South Africa's renewable energy policy roadmaps

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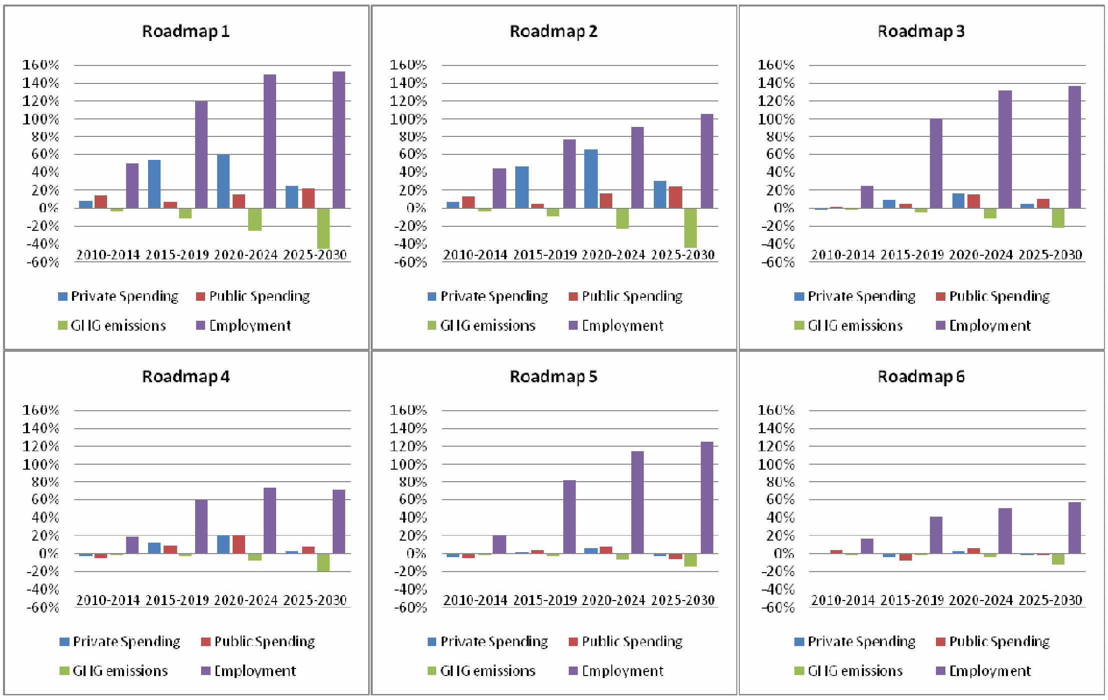
Executive summary

South Africa's renewable energy policy to date has largely been driven by a 10,000 GWh target by 2013 and renewable energy project subsidies offered through the REFSO. In 2009 a REFIT was published, which has resulted in a great interest by IPPs to develop renewable energy projects in South Africa. Nonetheless, under existing renewable energy policy few renewable energy projects for electricity generation have been deployed. SWHs have seen some market growth in 2008 and 2009 largely facilitated by a SWH subsidy and increased energy awareness due to nation-wide electricity blackouts in 2008.

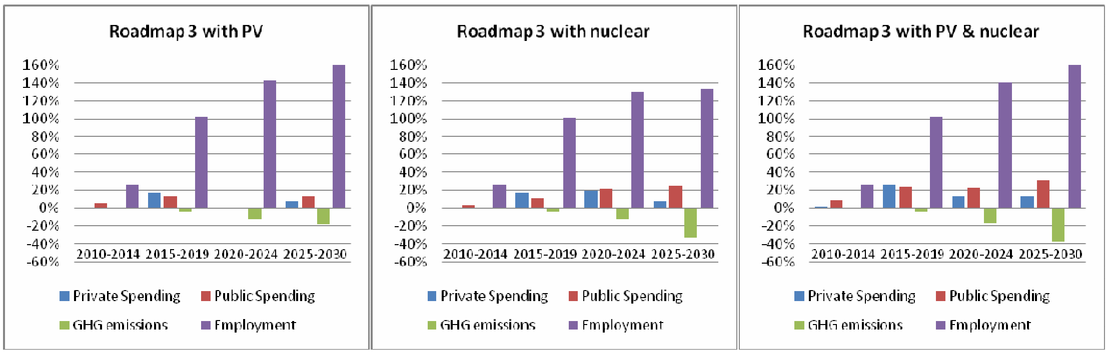
N this study renewable energy Roadmaps have been projected for electricity generation from wind, CSP and PV and for high and low SWH rollout programmes that reduce the demand for electricity. Six roadmaps were developed. Electricity targets of 15% (Roadmaps 5 & 6), 27% (Roadmaps 3 & 4) and unlimited (Roadmaps 1 & 2) by 2030 were assessed, as well as high (Roadmaps 1, 3 & 5) and low SWH (Roadmaps 2, 4 & 6) strategies. The policy Roadmaps are compared to a Baseline projection in which only new supercritical coal power plants, such as those currently under construction, are built to meet South Africa's growing electricity demand and no SWHs are deployed.

Roadmap	*RE electricity scenario*	*SHW rollout*
1: Unrestricted; high SWH strategy	Maximised	High
2: Unrestricted; low SWH strategy	Maximised	Low
3: 27% target; high SWH strategy	27% target	High
4: 27% target; low SWH strategy	27% target	Low
5: 15% target; high SWH strategy	15% target	High
6: 15% target; low SWH strategy	15% target	Low



The most employment benefits are recorded for the Roadmaps supporting a high SWH rollout. A high SWH deployment target results in at least 6 GW of electricity generation capacity saved, while the low SWH target only prevents 2 GW of electricity generation capacity from being deployed. The unlimited renewable energy target projections result in the highest GHG savings, while the 27% target projections stabilise GHG emissions form electricity. Reaching a 15% renewable electricity target does not result in any price increased above those projected for the Baseline and if a carbon tax is considered in all renewable projections the Baseline projection results in the highest price estimates by 2030.

The renewable energy policy Roadmap 3, with a target of at least 27% electricity supply from renewable sources and a high SWH rollout strategy, is identified as the most favoured projection for South Africa. This strategy would create the most possible employment and stabilises the GHG emissions from the electricity sector. A mixture of wind (30%) and CSP (70%) would be the largest contributors to achieving this target in 2030, supported by the REFIT.



By completing sensitivity analyses on Roadmap 3 it is seen that PV can play a more important role if higher technology learning rates are encouraged by an effective REFIT with sensible tariff degression. Furthermore, higher GHG emission reductions can be achieved at a lower cost compared to a renewables only strategy (Roadmap 1) by encouraging nuclear to supply the additional electricity demand from 2020. Furthermore the price of electricity under the nuclear sensitivity projection is below the original Roadmaps 1 and 3, and the Baseline projection if carbon taxes are considered in the analysis. This indicates that it may be the most economical strategy on the assumption that the cost of nuclear will not rise into the future.

