some administrative hurdles and delays in project approvals, high capital costs, technical workforce capacity and high levels of complex multi-tiered regulation which created barriers to renewable energy development in some of Australia's territories [58].

6.4.10 Czech Republic

The Czech State Energy Policy adopted a set of renewable energy targets of 15-16% of total energy consumption and 17% of electricity production by 2030. Feed-in Tariffs with duration of 15 years and green bonuses were introduced in 2006. Producers benefited from purchase obligations with the regional distribution system operator and they could find their own customers [12]. The Czech PV market grew exponentially between 2009 and 2010 due to low administrative barriers and favourable FITs that were introduced which demonstrated that the FITs have the capacity to develop a strong market. The country jumped from being an unknown PV player to be a huge player by adopting dynamic market control mechanisms. This approach has assisted the Czech Republic to be recognised in the global solar PV market

6.5 Conclusions on PV support schemes in the top ten countries

As previously discussed, Europe's domination of the market was significantly reduced from 22 GW to 16.9 GW but still dominated the market by having a 59% share of the PV market. The majority of the top ten countries in terms of installed solar PV capacity are seen to have some form of support, with the best adopting feed-in tariff support schemes.

It would therefore be important to look at how the continent adopted support schemes that would break down the barriers to renewable energy development. The map below shows the countries in Europe and the type of support schemes that were adopted by the countries. This further demonstrates the preference of the FIT scheme as compared to other type of support schemes. [12].

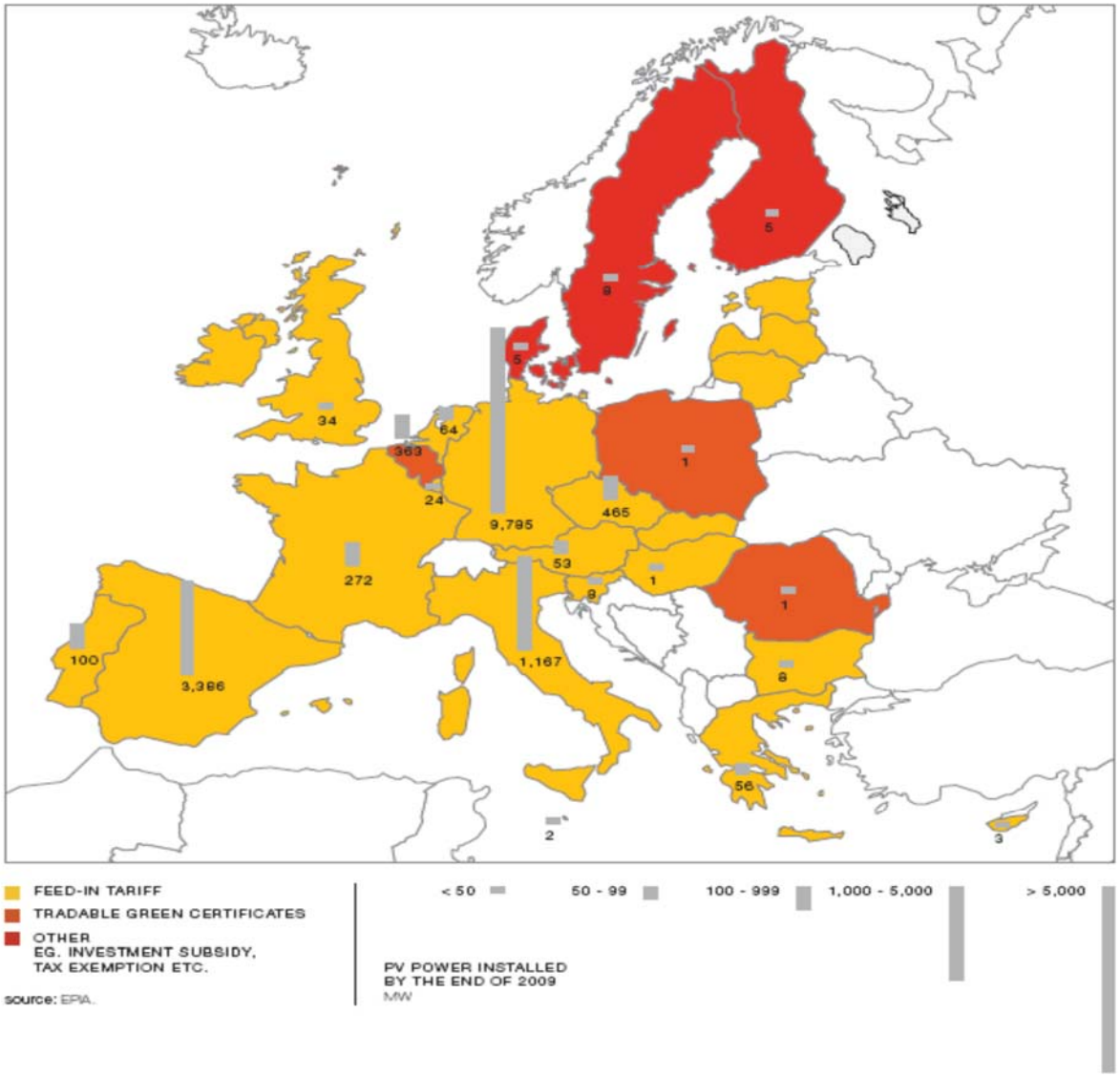


Figure 8: Map of Support Schemes in Europe [12]

7. ANALYSIS OF THE ENVIRONMENT CHANGE ON THE VIABILITY OF SOLAR PV PROJECTS UNDER REBID VERSUS UNDER REFIT

7.1 Overview

This chapter will focus on the solar PV results of the current bidding process (REBID) in economic terms. The DoE REIPPPP programme is the largest renewable energy procurement in Africa and probably the most complex public-private partnership ever run on the continent [41].

This analysis will be measured against the LCOE under the following scenarios:

- REFITs as announced as well as the revisions which were never implemented. The focus will be on the projected levels of the LCOE that were to be paid to developers:
- Benchmarking the historic and current LCOE in various developed markets bearing in mind the differences that may be between the markets. This is expected to give an indication of the global average for solar PV so as to compare with the average solar PV bid prices under the REBID.
- A calculation of the solar PV LCOE will also be done using current financial assumptions. A solar PV excel model will be used to calculate a realistic solar PV LCOE range that is applicable to the South Africa market.

These approaches are meant to analyse whether the developers are bidding at the appropriate levels that will ensure that they recover costs associated with their developments as well as "earn a reasonable return" as envisaged by the Electricity Regulation Act, Act No. 4 of 2006.

7.2 Solar PV qualification criteria under the REBID

7.2.1 Bid Price

It is important to note that several strict criteria were used to select preferred bidders for solar PV technology but the main criterion was based on price which had a weight of 70% of the bid evaluation criteria. The RFP specified that bidders had to submit their proposed prices per MWh for the Energy Output to be generated through the applicable technology.

The indexation in question had to be transparent, involve a single adjustment on 1 April each year (starting on 1 April 2012) and be based on an annual CPI adjustment reflecting any change in CPI in the immediately preceding year commencing 1 January and ending 31 December 2012 [41].

7.2.2 Other criteria

As stated above, the bid price had the major share of the bid evaluation criteria with the rest therefore having a weighting of only 30%. The other criteria included the following:

- Eligible capacity was specified as a minimum of 1 MW and a maximum of 75 MW for a single gird connection point
- Proven technology which specified the requirements for technology to be commercially proven and complying to international standards such as IEC/EN
- Proof of energy resource assessment such as 10 years of solar data taken from specified sources
- Expected average annual yield from the proposed plant for the first 20 years which has to be verified by an independent expert
- Demonstrate developer and contracting company capabilities
- Compliance with Codes
- Water consumption
- Project schedule and capability of beginning commercial operation by June 2014
- Economic development scorecard
- Bid guarantee submission

By implication, this meant that the bids would be evaluated on the bidding price that is submitted by the potential developer.