This study certainly shows how active renewable energy policy can result in higher employment and GHG savings, often at very little additional investment requirements. It is recommended that assessments of renewable energy policy in South Africa would have to incorporate a more detailed analysis of energy efficiency policy and targets, beyond the SWH rollout assed in this study, as these will have a notable influence on the electricity demand in the country. A more detailed review of the maco-economic impacts, beyond the employment benefits as was done for this study, would also be necessary.

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Abbreviations

ACED	African Clean Energy Development
CABEERE	Capacity Building in DME in Energy Efficiency and Renewable Energy
CEF	Central Energy Fund
CERs	Certified Emission Reductions
CO_2	Carbon Dioxide
CSIR	Council for Scientific and Industrial Research
CSP	Concentrating solar power
DME	Department of Minerals and Energy
DNI	Direct normal irradiation
DoE	Department of Energy
DTI	Department of Trade and Industry
EIA	Environmental Impact Assessments
GHG	Greenhouse gases
GJ	Gigajoule
GW	Gigawatt
GWh	Gigawatt hours
GWC	Growth Without Constraint
IEA	International Energy Agency
IPPs	Independent Power Producers
IPAP	Industry Policy Action Plan
IRP1	Integrated Resource Plan 1
IRP2	Integrated Resource Plan 2
LTMS	Long-term mitigation scenarios
LOLP	Loss of load probability
MW	Megawatt
NERSA	National Energy Regulator of South Africa
PPAs	Power purchase agreements
PV	Photovoltaic
R	South African Rands (2009)
REFIT	Renewable energy feed-in tariff
REFSO	Renewable Energy Fund Subsidy Office
SWH	Solar water heaters
TJ	Terajoule
TWh	Terawatt hours
WASA	Wind Atlas for South Africa

1. Introduction

1.1 Scope of the report

This report is on developing South Africa's renewable energy policy roadmaps. It is the final report for the second of two projects assigned to the Energy Research Centre by UNEP under its broader agenda of 'enhancing information for renewable energy technology deployment in Brazil, China and South Africa'. It aims to project the impact different renewable policy options will have in South Africa. The renewable energy policy roadmaps focus on a feed-in tariff coupled with an electricity generation target for renewable electricity policy and Solar Water Heater rollout targets for other renewable energy policy. Deployment projections till 2030 are developed highlighting changes in the following parameters: private sector and government investments, employment creation and carbon dioxide emission levels, all relative to a baseline projection.

The renewable energy technologies being assessed include solar water heaters (SWH) and electricity generated from wind farms, concentrating solar power (CSP) and large-scale (more than 1 MW) solar photovoltaic (PV) systems. These four technologies were chosen because they are thought to bring an extensive contribution to the renewable energy supply of South Africa. In addition off grid renewable energy systems should be considered, but are beyond the scope of this report.

It is important to realise the renewable energy technology potentials in the context of South Africa's development needs. Besides their favourable environmental contribution, their contribution to society, in the way of employment and economic benefits, should be considered. In this regard the benefits and costs of the four renewable energy technologies are mapped according to different policy interventions. Since South Africa has published a renewable energy feed-in tariff (REFIT) this is the main policy intervention mapped, though renewable energy targets that 'cap' the REFIT are also assessed.

The compilation of this paper was based on desktop reviews; data interpretation from multiple sources; expert opinion of the authors and peer reviewers; and interviews with experts in the field. A number of interviews were conducted at the ISES International Solar Energy Society Conference in October 2009 and the Energy 2010 Indaba in February 2010. The data used in this report to formulate the projections is from a number of sources that have been independently reviewed. The roadmap projects have been largely modelled with the help of the Sustainable National Power Planning (SNAPP) tool.

1.2 The South African power sector – context for renewables

Although South Africa has very good solar and wind resources the deployment of renewable energy technologies has been slow to take off. More than 90% of South Africa's electricity is generated from the burning of coal. Eskom, South Africa's state-owned utility, has 27 operational stations in South Africa that make up 40.7 GW of the country's capacity (Eskom, 2009a). Additional capacity is from imports and Independent Power Producers (IPPs), resulting in a total capacity of about 43.5 GW, which aims to supply the forecasted peak demand of 36 GW (over 220 TWh).

Until recently the country was able to supply the lowest electricity prices in the world at R 0.25/kWh on average or less, though in 2008 demand for electricity outstripped supply and the electricity provider had to resort to load shedding. To alleviate the electricity shortfall Eskom has embarked on a capacity expansion programme which includes about 10 GW of capacity from coal, by return to service mothballed plants and through the construction of Medupi and Kusile, as well as 1.2 GW from the Ingula pumped storage scheme. Furthermore Eskom aims to construct a 100 MW concentrating solar power (CSP) plant and a 100 MW wind farm (Davidson, Hirst, & Moomaw, 2010).

According to Eskom (2009b) the price of electricity in South Africa has not allowed for the recovery of all the incurred costs and the building of reserves to sustain their current asset base, nor did it support the capital expansion programme. Since 2008 the country has seen dramatic price rises, including 31.3% in 2009/10 resulting in an average electricity price of R 0.33/kWh, which incorporated a R 0.02/kWh environmental levy, and 24.8% in 2010/2011 resulting in an average electricity price of R 0.42/kWh. Furthermore the recent multi-year price determination approved by the National Energy Regulator of South Africa (NERSA) implicates that the 2011/12 and 2012/13 financial years will see price rises of 25.8 % and 25.9 %respectively (NERSA, 2010a). These price increases are dramatic and have not been seen before in South Africa.

By 2013 the average price for electricity is therefore expected to be about R 0.66/kWh. The revenue incurred will finance Eskom's own primary energy costs, operations expenditure and demand side management activities, while still allowing for some return on its assets. NERSA (2010a) also expects R 2.3 billion, R 4.3 billion and R 5.8 billion of the allowed revenue to be directed at Independent Power Producers (IPPs) and Co-generation projects for the 2010/11, 2011/12 and 2012/13 financial years respectively. This is thought to cover the costs of funding additional renewable energy and co-generation capacity of 343 MW in 2010, 518 MW in 2011, 284 MW in 2012 and another 300 MW in 2013 as outlined in the Integrated Resource Plan 1 (IRP1) signed off by the Minister of Energy on 16 December 2009 (DoE, 2010).