7.3 Trends in the Solar PV REBID Prices

The option selected by the DoE was based on meeting the requirements of the legislative framework in the country regarding procurement of goods and services. This is coupled with the need to streamline costs associated with services by ensuring that service providers become as efficient as possible thus reducing the price of the goods or services. As mentioned before, all technologies had a price cap at, or under which the bidders were expected to bid. In the case of the solar PV, this was set at R2.85/kWh for the first and second bidding rounds and R1.40/kWh for the third round going forward. As expected, the announcement of the preferred bidders during the first, second and just now the third round witnessed a huge drop in average solar PV (not limited to solar PV) bid prices which is graphically shown below.

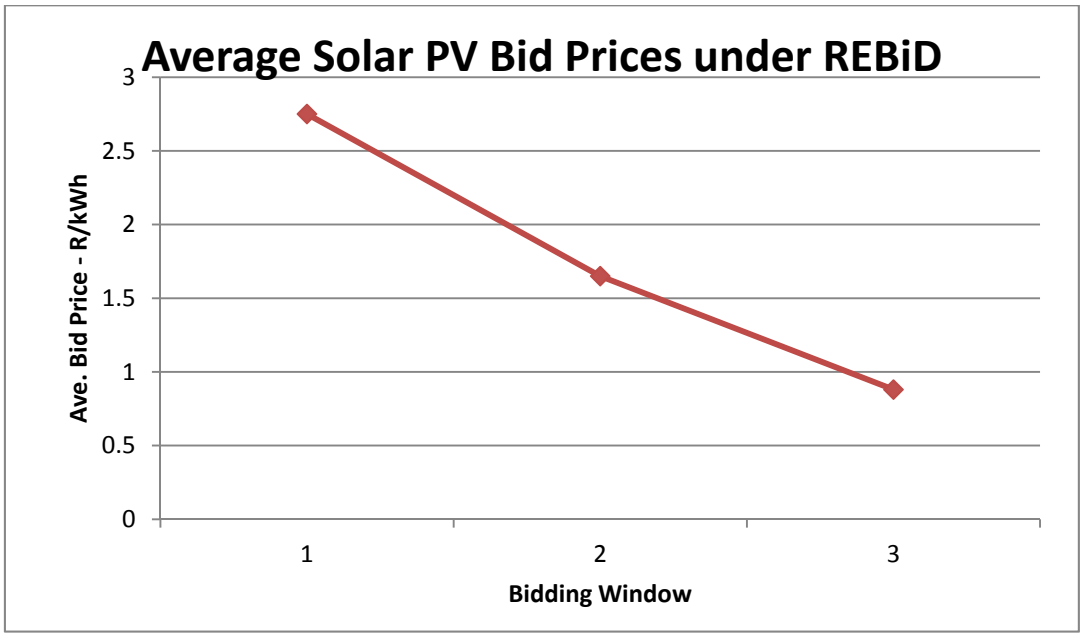


Figure 9: Average Solar Bidding Prices for the REBID Windows

The graph shows a rapid decline of the average bidding prices from the first window to the third window. The percentage reductions from the first window to the recently announced third window are tabulated below.

Table 7: Solar PV REBID Window Average Price Drops

Phase 1 versus Phase 2	Phase 2 versus Phase 3	Phase 1 versus Phase 3
40%	46.7%	68%

The important issue to be discussed and explored by this dissertation is whether the decline is due to a fall in the prices of system components (major component being the PV modules), change in the financial assumptions (such as cost of capital reduction, operation and maintenance cost reductions) or is driven by the high level of competition that is playing out in the bidding rounds. The report will seek to establish whether such reductions are sustainable in the long run and the possible implications on the South African solar PV market going forward.

7.4 Solar PV REBID Prices versus Projected REFIT Rates

As discussed earlier, the REFIT rates were discontinued based on their misalignment with the South African state procurement systems. They were developed on sound technical and economic principles and were highly praised by both local and international players in the renewable energy fraternity. The REFIT tariffs announced during the initial phase in 2009 and the review of 2011 for solar PV are as shown in graph 7-2:

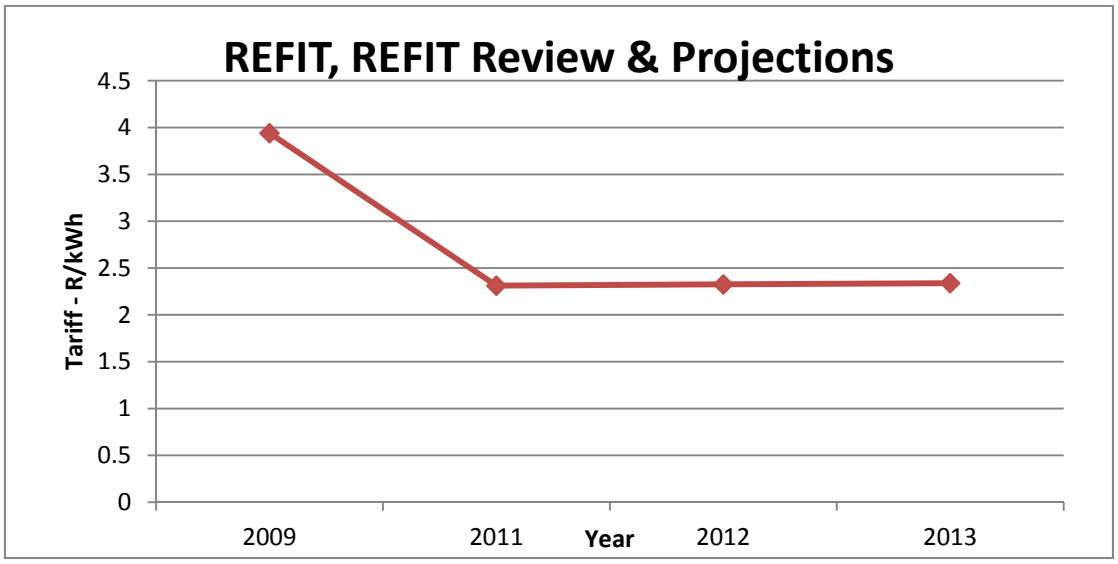


Figure 10: Solar PV REFIT Tariffs, Review and Projections

The REFITs graph shows a huge drop between the initial announcement in 2009 and the subsequent review in 2011 due to the change in the financial assumptions as discussed previously. It is important to note that the review did not take into consideration the

reduction in costs due to technology improvements in solar PV. However, the REFIT solar PV tariff projections for 2012 and 2013 which will be compared with the REBID window 2 and window 3 respectively.

Although both window 1 and 2 were announced in 2012, the comparison will be done with the latter in order to approximate a fair comparison.

The comparison between the REFIT review projections and the average bid prices for PV is as shown in the graph below.

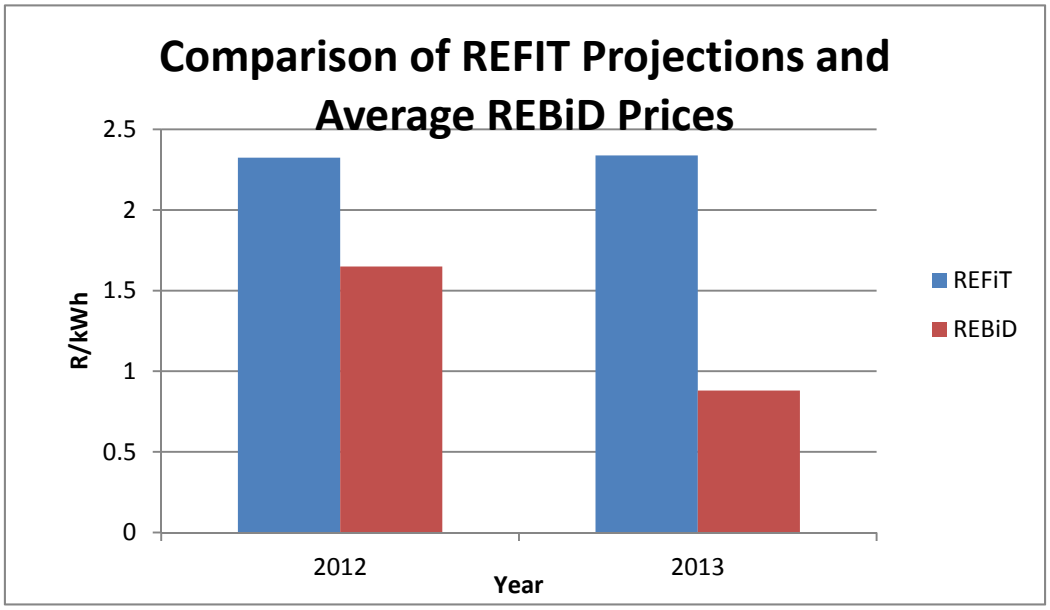


Figure 11: Comparison of REFIT Review Projections and average REBID Tariffs

The comparison clearly shows the growing gap between what the projections for REFIT and the actual average bid prices for the REBID. The gap between the two approaches grows from about 29% in 2012 to more than 62% in the following year.

Whilst technology improvements were not taken into account in the REFIT projections, it is known that for solar PV the LCOE decreases by about 22% for every doubling of capacity. As an example, the installed capacity globally increased by about 44% from almost 68 GW to 98 GW and the trend is expected to continue in that fashion [36, 48].

It is unlikely that even with huge advances in technology the price under REBID would not fall by such a huge margin as discussed earlier.

7.5 Solar PV REBID Prices versus International benchmark prices for PV

This section gives an overview of how the REBID average bid prices for solar PV compare with the average LCOE prices in various other jurisdictions around the world. Solar PV is commercially viable in nearly all regions in the world with significant potential for long term growth [40].

While it is acknowledged that the factors that influence the LCOE differ significantly in these jurisdictions, the section seeks to come up with conclusions on whether the prices in South Africa are too high or are too low. As is widely recognised, there has been, and there still is a persistent reduction to the cost of solar PV as technological improvements result in higher efficiencies, longer life spans and lower PV module prices. The graph below shows the average module price decline trend from around 1985 to 2010. The trend is continuing with the price now close to $1/W and below [32, 38].

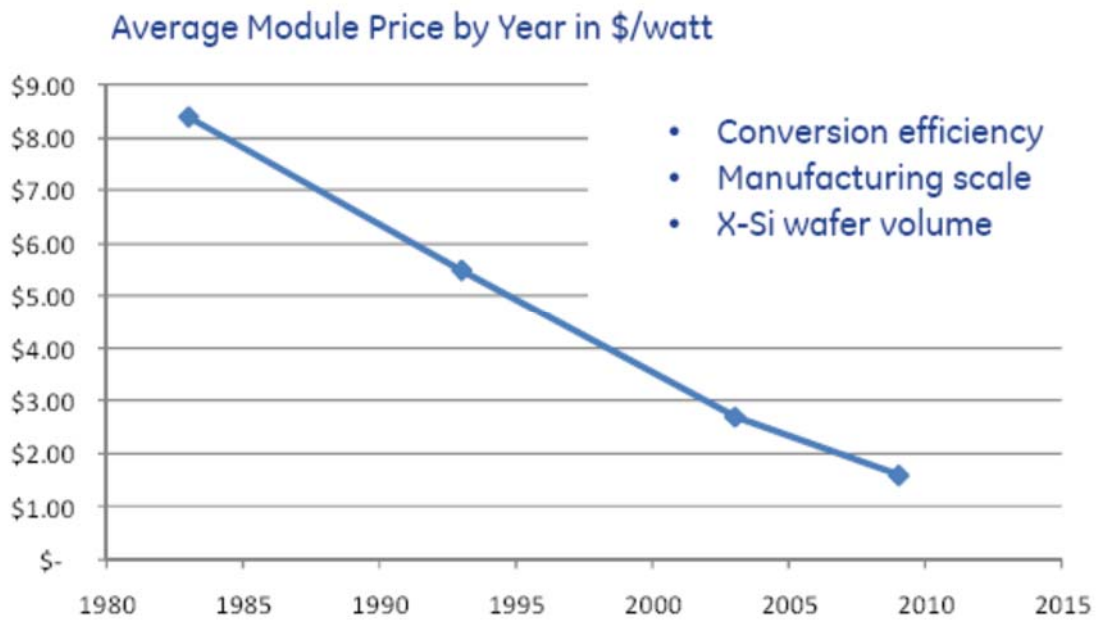


Figure 12: Average Module Price Decline by year in $/Watt [43]

7.5.1 Approach to benchmark comparisons

The concept of the LCOE will be used to compare South African prices under the REBID versus the trends worldwide based on credible international research organisations, including forecasted prices. The objective of the study is to evaluate whether the bid prices offered under the REBID will cover the investment and operating costs of generating electricity from solar PV. As discussed earlier, the LCOE in a given situation depends on the assumptions adopted. Different assumptions will result in differences in

the final LCOE figure for solar PV as discussed under the LCOE section. Besides the other factors such as capital costs, O&M and resource availability, the way the project is funded also affects the LCOE significantly. The following figure illustrates the typical cost components of an installed solar PV system.

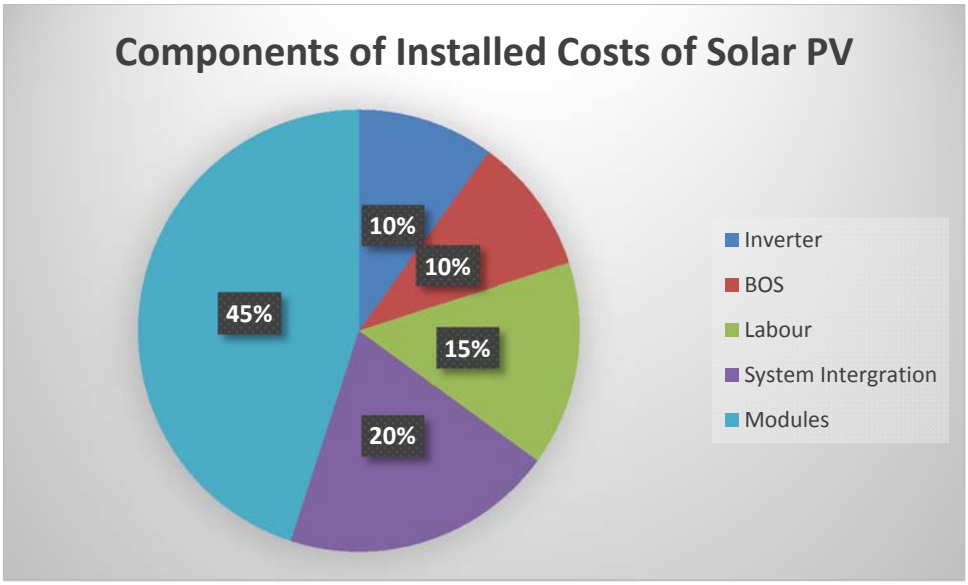


Figure 13: Typical Cost Components of Solar PV Installed [34]

In addition to the above, investors measure the risk or perceived risk in order to determine the levels of return required, which is based on the risk that they are taking to invest capital in a project (summarised by the Weighted Average Cost of Capital –WACC). These risks vary from project to project as well as between countries and/or regions especially for projects such as solar PV power plants. This means that the values that are given by the research institutions are based on a range of assumptions and are sometimes given as a range of values to cover the variations encountered in the data gathering.

Another important factor is the issue of subsidies in whatever form as discussed earlier. The LCOE can be modified to include subsidies that are offered by the governments hosting the project developers to encourage deployment of renewable energy projects such as solar PV plants.

For the purposes of this research report, the benchmark LCOE figures to be considered will exclude subsidies of any form. This enables the comparison to the REBID bid prices to be reasonable as no subsidies are included.

7.6 Benchmarks and Forecasts for Solar PV LCOE

Various sources will be used in coming up with the benchmarks of current and/or forecasted solar PV prices. It is to be acknowledged that the prices of PV have been falling at rates higher than previously anticipated and this has had the effect of rendering some forecasts inaccurate.