The process of developing the Integrated Resource Plan 2 (IRP2) is underway and thought to be completed by June 2010[1]. This plan is thought to present South Africa's electricity supply plan beyond 2013 to about 2030. According to Davidson, Hirst, & Moomaw (2010) future capacity may include up to 5 GW of renewable energy, mainly CSP, and 4.5 GW of hydro and gas, and 10.5 GW of nuclear power.

Until recently the transition to renewable energy was viewed as an economic cost. In the last few years however it is being increasingly seen as an opportunity to foster a more secure, labour intensive and sustainable economy and society. As Dow and Downing (2007) point out 'renewable energy could be the technological key to economically and socially sustainable societies'. This report highlights the employment benefit, GHG emission savings and investment requirements of different renewable energy policy interventions for South Africa.

Section 2 of the report gives an overview of the technologies being assessed, while Section 3 highlights recent renewable energy policy developments in South Africa. Section 4 describes the method used to project the roadmaps, Section 5 highlights the projection outcomes, Section 6 presents the roadmap results and Section 7 concludes the report.

2. Technologies assessed

2.1 Technologies making use of the solar resource

2.1.1 Solar water heaters for hot water supply

The global use of SWHs is driven by the socio-economic need for job creation, environmental concerns, energy security, national economy and peak demand reduction. Good solar conditions on their own do not necessarily lead to a SWH market penetration or lower prices. Accordingly solar thermal heating worldwide has expanded by 19 gigawatts of thermal equivalent (GW) in 2007 to reach a total capacity of 147 GW. Preliminary estimates for global thermal heating suggest additions of 18 – 19 GW, mostly in China (Chiu, 2009). In Rizhao, China, where about 99% of households use SWH the initial capital costs for SWHs are on par with conventional electric geysers.

There are three different types of SWHs currently available on the South African market: unglazed, flat plate glazed and evacuated tube SWHs. Most of the SWHs have three basic components: collar collectors, storage tank (except for unglazed SWHs) and a heat transfer medium. Unglazed SWHs are primarily used to heat pools to extend the swimming season. Most of the glazed SWH in South Africa are flat plate indirect, though in recent years evacuated tubes have entered the domestic market. Evacuated tubes are more expensive on account of increased installation costs but provide a greater efficiency due to less heat loss (Ozdemir, Marathe, Tomaschenk, & Eltrop, 2009).

[1] Speech delivered on behalf of Minister of Energy Dipuo Peters, MP at the Energy 2010 Conference, Johannesburg, by Mr TB Maqubela, Deputy Director General, 24 February 2010.

Significant growth took place in the SWH industry during the periods 1979 to 1983, and 2005 to 2008, averaging 42% per year and 72% per year respectively. The industry's growth spurts coincided with marketing efforts by the CSIR during the late 1970s and early 1980s and by Eskom and the CEF during the period 2005 – 2008. In 2008, for the first time in SA history, total (glazed and unglazed) collector sales have topped 100,000 m^2. According to some in the SWH supply industry, sales expanded by up to 400% during the first four months of 2008 during the load shedding period (Theobald & Cawood, 2009). The number of active companies in the SWH industry is also thought to have grown from 21 companies in 2007 to over 100 in 2008.

In comparison to the electric geyser, the most commonly used technology for heating water in South Africa, the payback period for SWHs is estimated at 4 – 5 years, and up to 7 years for evacuated tubes (Ozdemir, Marathe, Tomaschenk, & Eltrop, 2009). The potential market for SWHs in South Africa is huge. According to Gcabashe, some 100,000 homes are built every year; 30,000 homes are renovated; and about 400,000 electric geysers are replaced (DME & REMT, 2009). The biggest barriers to large-scale usage of SWHs in South Africa have been low electricity prices, low awareness and the high upfront cost of SWHs. These are more readily overcome where national governments legislate supportive policies. Of these, short-term input-related tax incentives and rebates to manufacturers have been least successful. Long-term performance related incentives work better, and long-term mandatory regulations have produced the highest national benefit, cost reduction and market penetration (Holm, 2005).

Eskom's demand side management (DSM) programme has been actively reducing electricity demand patterns for several years. The focus of DSM is on energy efficiency and actively managing electricity demand by consumers. Efficiency improvements include load shifting (scheduling of consumption activities to off-peak periods) and installation of technological solutions to actively reduce peak consumption (load alleviation). Public education and awareness building is also a large component of this programme. In particular the large scale installation of solar water heating systems will reduce the demand on the total electrical load and consumption at large. The UNDP/CEF 500 SWH Pilot Project showed that electricity saving of up to 2.3 MWh can be achieved per system per year (Nano Energy & SESSA, 2009).

The Nelson Mandela Bay Municipality is embarking on an ambitious programme to roll out 60,000 systems financed with a levy on the municipal service bills and the City of Cape Town is pioneering a SWH by-law to support its strategy to achieve 10% penetration of private homes by 2010 and 10% of city owned buildings by 2012. The City of Cape Town has pioneered the development of a By-Law and the Kuyasa Project has assisted more than 2,000 residents of Khayelitsha in installing SWHs. In total these incentives had only supported the rollout of 6 932 SWHs by the end of 2009 (DoE, 2009b), relative to the total of 18,500 units installed in 2008 (Theobald & Cawood, 2009).

It is estimated that approximately 40% of residential electricity consumption results from water heating. Eskom's incentive scheme aims at the uptake of approximately one million middle to high income residential SWH and it is thought to cost in the order of R4 billion over a five-year period (Nano Energy & SESSA, 2009). Holm (2005) indicates that by 2025 the residential demand for SWHs could be as high as 48 TWh, with an equivalent potential from the commercial sector. Accordingly the Draft National Framework for SWH (DoE, 2009b) highlights a longer-term target of 5 million SWHs by 2020, tending towards the projected potential of 10 million SWHs.

2.1.2 Concentrating solar power to generate electricity

Concentrating solar thermal power (CSP) generation technology has a limited deployment internationally; after a series of successful experimental plants were built in the 1980s in the US, no further investment was forthcoming until 2004, at which point global installed capacity was less than 300 MW. Since then, about 100 MW of new capacity has been completed, and favourable policy regimes in Spain and the USA have led to an explosion of new orders with around 8,000 MW of new capacity were under planning in 2009 (Spellmann, 2009). The IEA's Energy Technology Perspectives identifies solar thermal technology as a very promising option for areas of the world with extremely good solar resources, which includes about half the land area of South Africa (IEA, 2008).

While the technology is relatively new commercially, which entails significant risks and uncertainties; it is technically proven, ideally matched to South African conditions, and has the potential to develop on a massive scale globally. The lack of market maturity also implies that there would be opportunities for South Africa to develop a competitive advantage in design and manufacture of the technology, particularly if able to prove the technology at scale. South Africa has an excellent solar regime, with ample resource to provide significant future electricity generation, and potentially has the right mix of skills and manufacturing capabilities to create a competitive advantage in this market (Edkins, 2009). In addition, because CSP plants are most suitably located in areas with a very high incidence of solar radiation, there is little competition for alternative land use.