The price drops have largely been driven by higher than expected installations (economies of scale) and massive reduction in module prices due to technological innovations and improvements. Most solar PV forecasts had been conservative on the expected trend of price reductions and the actual installed capacities have surpassed targets, while the LCOE prices have gone below the target price.

7.6.1 Benchmark Studies

(a) China

The figure below shows the trends that the past, present and future cost of solar PV is expected to follow in China [40]. The study and analysis were conducted in 2009.

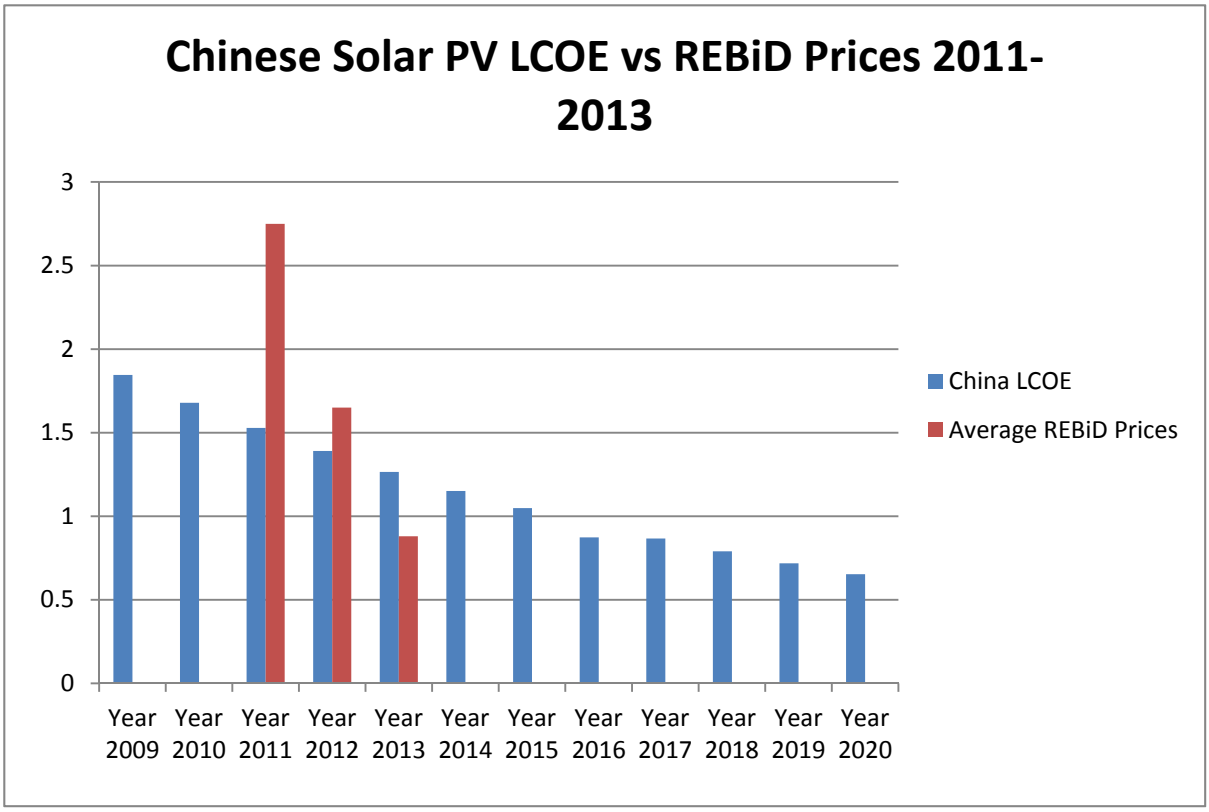


Figure 14: Comparison of Chinese LCOE Projections with average REBID Prices

This is compared to the average REBID prices with the first round being compared to the 2011 Chinese LCOE.

From the above figure, it can be seen that the projected Chinese LCOE is less than the average bid prices in the first and second rounds, but higher than in the third round. With the expected continual decrease in solar PV prices, the South African bid prices are expected to continue falling below the Chinese projections although at a lesser rate and will taper off at some point.

(b) North Carolina, USA [44]

The comparison is also done with the 8th ranked State in the USA in terms of cumulative installed solar PV capacity. The study was conducted in 2012. The figure below shows the trends and forecast of the LCOE without incentives. Although the first round was announced in early 2012, this will be compared with the 2011 North Carolina LCOE so that the second round is compared with the 2012 price.

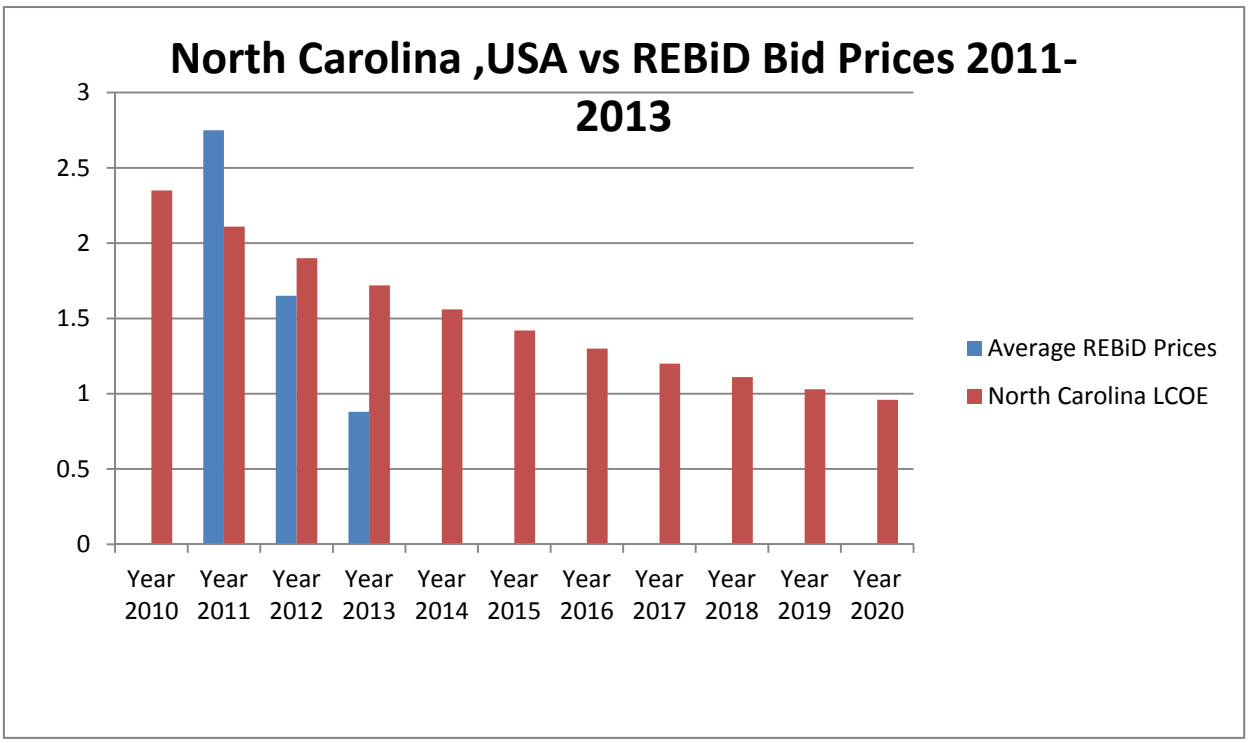


Figure 15: Comparison of North Carolina LCOE Projections with average REBID Prices

The figure above also shows that the average bid price in the first round in early 2012 (compared with 2011 LCOE) was higher than the North Carolina LCOE, while the second round bid price which was compared with the 2012 North Carolina LCOE was less but

comparable to the latter. However, the bid price in the third round was much lower than the projected North Carolina LCOE.