Almost all plants have onsite heat storage, which makes them dispatchable; solar thermal plants can thus generate peak electricity when required, and recent plants have very high availability factors – The Solar Tres plant in Spain currently under construction has an availability factor of 74%. Thus, unlike wind, which has availabilities of 15 – 35%, in the long term solar thermal technology has the potential to compete with other baseload technologies (Marquard, Merven, & Tyler, 2008).

All solar thermal pilot plants have been funded by consortia, comprising either all public (Solar One) or public and private parties. Utilities have played a role in funding and implementing the pilots, as has grant funding. Solar thermal plants have lead times of around three to four years, although there is significant uncertainty attached to this figure, given the scale and limited number of existing plants. In 2002 Eskom installed a 25kW solar dish as part of the South African Bulk Renewable Energy Generation (SABRE) programme and in 2010 it aims to build its 100 MW plant, which has been in the planning stages since 2001 and is supported by the World Bank loan (Davidson, Hirst, & Moomaw, 2010).

Besides Eskom's 100 MW demonstration plant, the SKA MeerKAT radio telescope array programme collaborated with the University of Stellenbosch on a feasibility study for a 100 MW CSP plant and a 0.5 MW PV system[2]. The Clinton Climate Initiative is partnering with the Department of Energy to set up a solar park in the Northern Cape, which could add up to 5 GW of capacity to South Africa's electricity generation (*Engineering News*, 2009). Siemens is also currently conducting a feasibility study on a possible 210 MW CSP plant in the Northern Cape to possibly come online by 2014 and the Industrial Development Corporation is also investigating a CSP demonstration plan (DTI, 2010). In total there seem to be about 500 – 600 MW of CSP currently undergoing pre-feasibility and feasibility stages of development, with 75% of these able to deploy by 2013[3].

South Africa receives some of the highest annual irradiation globally. Various solar resource assessments for South Africa indicate that the Northern Cape Province has the highest solar resource in the country. The annual radiation measures from the best sites in the Northern Cape are more than 30% higher than for the best sites in Spain. Upington, for example, has more than 6.5 kWh/m^2 daily average global horizontal irradiation. In the Free State, North West, Limpopo and in the interior parts of the Western Cape and the Eastern Cape the solar resource is also excellent. The rest of the country still has a good solar resource (Fluri & von Backstrom, 2009). The solar potential in South Africa is therefore considerable, and Howells (1999) estimates the theoretical potential to be 8,500,000 PJ/yr (2,361,300 TWh/yr) (Winkler, 2005).

2.1.3 Large-scale photovoltaic systems

Internationally the PV industry grew by 10GW in total in 2008. Germany remains the global leader with 5.3 GW of installed capacity and twelve utility-scale projects. The largest plant, Woldpolenz, at Muldentalkreis has 40 MW of capacity and produces 40,000 kWh of electricity per year. The Woldpolentz plants cost five times more per MW than Medupi Power Station, but the difference is that Medupi has operation and maintenance costs that are twelve times more expensive than those of Woldpolentz (Cartwright, 2010). In 2007 two large-scale PV plants were completed in the US (14 MW) and Spain (20 MW) respectively.

In South Africa PV systems are all small-scale (less than 1MW) mainly for off-grid (rural) applications where the cost of extending the grid is high. Typical applications include schools, health

2 Wikus van Niekerk & Tom Fluri presentation 'Solar Power for SKA', 17 February 2009, Centre for Renewable and Sustainable Energy Studies, Stellenbosch University.

3 Presented by Pancho Ndebele, 9 March 2010, DBSA 'Promoting a CSP Industry in Southern Africa' Workshop.

centres, and for rural households, with a total estimated installed capacity of 21 MW (Holm et al, 2008). This type of PV use is known from key markets like Bangladesh, China, Sri-Lanka and Kenya. However, globally PV is primarily used in grid-connected application, where 60% average annual growth rates have been seen for the period 2002-2006 (REN21, 2007).

The generation regulation in South Africa has not yet been updated to allow for such electricity generation from PV. Similarly, there have been no incentives to date to develop large-scale PV (more than 1 MW) installation. Nonetheless, under the second phase of REFIT published in 2009 PV installations that are larger than 1 MW are eligible for financing at R 3.94/kWh (NERSA, 2009b). A later revision of the REFIT (phase 3) may see the incorporation of small-scale PV installations[4]. Electricity from PV systems is still thought to cost more than electricity from other renewable energy technologies, including CSP or wind (see Figure 3).

2.2 Wind farms generating electricity

Wind power is one of the most mature new renewable technologies, is currently in use throughout the world, and is still growing very rapidly, particularly in developing countries such as China and India. Within a very short time, the Chinese wind programme has accelerated to a point where 13,800 MW of new wind power was being installed in 2009, doubling its existing wind power capacity for the seventh year running. Already in 2008 40 Chinese companies were involved in manufacturing 56% of the equipment (Global Wind Energy Council, 2008), and since then China has continued its emergence as a global manufacturer of wind turbines. An additional 30,000 MW was expected to be installed globally in 2009, based on a 23% increase in the first quarter of 2009 (World Wind Energy Asssociation, 2009). There is also a trend towards larger-scale installations – currently, wind farms of over 1,000 MW are being planned in a number of locations.

International wind farm operators are typically either large utilities who have moved into the wind space (Iberdrola, Florida Power and Light, Endesa, DONG, Vattenfal, E.ON and RWE), and large Independent Power Producers (IPPs), often financed by investment banks (Global Wind Energy Council, 2008). On the manufacturing side, the industry has seen a number of mergers and acquisitions recently, with the large industrial conglomerates moving into the market. Major manufacturers now include Alstom, Arriva, Suzlon and General Electric, as well as emerging manufacturers in developing countries. The wind market is therefore dominated by large and well established manufacturing and operating companies, utilities and well backed IPPs, with a trend towards consolidation of the smaller developers. From an industry growth perspective, more wind power was installed in Europe than any other technology, some 40% of all new power generation capacity, while in the US the wind accounted for 30% of all new generation capacity installed. Significantly in 2008, for the first time in decades, the majority of the market growth was outside of Europe, concentrating primarily in the US and China (GWEC & Greenpeace, 2008). The boom in wind has resulted from clear government support for the technology. In Europe this has largely been in the form of feed-in tariffs, whilst in the US portfolio standards have played a major role.

Large scale wind farms have a relatively short lead time of around two years, plus an additional margin for EIAs, which is a key advantage of the technology. However, lead times on plant manufacture for a large-scale wind programme can be substantial, as there is currently a significant under-supply of wind turbines internationally, with large orders needing to be placed years in advance, and requiring sizeable financial backing to secure the delivery date from the manufacturers (GWEC & Greenpeace, 2008). With the expansion of the market globally, equipment shortages are likely to ease in the near future. Given the maturity of the technology, the costs of wind generation are known with a high degree of certainty.

A wind programme in South Africa thus has the advantages of comprising a well understood, low risk and mature technology, subject to developing appropriate local skills and infrastructure. The opportunities for competing on a cost basis in manufacturing are minimal at present, and an extensive programme would initially be implemented with imported equipment and using international expertise. However, the introduction of a large-scale programme could provide local

4 According to Diteboho Makhele, Camco, presenting 'Socio-economic impacts and regulatory framework requirements for a solar PV feed-in tariff in South Africa', ISES Solar World Congress 2009, Joahnnesburg.

economic opportunities for component manufacture, and with an appropriate industrial policy it would be possible to leverage South Africa's relatively cheap steel resources. The distance from other international manufacturers will also confer a competitive advantage, especially for less-specialised large-scale components such as steel towers. A large-scale wind programme will require significant infrastructure and planning support. Sites will need to be identified and taken through EIA processes, with planning required to absorb the heavy-load transport throughout the country. Proactive state involvement could significantly lower transaction costs in this regard.

To date there are two wind projects, the Eskom Klipheuwel Wind Energy Demonstration Facility (KWEDF), which consists of three units with a total capacity of 3.2 MW and the Darling Wind Farm with an initial capacity of 5.2 MW. Another 23 MW of equipment capacity is off-grid, estimated from individual windmills at boreholes (Holmet al, 2008). Eskom is building the Sere 100 MW wind farm in the Western Cape with the support of the World Bank loan (Davidson, Hirst, & Moomaw, 2010). Already there are many privately owned wind farm developers in South Africa, of which a number of them have stated their project ambitions and started wind monitoring at their sites.

Table 1: IPP wind projects under development in South Africa

Site	*Province*	*Owner*	*MW*
Cookhouse	EC	ACED (Macquarie)	300 MW
Flagging Trees	EC	ACED (Macquarie)	100 MW
Hopefield	WC	African Infrastructure Investment Fund	100 MW
Jeffrey's Bay	EC	Mainstream/Genesis Eco-Energy	50 MW
Brand-se-Baai	WC	Exxaro	100 MW
Tsitsikamma Community Wind Farm	EC	Consortium including Exxaro, Tsitsikamma Development Trust & Watt Energy (46%). Balance by DANIDA & Danish IPP, European Energy (54%).	40 MW
Coega IDZ	EC	Electrawinds	57.5 MW
40km SW of PE	EC	Central Energy Fund	25 MW
Caledon Wind Farm	WC	Epipspan (Pty) Ltd – trading as Caledon Wind.	300 MW
Eastern Cape Wind Project	EC	Red Cap Investments	50 MW

It is largely due to the announcement of the Renewable Energy Feed-In Tariff (REFIT) in March 2009 that interest in developing wind projects, with up to 7,000 – 8,000 MW of generating capacity being discussed[5], has been created. Projects underway accumulate to about 1,100 MW of capacity (Table 1). The wind power generation potential for South Africa is estimated at 80.54 TWh. This could be realized with an installed capacity of about 30.6 GW. The best potential is found in the Western Cape and parts of the Northern Cape and the Eastern Cape (Hagemann, 2008).

3. Policy developments

3.1 Renewable energy for electricity generation

The Department of Energy has established a target for renewable energy production at 10,000 GWh by December 2013. According to the draft National Integrated Resource Plan for Electricity 6,000 GWh of this target is expected from on-grid electricity generation.[6] At the Department of Minerals and Energy (DME) Renewable Energy Summit in March 2009, the then Energy Minister indicated that more ambitious targets 'for the period 2013 and 2018 could be set in the range of six

5 According to Thomas Donnelly, Macquarie Africa (Proprietary) Limited, October 2009.

6 The Draft Integrated Resource Plan for Electricity is still up for review and not yet publically available, although it has been leaked to the media.

to nine percent and nine to fifteen percent of the current capacity respectively' (DME 2009). This may result in a renewable energy target of 14.5 – 22 TWh for 2013 and 22 – 36 TWh for 2018.

The DME's macroeconomic study of renewable energy, developed under the Capacity Building in Energy Efficiency and Renewable Energy (CaBEERE) project, established that the achievement of the 10,000 GWh target would provide a number of economic benefits, including increased government revenue amounting to R 299 million, increased GDP of up to R 1 billion per year and the creation of an estimated 20,500 new jobs. Furthermore, the development of renewable energy beyond the 10,000 GWh target holds employment benefits and would maximise the number of jobs created per TWh (NERSA, 2009).

The Renewable Energy Feed-in Tariff (REFIT) was developed by NERSA to support the introduction and development of renewable energy options. Phase 1 of this programme focuses on wind, concentrated solar, land-fill gas and small hydro plant. The respective tariffs are: Wind: R 1.25/kWh; small hydro: R 0.94 /kWh; landfill gas: R 0.90 /kWh; and concentrating solar: R 2.10 /kWh (Table 2).

According to NERSA (2009) the key principles that under pin the establishment of the REFIT in South Africa include:

- guaranteed access to the national grid;
- guaranteed purchase price for a fixed duration;
- an obligation to purchase and to discharge the power generated;
- burden sharing of the additional cost throughout electricity consumers;
- a dynamic mechanism that reflects market, economic and political developments;
- for new projects as a result of learning effects and cost reductions;
- the potential to set a cap on the maximum available subsidy per year;
- a willing seller, willing buyer approach still applies.

According to the Government Notice (DoE, 2009) on the Electricity Regulation Act, 2006, gazetted on 5 August 2009, the electricity regulations on new generation capacity indicate that procurement of renewable energy under the REFIT Programme must take into account 'compliance with the integrated resource plan and the preferred technology', in effect capping the REFIT under whatever target is put forward in the IRP. This was further explained in NERSA's 'Rules on selection criteria for renewable energy projects under the REFIT Programme' (NERSA, 2010b).

A draft of Phase 2 of the REFIT was presented for public comment in July 2009. The Consultation Paper introduced tariffs in respect of a further five renewable energy technologies (NERSA, 2009b): Concentrated solar power trough without storage at R 3.14/kWh, solid biomass at R 1.18/kWh; biogas at R 0.96/kWh; photovoltaic systems (large ground or roof mounted) at R 3.96/kWh; and concentrated solar power (central tower) with six hours storage at R 2.31/kWh (Table 2).