(c) US Energy Information Administration (EIA) Annual Energy Outlook 2013 Report [46]

The US EIA report presents the average levelised cost for generating technologies that will be brought online/entering into service in 2018 as presented in the Annual Energy Outlook 2013 (AEO2013) Early Release Reference case. The focus of this report will be the figures for solar PV technology. These values are the averages for the 22 US regions used in the modelling. The aim of the comparison is to show how the average LCOE forecasted for plants to come online in 2018 compares with the current REBID prices throughout the phases. The averages are based on a set of assumptions which include a real after-tax WACC of 6.6%. As mentioned previously, prices tend to vary even within one region due to solar resource level, grid integration costs as well as factors such as labour rates. The average LCOE figures do not include subsidies of any form.

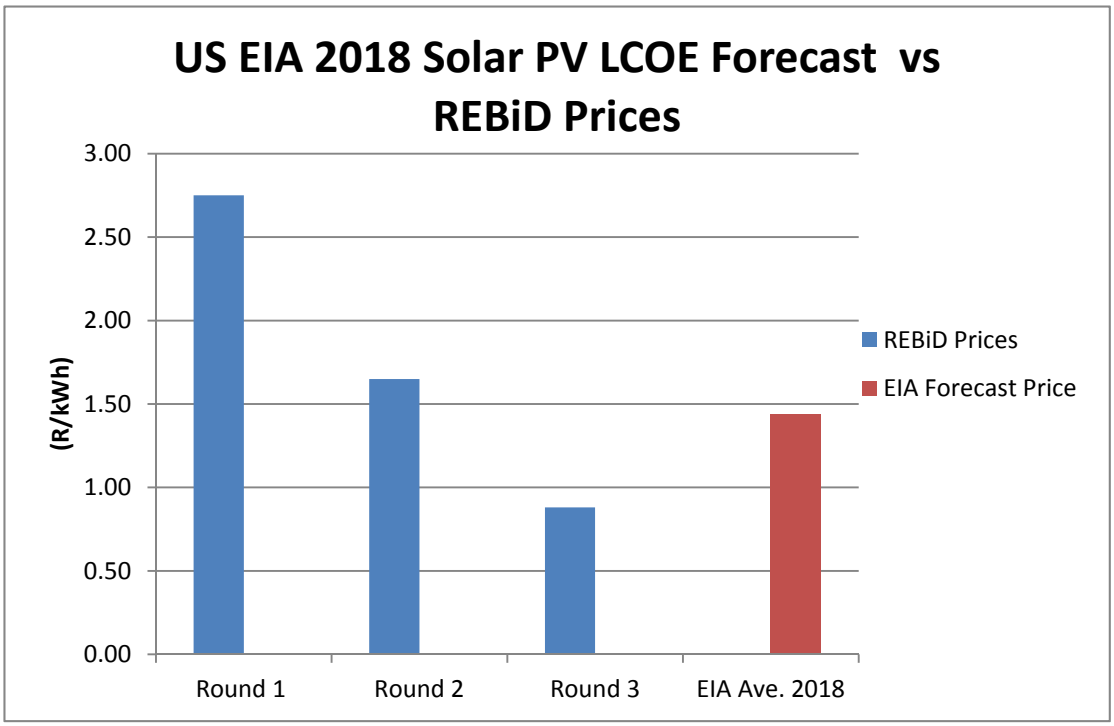


Figure 16: Comparison of the US EIA 2018 Solar PV LCOE Forecast with average REBID Prices

The figure shows that that the forecasted solar PV LCOE for plants coming into service in 2018 in the US is less than the price for rounds 1 and 2, but once again higher than the

prices bid in the third round. This reflects that the EIA average in five years time is much higher than the latest third round bid price. This is in spite of the fact that the cost of capital is generally lower in the US compared to South Africa, and labour rates are higher in the US than in South Africa for example. Although capital costs are a major cost component of the total installed solar PV cost, developers are sourcing the panels from common markets e.g. China and thus there is less variation in the overnight capital costs across the globe.

(d) Lazard Levelised Cost of Energy Analysis [7]

The last comparison is with the figures published by Lazard in 2013 on the LCOE of various technologies including solar PV. The figures cover both solar PV crystalline as well as thin film technologies. The LCOE is based on a set of assumptions which ultimately determine the value arrived at. No incentives are considered and utility scale plants will be presented as part of this report. As before, the range will be compared with the pries that were bid in the DoE REIPPPP programme. The comparison is shown graphically below.

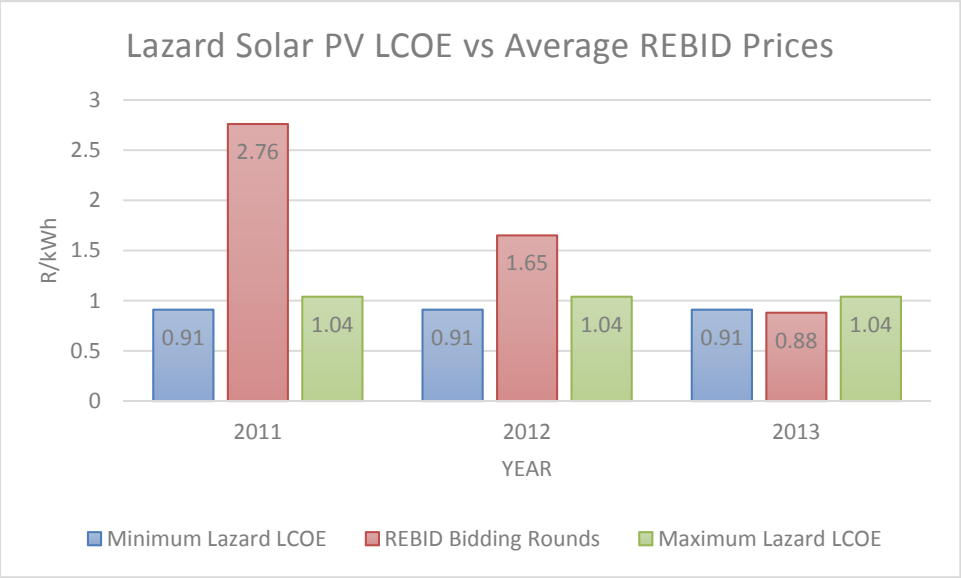


Figure 17: Comparison of the Lazard Solar PV LCOE Analysis with the average REBID Prices

The graph shows a comparison of the average REBID prices which indicate that the prices in the first and second round were much higher than the minimum and maximum of the Lazard report. This trend would be expected in the solar PV domain due to the price reductions as has been alluded to. However, the average bid price in the third round compares favourably with the Lazard minimum and maximum LCOE figures.

The average bid price is slightly less than the Lazard benchmarks and the differences could be attributed to the set of assumptions that are adopted in each case. The comparison with Lazard benchmarks conducted in the same year as the third round bids were announced, seems to suggest that the bid prices that were announced in the South African market are reasonable and the reductions are based on prudent costs and assumptions which will enable the investor to cover its costs and obtain a reasonable return as stipulated by the Electricity Regulation Act, Act No.4 of 2006.

Since different benchmarks used in the report arrive at different conclusions, it would be useful to calculate the LCOE for solar PV as part of this report. The result obtained from such a calculation would enable a fair assessment of the REBID prices as well as evaluate the benchmarks used in the report. It is once again emphasised that the LCOE values are driven by assumptions in each case. The solar PV LCOE calculation to be performed in the next section will outline the assumptions adopted, which should reflect the South African market to a greater extent, in order to come up with a fair analysis and conclusion.

7.6.2 LCOE Calculation Assumptions Adopted for the South African PV Market

The background to the calculation of the LCOE, its advantages and disadvantages has been covered in earlier sections. This section will determine an indicative value for solar PV in the South African market based on several assumptions. Once again, the values of the various parameters are averages which however should enable the author to make correct conclusions.

(a) Model Adopted

The model to be used is called the ECM Calculator (theory adopted from a paper by K.Branker, M.J.M Pathak et al ‘’A Review of Solar Photovoltaic Levelised Cost of Electricity’’, 2011)[ref] which calculates the simplified LCOE for solar PV. The model has an input page that allows the best estimates for the business to be input into the model including the various assumptions adopted. These assumptions relate to the solar PV system under investigation. As already discussed, typical solar PV projects are capital intensive and therefore the financial assumptions are also input into the model such as the interest rate,

gearing ratios and loan term. The model calculates the LCOE for a user specific loan term but also gives the LCOE for default loan terms from 5 up to 40 years with 5 year intervals. It also then provides the best period that will give the lowest LCOE for a PV system. The model costs are given in Canadian Dollars ($CAD) and the default exchange rate is 1Canadian Dollar = 10 South African Rand.