Table 2: REFIT tariffs published by NERSA

REFIT Phase	*Technology*	*R/ kWh*
Phase I	CSP	2.10
	Wind	1.25
	Small hydro	0.94
	Landfill gas	0.90
Phase II	CSP trough without storage	3.14
	Large-scale grid-connected PV systems (≥1MW)	3.94
	Biomass solid	1.18
	Biogas	0.96
	CSP tower with 6 hours per day storage	2.31

Key issues that raised at the public hearing included whether the procurement process would be on a 'first come first serve' basis, whether the role of Eskom as the single buyer would be in conflict with the company's own interest in developing renewable and to what extent NERSA would be able to mandate Eskom to engage into a Power Purchase Agreement (PPA) with a REFIT generator (Brodski, 2009).

Furthermore, the REFIT has been criticised for not allowing for renewable energy targets that are high enough to encourage the development of a local renewable energy technology supply industry. The additional renewable energy and co-generation capacity of 343 MW in 2010, 518 MW in 2011, 284 MW in 2012 and another 300MW in 2013 as outlined in the Integrated Resource Plan 1 (IRP 1) (DoE, 2010) is not thought to be sufficient. IPPs are hoping for much higher REFIT caps to be established under the IRP 2 process currently underway.

In general the REFIT was established in South Africa on the grounds that it has proved to be the most effective policy instrument to deploy renewables, as experienced in the German and Spanish examples of using of a feed-in policy. The benefits of a feed-in tariff include that the premium risk for investors can be minimised by establishing long-term assurance for their electricity sales at a set tariff. This allows for improved access to finance for developers, as well as market assurance, which is thought to drive renewable energy technology development and learning, resulting in lower costs of electricity generation from renewable sources in the long run. Furthermore, the deployment of a number of different technologies can be encouraged with a REFIT, resulting in a more diversified electricity supply base (NERSA, 2009).

Feed-in tariff (FIT) policies are implemented in more than 40 countries around the world and are cited as the primary reason for the success of the German and Spanish renewable energy markets (Cory, Couture, & Kreycik, 2009). Experience from Europe is beginning to demonstrate that properly designed FITs may be more cost-effective than renewable energy portfolio standards (RPS), which make use of competitive solicitations. Winkler (2005) mentions that neither setting quantity targets nor regulating prices alone will be sufficient and Cory et al. (2009) show how a FIT can support a quantity based target for renewable electricity generation. Considering this the report projects renewable energy policy roadmaps for South Africa based on achieving a RPS target through a FIT mechanism.

3.2 Solar water heater programme

With regard to energy efficiency Eskom has embarked on a demand side management (DSM) programme that through technical and behavioural measures aims to reduce power demand by 10%. The accelerated programme aims to achieve 3,000 MW of savings by 2013 and an additional 5,000 MW by 2026 (Eskom, 2008).Technology-specific actions include the mass-rollout of CFLs to replace incandescent light bulbs, financial support to consumers to switch from electric water geysers to Solar Water Heaters (SWHs), a rollout of electric geyser blankets and efficient shower heads, incentives for consumers to switch from electric stoves to gas stoves and support towards smart metering devices and energy efficient motors.

A draft of the South African National Solar Water Heating Framework and Implementation Plan was presented in November 2009, which highlights a target of 1 million SWH within the next four and a half years within all categories of formal households and a vision for 5.6 million installations by 2020 creating a minimum of 40% SWH penetration in the existing 12 million households (DoE, 2009b). In the IRP 1 the Department of Energy (2010) states that the 1 million SWHs by 2014 DSM programme should commerce from 1 March 2010.

The SWH industry has received further support through the publication of the latest Industry Policy Action Plan (IPAP2) in February 2010 by Department of Trade and Industry (DTI, 2010). In it the SWH milestones are:

- By the second quarter of the 2010/11 financial year (ending March 31, 2011), the DoE will introduce a subsidy programme covering one-million units by 2014.

- By the end of December 2010, the DTI and the National Regulator for Compulsory Specifications will publish amended national building regulations to make it compulsory for new buildings and upgrades to homes to install SWHs and other energy efficiency building requirements, from March 2011.
- By the end of September 2010, the DTI will ensure that legislation is enacted to make it compulsory to install a SWH when an existing geyser is replaced.
- Between 2010/11 and 2012/13, DTI incentives and Industrial Development Corporation industrial financing will be leveraged to support investment and increasing manufacturing and installation capacity in the SWH value chain.

4. Method for projecting renewable energy policy roadmaps

4.1 Policy roadmaps

Using the electricity generation assumptions outlined above a baseline projection is determined to which different policy interventions are projected. In developing the policy roadmaps for renewable energy generation in South Africa this report focuses on the impact the REFIT can have on encouraging electricity generation from wind and solar (CSP and large-scale PV) compared to the baseline. Three scenarios are modelled from 2010 to 2030, with 2015, 2020 and 2025 midpoints:

1. Renewable deployment maximised. This is based on the current interest by renewable energy project developers in deploying their technology. REFIT supports the deployment until the technologies become cost competitive.
2. REFIT is implemented in support of achieving a 27% electricity generation target by 2030. This is the target established by the long-term mitigation scenarios (LTMS) study (Winkler H. , 2007) and is estimated to be the minimum penetration rate for renewables required for South Africa to achieve its target of peaking emission reductions by 2020-2025.
3. REFIT is implemented in support of a renewable energy target of 15% by 2030. This is the economically efficient target for renewables if learning rates for the different technologies, as stated above, are assumed.

Table 3: Six renewable energy policy roadmaps

Roadmap	*RE electricity scenario*	*SHW rollout*
1: Unrestricted; high SWH strategy	Maximised	High
2: Unrestricted; low SWH strategy	Maximised	Low
3: 27% target; high SWH strategy	27% target	High
4: 27% target; low SWH strategy	27% target	Low
5: 15% target; high SWH strategy	15% target	High
6: 15% target; low SWH strategy	15% target	Low

For each scenario a high and a low SWH strategy is also developed. This is based on incorporating the large-scale rollout of SWHs in line with South Africa's deployment targets for 2020 and beyond. In effect six roadmaps are presented, see Table 3.

4.2 Electricity generation technologies

This report projects renewable energy policy roadmaps by building on the modelling undertaken for the LTMS (Winkler, 2007) and other publications by the ERC (Marquard et al, 2008).

All major electricity generation types are considered, whether coal-based, nuclear or from renewable sources. The characteristics and costs of the different technologies are based on the input data for the Energy Information Administration *International Energy Outlook 2009* (EIA, 2009), as well as the input data for the National Integrated Resource Plan 3 (NIRP3). These are presented in Table 4 below. Some technology costs were converted from a foreign currency, typically US dollars, at the exchange rate in 2009, while costs sourced from other years were expressed in 2009 real terms by inflating according to the producer price index of the relevant country. Wherever possible the most up-to-date information from within South Africa was used, such as basing the capital cost for supercritical coal on the cost estimates for Eskom's Medupi plant, which is expected to come online in 2012 (Eskom, 2009a).