(b) Assumptions adopted

The assumptions that apply to the South African market were incorporated into the model, together with other standard assumptions that would apply to any solar PV project on the globe. Below is a set of assumptions that were adopted in the calculation of LCOE.

i. Rated system size – the reference plant for solar PV has been adopted as 10 MW as per Electric Power Research Institute report that was used in the formulation of the IRP2010, the REFIT tariffs published by NERSA, as well as the Lazard report discussed above.

ii. The project life is 20 years.

iii. The capacity factor for solar PV in South Africa based projects has been set at about 20%.

iv. The inverter replacement period is 10 years as per the international guidelines.

v. PV system warranty normally given by manufacturers is about 30 years for their modules.

vi. The rate of degradation of the solar PV system per year will be set at 0.5% as is the norm worldwide [59].

vii. Capital costs for the solar PV system installed are set at $2000/kW or R20,000/kW as per the latest average values for the DoE Renewable Independent Power Producers' Procurement Programme (REIPPPP) bidding programme.

viii. O&M costs are assumed to be fixed and are about $20/kW-yr – assuming fixed tilt configuration.

ix. The loan tenure is assumed to be 13 years which is an indicative figure of the average tenure granted by lenders in the South African market. It assumes constant repayments over the life of the loan.

x. The discount rate/WACC is one of the most important factors in the determination of the LCOE. To substantiate their investment projects, enterprises usually use WACC with respect to the tax effect as shown in equation (4) below [26].

$$WACC = R_d \times W_d \times (1 - t) + R_e \times W_e \qquad (4)$$

Where

$$W_d = \frac{D}{D+E} \times 100\%$$

And;

$$W_e = \frac{E}{D+E} \times 100\%$$

Explanations:

- R_d – cost of debt in terms of percentage;
- R_e – required return on investment (after taxation) in terms of percentage;
- W_e – percentage share of equity in capital employed[1];
- W_d – percentage share of debt in capital employed;
- D – market value of debt;
- E – market value of equity;
- t – effective profit tax rate.

[1] Employed capital is defined as the sum of equity and debt.

In the context of the South African market, the typical values of the share of debt and equity used to calculate the WACC in the renewable energy sector are given below:

W_d =0.7, W_e = 0.3

The required average rate of return on investment for current projects under the DoE REIPPPP, R_e is about 8% on average while the cost of debt in terms of percentage is about 12%.

$$\text{Therefore the post} - \text{tax } WACC = (12)(0.7)(1-0.8) + (0.3)(8) = 8.45\%$$

This is the value that is to be input into the model to determine the solar PV LCOE. It is important to note that the WACC has decreased significantly from about 12% to 9.8% in the REFIT Phases 1 and 2. This will naturally decrease the overall LCOE due to reduced financing costs.

7.7 Results of the Solar PV LCOE Calculation

Based on the assumptions discussed in the previous section, the LCOE for the South African market at the present moment is calculated. The assumptions are input into the ECM032 model to produce a summary of results. These results are summarised in the section below. The LCOE is calculated in Canadian dollars per kWh and converted to South African Rand (ZAR) respectively.

Table 8: Summary of Calculated LCOE Results

Executive Summary									
The interest paid on money financed for the PV project is the most significant variable in determining the project's LCOE. In this project, a custom term of 13 years was selected. The LCOE for this custom term is compared with the default loan terms calculated at 5-year increments from 5 to 40-year loans									
Loan term (Years)	13	5	10	15	20	25	30	35	40
LCOE ($CAD/kWh)	0.1167	0.1171	0.1168	0.1166	0.1165	0.1163	0.1162	0.1161	0.116
Loan term (Years)	13	5	10	15	20	25	30	35	40
LCOE (ZAR/kWh):	1.167	1.171	1.168	1.166	1.165	1.163	1.162	1.161	1.16

Legend		
	Your Custom Loan Term:	
	Default 5-year increment terms:	
	Lowest LCOE Case	

7.7.1 Analysis of Results

The LCOE results for the above are also graphically shown below.

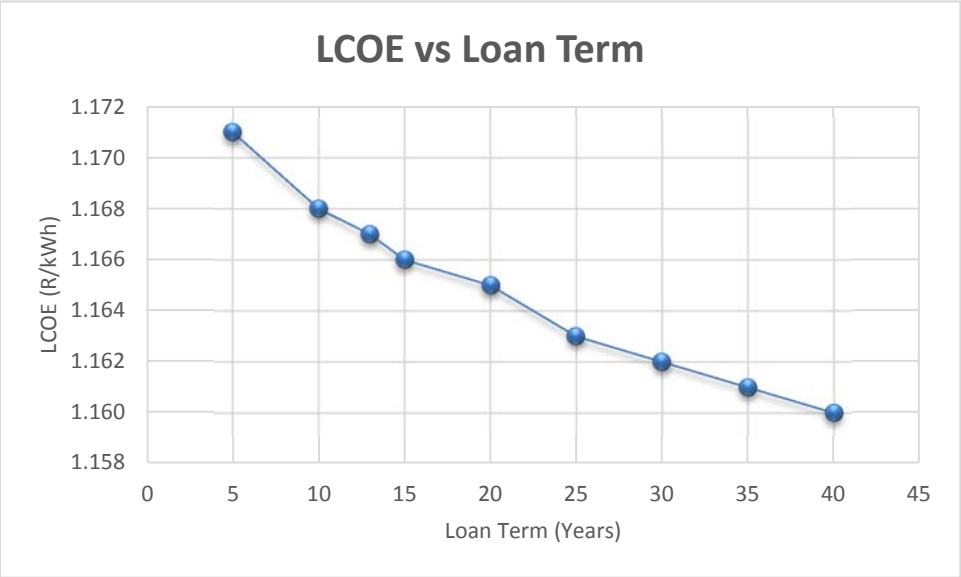


Figure 18: LCOE vs. Loan Term

The custom finance term is 13 years in line with the average loan terms offered by the lending institutions. The model also outputs the loan term that gives the lowest LCOE as well as values obtained at different loan terms, which are by default in increments of 5 years. The LCOE is about R1.17/kWh under the current market conditions. The figure is graphically compared to the REBID phases below.

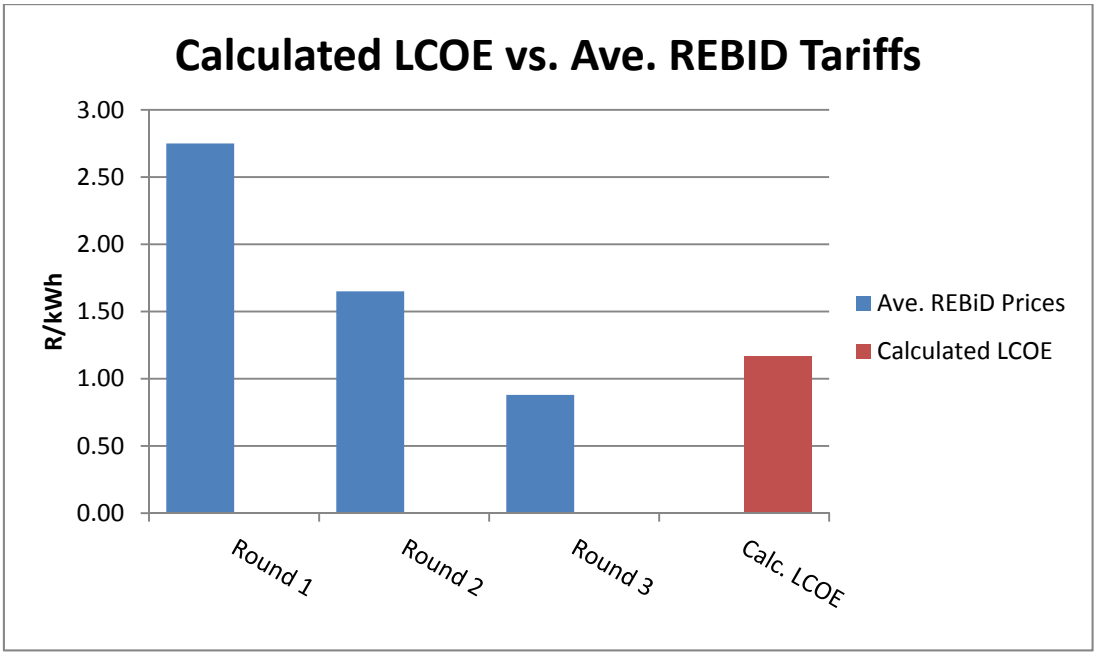


Figure 19: Calculated LCOE vs. average REBID Prices

The calculated LCOE is lower than the first and second bid prices but higher than the bid price for round 3, just like in the benchmark cases. The calculated price is about 33% higher than the REBID price under the DoE REIPPPP. This trend has been maintained throughout the benchmarks that were done in the previous section.

7.7.2 Accuracy of Results

The LCOE calculation was done using the most recent data available in the South African market. The input parameters were based on actual averages that were available in the market pertaining to the DoE's REIPPPP where possible. The averaging of values might not reflect the best estimate but is sufficient to give an indication of trends in the market. The benchmarks used are from reputable sources that gather information from all over the world periodically and maintain databases of such information. By their very nature, power generation projects of similar size and form will not have exactly the same costs associated with them. However, indicative values can be obtained in the form of averages that are based on valid assumptions. On this basis, the results presented in this report are deemed to accurately reflect the solar PV market.

7.8 Discussion of Results

The results obtained from the LCOE calculation follow the general trend that was observed in all the benchmarks that were compared with the REBID average prices. Although it is acknowledged that there are differences in the assumptions in each case ranging from capital costs, O&M costs, resource availability and financing due to the different jurisdictions, there is a general agreement of the trend followed in each of the cases whether in the USA, China, or global averages.

As previously alluded to, even projects that are within one jurisdiction can have different LCOE, if for example they are funded differently e.g. different gearing ratios and expectations on the internal rate of return (IRR).

While the prices differ in the various benchmarks, the REBID and the calculated value, the cost of solar PV has been reducing significantly worldwide and this is a trend observed in all the cases. In fact, the cost has been reducing at a higher rate than predicted in some

cases especially for forecasts that were done more than two years ago. Solar PV has been exceeding both the expected installations and the predicted price reductions and the trend is expected to continue until a point of saturation is reached.

REFITs are extremely simple to implement from an administrative point of view but are very costly in terms of subsidies whether recovered through tariffs or government subsides [19].

It is important to stress that the majority (if not all) the jurisdictions that have adopted the FIT have introduced some form of degression over the years to cater for the reductions in the PV module price and improvements. This avoids windfall profits for developers especially considering that the terms of the PPAs are usually between 15-20 years.

Although there were significant reductions envisaged by the REFITs as published in the consultation paper, the FITs were likely to be overtaken by the actual reductions in solar PV modules which saw a reduction of 60% in the last two years (2010-12) as reported in the IRENA document [54].

The reductions in solar module prices have surpassed predictions done as early as February 2012 such as the National Renewable Energy Laboratory (NREL) report that predicted that the capital cost for utility scale (10 MW , non-tracking) solar PV would reach the $2000/kW price in 2030 (11).

Developers are also forced to reduce costs by bidding larger plants and choosing the best sites to maximise energy production and lower grid integration costs for example. The competition introduced by the bidding process will eventually force developers to set up industries in South Africa to reduce overhead costs and benefit from localisation points, thus benefitting the economy through job creation.

What is encouraging already is the fact that the first and second round projects have reached financial close and some projects have been completed or are under construction and on schedule. Commercial banks have also demonstrated their confidence with the system and they have been supportive of the projects in all the bidding rounds that have been announced thus far.

8. CONCLUSIONS

There is no doubt that solar PV, and renewable energy in general, will play an important role in the South African energy supply mix especially due to the significant solar resources available in the country and the continued decline in the cost of the solar PV modules.

The hypothesis in the report envisaged that the best approach to introduce solar PV in emerging markets like South Africa would be feed-in tariffs (FITs) whose advantages are price certainty, simplicity and accessibility. This view/approach is not supported by the work done in this report as illustrated by the following pros for the REBID programme:

- The programme allowed the efficiencies gained in the PV market to be factored early into the bidding programme resulting in generally lower electricity prices to the South African consumer.
- There programme created an environment that encourages innovation and efficiency as there was competition to reduce prices in order to be awarded contracts.
- The REBID model does not result in windfall profits as it takes into account reductions in the prices of raw materials, which is not the case with the REFIT approach
- As confidence grows in the SA market, there has been a reduced risk premium required by developers and funders alike. The REBID model managed to exploit the reduction in risk and thus the expected returns by project developers and funders.
- The SA REBID programme also has the advantage of having a price cap rather than a pure bidding process that balanced the risk of projects being constructed once the contract has been awarded.
- Through successive bidding rounds, it is therefore possible to progressively reveal the shape of the cost curve [19].

It is clear that a well-designed tendering process can provide a high degree of certainty and stability that is required by potential developers and the South African system is

proving to be one such case as it also protects the consumers from very high electricity prices.

8.1 Recommendations

To ensure the continued successful implementation of the DoE's REIPPPP programme, it is recommended that:

- The government (or through its appointed transaction advisors) continually monitors the developments in the solar PV market especially in terms of deployment and prices as subsequent bidding rounds are announced. As seen for the first and second rounds, although the cap was set at R2.85/kWh, the prices dropped significantly below the cap. It might be essential for the price cap for solar PV to be revised with each round taking into consideration developments in the solar PV market until the saturation point where the price will become more or less constant.

- Tendering systems tend to favour established market players over new entrants as seen even in the SA market where some companies have been selected as preferred bidders in all bidding rounds. There should be mechanisms in place to prevent manipulation of the market and collusion among participants [18].

- As the solar PV market is still in its infancy in the SA market, the government should consistently set ambitious but attainable targets which are dynamic and responsive to market signals. In addition, it should also introduce support mechanisms for innovation, research and development to accelerate diffusion and social acceptance of the technology into the market [39, 52].

- Bid preparation is a complicated and expensive process and small solar PV developers are unlikely to afford to compete in the bidding phases. Although there is an allocation for small RE plants, the process for these should be streamlined as much as possible to ensure that small projects are also implemented especially for the locals who might not have the financial muscle of internationally based companies with vast experience, resources and healthy balance sheets.

- Bidding processes are normally preferred due to the cost reduction that comes with the competition. However, the government has a responsibility to balance the short term cost impacts with the long run benefits such as jobs and lower average price reductions [18].
- Developers seek policy stability and longevity. In this regard, it is imperative that government enacts formal commitments in the energy sector such as the IRP and IEP and synchronise these. Timely revision as envisaged should be prioritised to show government commitment to its plans.
- The stringent criteria used in the bidding process should be continued and should ensure that the quality of bids is at a similar level and that they are realistic and not speculative.

References

1. European Photovoltaic Industry Association, "Supporting Solar Photovoltaic Electricity - An Argument for Feed-in Tariffs", Creating Markets for RES.

2. United States Energy Association, "Handbook on the Best Practices for the Successful Deployment of Grid-Connected Renewable Energy, Distributed Generation, Cogeneration and Combined Heat and Power in India", Asia-Pacific Partnership on Clean Development and Climate, 2009.

3. Morgan Bazilian et al, " Reconsidering the Economics of Photovoltaic Power", Matt Cambell, "The Drivers of the Levelised Cost of Electricity for Utility-Scale Photovoltaics", Sunpower, 2008.

4. http://social.csptoday.com. Last accessed on 03 January 2014.