Table 4: Electricity plant characteristics and cost assumptions for South Africa

Source: EIA (2009)

Plant description	*Capital cost (2009)* *R/kW*	*Fixed O&M* *R/kW*	*Variable O&M* *R/MWh*	*Efficiency* *Fraction*	*Avail-ability* *Fraction*	*Life-time* *Years*	*Unit size* *MW*	*Forced outage* *Rate*
Existing coal Large	7065	199	8	0.3	0.87	50	564	0.06
Existing coal Small	7065	275	10	0.3	0.80	50	114	0.13
Supercritical coal	25000	230	29	0.4	0.86	30	794	0.07
OCGT liquid fuels	5722	101	30	0.3	0.93	25	120	0.03
PWR nuclear	37445	751	4	0.3	0.84	40	1350	0.07
Landfill gas	21076	953	0	0.3	0.86	25	30	0.08
Biomass	31212	538	56	0.4	0.90	25	80	0.05
Wind 30%	16424	253	0	1.0	0.30	20	1	1.00
Wind 25%	16424	253	0	1.0	0.25	20	1	1.00
CSP central receiver	67461	474	0	1.0	0.60	30	100	0.04
CSP parabolic trough	44974	474	0	1.0	0.40	30	100	0.04
Solar PV	50042	97	0	1.0	0.23	15	5	0.00
Combined cycle gas	8763	104	17	0.5	0.90	25	387	0.05
Pumped storage	13010	58	0	0.7	0.22	50	333	0.03
Imports						50	375	0.17

Future fuel costs are based on a number of sources including NIRP3 projections. Similar to in the LTMS oil prices are projected to increase from US$ 30 per barrel in 2003 to US$ 97 per barrel in nominal terms in 2030 (Winkler (ed), 2007). Diesel prices are assumed to drop from the R 203/GJ peak in 2008 to R 139/GJ in 2009, rising thereafter to R 209/GJ in 2030, while natural gas rises from R 40/GJ in 2009 to R 89/GJ in 2030 (Figure 1).

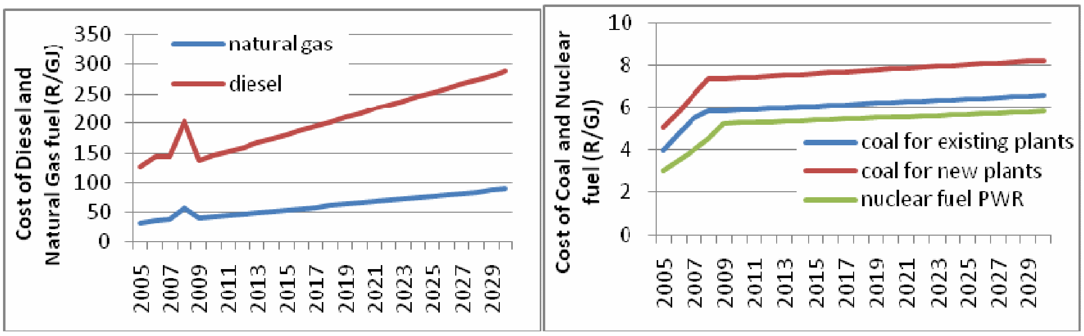


Figure 1: Projections of fuel prices for nuclear, coal, natural gas and diesel (2008 R/GJ)

Nuclear fuel is expected to approach R 6/GJ in 2030, while coal for old power plants is thought to reach R 6.5/GJ and coal for new power plants rises to R 8.3/GJ in 2030 (Figure 1).

4.3 Electricity demand determination

Eskom has 27 operational stations in South Africa that make up 40.7 GW of the country's capacity (Eskom, 2009a). Additional capacity is from imports and independent power producers (IPPs), resulting in a country capacity of about 43.5 GW, which aims to supply the forecasted peak demand of 36 GW (over 220 TWh). Projecting electricity demand based on the GDP and population growth forecasts, as presented in the LTMS, results in an expected demand of about 430 TWh by 2030 upstream up transmission (Figure 2).

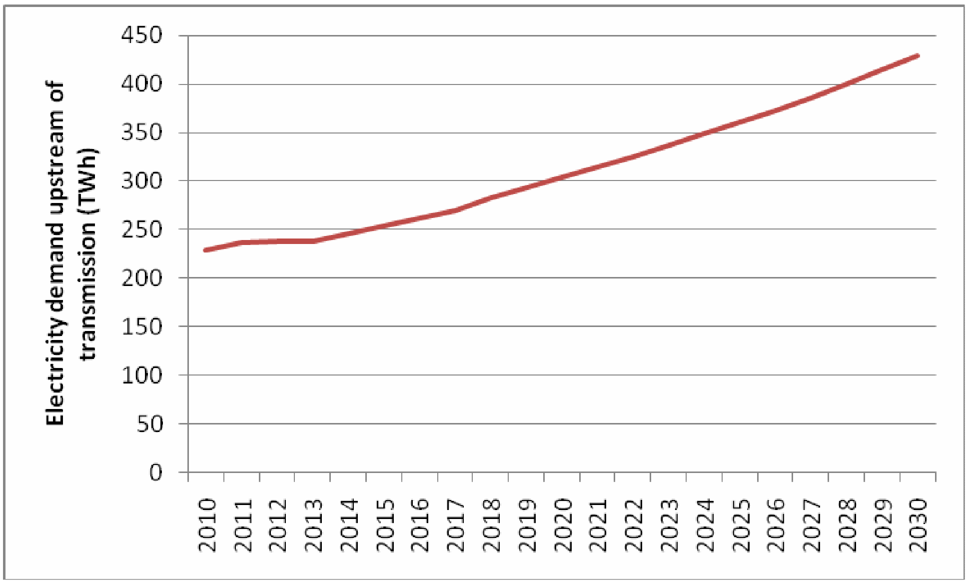


Figure 2: Electricity demand upstream of distribution projected for South Africa till 2030

Based on the historical growth trend of South Africa's gross domestic product (GDP) and comparing it to trends in other countries, the time-dependent GDP projection was sourced from the LTMS study (Winkler (ed), 2007). This series starts at a growth rate of 3% in 1993 and increases to about 6% before it starts to flatten out around 3% in the long-term. This trend is consistent with the growth targets of AsgiSA (AsgiSA, 2006). It was projected that the majority of this GDP would continue to be generated by the services sub-sector of the commercial sector throughout the entire period, with the contribution of the mining sector declining over time. The South Africa population is projected to grow by no more than 15% of the 2001 population level by 2050 because of the high rate of HIV infection in the country.