5. S.M Pietruszko et al, ‘’Development of Photovoltaics in the Central and Eastern European States’’, IEEE 2009.

6. Mr. Peter Kaderjak, Ms. Zsuzsanna Pato, Ms. Palma Szolnoki, ‘’Renewable Energy Regulation’’, INOGATE Programme Hungary, 2011.

7. Lazard, ‘’Lazard’s Levelised Cost of Energy Analysis’’-Version 7.0, August 2013.

8. European Photovoltaic Industry Association, ‘’Global Market Outlook for Photovoltaics Until 2016", EPIA, May 2012.

9. http://www.pvresources.com/SiteAnalysis/SolarRadiation.aspx. Last accessed on 06 January 2014.

10. Severin Borenstein, ‘’The Market Value and Cost of Solar Photovoltaic Electricity Production’’, Centre for the Study of Energy Markets, January 2008.

11. Black & Veath, ‘’Cost and Performance Data for Power Generation Technologies’’, Prepared for the National Renewable Energy Laboratory, 2012.

12. European Photovoltaic Industry Association, ‘’Solar Photovoltaic Electricity Empowering the World", Solar Generation 6, 2011.

13. Cecile Bordier,‘’Development of Renewable Energies: What Contribution from the Carbon Market?’’, Climate Report, Issue No. 16, December 2008.

14. SAIEE Wattnow Magazine, ‘’Independent Power Production and Infrastructure Development’’, May 2013 Issue.

15. Juraj Betak, Marcel Suri, Tomas Cebecauer, Artur Skoczek, ‘’Solar Resource and Photovoltaic Electricity in EU-MENA Region’’, Geomodel Solar, http://geomodelsolar.eu.

16. Tom Penick, Bill Louk, ‘’Photovoltaic Power Generation’’, December 4, 1998.

17. Fred Beck, Eric Martinot, ‘’Renewable Energy Policies and Barriers’’, Encyclopaedia of Energy, 2004.

18. Sabina Sequeira, ‘’Renewable Portfolio Standards, Feed-In Tariffs, and Tendering: Instituting Effective Mandated Market Policies in China’’, May 8 2006.

19. Philippe Menanteau et al, ‘’Prices versus quantities:Choosing policies for promoting the development of renewable energy’’, Institut d’ Economie et de Politique de l’Energie, France, 2002.

20. COP17 Fact Sheet, ‘’Eskom Generation Plant Mix’’, 28 November-09 December 2011.

21. RETScreen Engineering & Cases Textbook, "Photovoltaic Project Analysis Chapter", RETScreen International Clean Energy Decision support centre, 2001-4.

22. Melanie Gosling, ‘’Government’s U-turn on wind energy rates’’, Environment Writer, 20 June 2011.

23. Max Edkins, Andrew Marquard, Harald Winkler, ‘’South Africa’s Renewable Energy Policy Roadmaps’’, Energy Research Institute, University of Cape Town, June 2010.

24. TERI Report to Central Energy Regulatory Commission, ‘’Pricing of Power from Non-Conventional Power Sources, India.

25. Morgan Bazilian et al, ‘’Re-Considering the Economics of Photovoltaic Power’’.

26. Bridge to India, ‘’The India Solar handbook’’, June 2012 Edition.

27. Hilton Trollip, Andrew Marquard, ‘’Prospects for Renewable Energy in South Africa’’, Heinrich Boll Stiftung Southern Africa.

28. Josephine K. Musango et al, ‘’Sustainable Electricity Generation Technologies in South Africa: Initiatives, Challenges and Policy Implications’’, Energy and Environment Research Paper Vol. 1, No. 1, December 2011.

29. Seth B. darling et al, " Assumptions and the Levelized cost of Energy for Photovoltaics", www.rsc.org.

30. APCO Worldwide, ‘’Market Analysis Report: China’s Renewable Energy Industry’’, Presented to Israel Export& International Cooperation Institute, November 2010.

31. United States Department of Energy, "Sunshot Vision Study", February 2012.

32. Karin Corfee, "Costs of PV and Concentrating Solar Thermal generation in Canada", CEC Workshop, Navigant Energy, March 7 2013.

33. Joshua Krautmann, Jinwen Zhu, " Photovoltaic Solar Energy Systems: market Trends in the United States", International Journal of Applied Engineering (IJAPE), Vol. 1, No. 3, December 2012.

34. J.R. DeShazo et al, " Designing an Effective Feed-In Tariff for Greater Los Angeles" , Los Angeles Business Council Study and UCLA School of Law.

35. Energize Magazine South Africa, "Energize Renewable Energy Supplement", Vol. 1, June 2013.

36. Fraunhofer ISE, "Photovoltaics Report", Fraunhofer Institute for Solar Energy Systems ISE, December 11, 2012.

37. National Energy Regulator of South Africa (NERSA), "Reasons for Decision; Renewable Feed-In Tariffs Guidelines", 26 March 2009.

38. United States Department of Energy, "Photovoltaic (PV) Pricing Trends: Historical, Recent and Near-Term Projections", November 2012.

39. Mark Fulton, Nils Mellquist, " The German Feed-In Tariff for PV: Managing volume Success with Price Response", Deutsche Bank Group Climate Change Advisors, May 23, 2011.

40. Yin Lin-Lin, " Economic Analysis of Solar Photovoltaic Based on Life Cycle Costing", Technical and Economic Consulting Centre of Electric Power Construction, China Electricity Council.

41. Anton Eberhard, " Feed-In Tariffs or Auctions", University of Cape Town, Note Number 338, April 2013.

42. Matt Cambell, "The Drivers of the Levelised Cost of Electricity for Utility-Scale Photovoltaics", Sunpower, 2008.

43. Annie Hazlehurst, "Economic Analysis of Solar Power: Achieving Grid Parity", Stanford Graduate School of Business.

44. North Carolina Sustainable Energy Association, "Levelised cost of solar Photovoltaics in North Carolina", February 2012.

45. International Energy Agency, "Technology Roadmap - Solar Photovoltaic Energy", 2010.

46. United States Energy Information Administration, "Levelized Cost of new generation Resources in the Annual energy Outlook", 2018 Levelized costs for AEO2013.

47. International Energy Agency, "Photovoltaic Systems Programme Annual Report 2012".

48. International Energy Agency, "A Snapshot of global PV 1992-2012", Report IEA-PVPS T1-22:2013.

49. KPMG, "Taxes and Incentives for Renewable Energy", KPMG International, June 2012.

50. http://www.pv-insider.com/africa/pdf/PVSouthAfricaMap.pdf. Last accessed 08 January 2014.

51. National Energy Regulator of South Africa (NERSA) Consultation Paper, "Review of Renewable Energy Feed-In Tariffs", March 2011.

52. United Nations Industrial Development Organisation, " Scaling up Renewable Energy in Africa", 12th Ordinary Session of Heads of State and Governments of the African Union, January 2009.

53. National Energy Regulator of South Africa (NERSA), "Reasons for Decision; Renewable Feed-In Tariffs Phase II", 29 October 2009.

54. International Renewable Energy Agency (IRENA), "Summary for Policy Makers: Renewable Power Generation Costs", November 2012.

55. Michael G. Pollitt, ‘’UK Renewable Energy Policy since Privatisation’’, Electricity Policy Research Group, University of Cambridge, January 2010.

56. Paolo Agnolucci, ‘’Opportunism and Competition in the Non-Fossil Fuel Obligation’’, Tyndall Centre for Climate Change Research, Working Paper 78, July 2005.

57. International Renewable Energy Agency (IRENA), "Renewable Energy Technologies: Cost Analysis Series", Volume 1: Power Sector, Issue 4/5, June 2012.

58. Liam Brynes et al, ‘’Australian Renewable Energy Policy: Barriers’’, School of Agriculture and Food Sciences, St. Lucia Brisbane, Australia.

59. Dirk C. Jordan, Sarah R. Kurtz, “Phtovoltaic Degradation Rates – An analytical Review”, Journal Article, NREL/JA-5200-51664, June 2012.