4.4 Technology learning rates and levelised cost of electricity

Based on a number of learning rates cited in the peer-review literature learning ratios of 19%, 25%, 15% and 20% were chosen for wind, PV, CSP parabolic trough and CSP power tower technologies respectively (Table 5). The doubling time is assumed to increase by 1.5 for each doubling of deployment, due to the higher amounts of deployment required to achieve the next doubling (Winkler et al, 2009).

Table 5: Learning rates for this study and summary of ranges in the international literature

Source: Winkler, Hughes, & Haw (2009)

Energy technology	*Range of learning rates in the literature (%)*	*Learning ratios, this study (%)*
Wind	5–40%	19%
Solar photovoltaic	17–68%	25%
CSP, parabolic trough	2-32%	15%
CSP, power tower	5-20%	20%

Such learning rates result in cost reductions for the different technologies being considered, see Figure 3. The levelised cost of electricity calculations are based on the 'annuity' method as explained in Marquard et al. (2008). In the short term electricity from wind is thought to cost R 0.80

– 0.95/kWh depending on how good the wind resource is, while CSP is about R 1.38/kWh hour for parabolic trough and R 1.45/kWh for central receiver. Central receivers are expected to become cheaper in time generating electricity at R 0.80/kWh in 2030, while wind is still the cheapest at R 0.60 – 0.70/kWh in 2030. Large-scale PV farms are thought to generate electricity at R 2.72/kWh, though these experience the greatest cost reductions and by 2030 they are competitive with parabolic trough CSP at R 1.00/kWh. If, however, PV systems experience even higher learning rats, the cost of generating electricity by 2030 may be as low as R 0.65/kWh, see Figure 3.

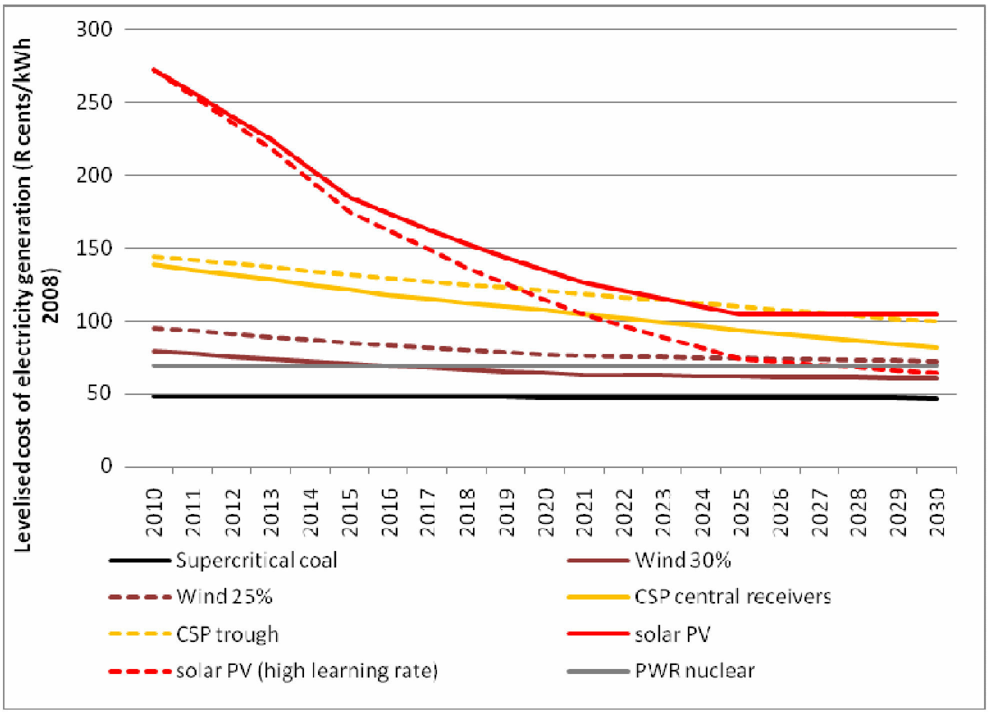


Figure 3: Estimated cost reductions for renewable energy technology

By comparison supercritical coal, such as Eskom's new plant Medupi, is thought to generate electricity at a cost of R 0.48/kWh, though this may rise if carbon capture becomes mandatory or further carbon levies are applied to non-renewable electricity. The cost of generating electricity from nuclear plants is expected around R 0.70/kWh (Figure 3).

The price of a 200 litre SWH system is estimated at R 13,000 – 30,000 per unit. If a life cycle costing approach to the price of energy delivered by solar home systems is taken, one obtains in the order of R 0.60/kWh (Nano Energy & SESSA, 2009). SWH are expected to come down in price annually at a rate of about 3% (Agama Energy, 2003).

4.5 Ensuring electricity supply meets demand

Each projection is designed to ensure that the electricity generation capacity built meets the demand of the South African system. The amount of SWHs deployed reduces the demand for electricity. Each unit installed results in 0.6 kW of power subtracted from peak demand, which is 2.3 MWh of electrical energy subtracted per unit per year (Nano Energy & SESSA, 2009). To ensure that the electricity generation capacity deployed is sufficient for each roadmap projection the reserve margin, the reserve margin (AF) and the loss of load probability (lolp) are monitored.

4.5.1 Reserve margin

The reserve margin is a measure of the generating capacity available over and above the amount required to meet the system demand (power in MW) requirements to allow for such factors as generator breakdown, severe weather, demand forecast uncertainty and transmission problems that could result in a loss of generation.

Reserve Margin = (installed capacity – maximum demand)/maximum demand.

The lower the reserve, the higher are the risks of blackouts. The higher the reserve, the lower are the risks of blackouts but the higher the investment expenditure. There is currently no explicitly defined generation security standard in South Africa for electricity generation. NIRP3 used a 19% reserve level in its base case and Eskom has recently stated that a reserve of 15% to 25% is the desirable range; however, this is higher than what has been considered in the past. For all roadmap projections we ensure that the reserve margin remains above 10%.

4.5.2 Reserve margin

In this study another reserve margin indicator is calculated that takes into account what percentage of the installed capacity of each technology type can contribute to the capacity meeting the peak (MW). This indicator is called reserve margin.

$$RM(AF) = \left(\sum_{i=1}^{n} \frac{c_i AF_i}{\max demand_i} \right) - 1,$$

where c_i is the installed capacity of tech i, AF_i is the available capacity (on average) that is able to contribute to meeting peak demand. The roadmaps are projected to ensure that the reserve margin (AF) with capacity imports from the region remains above 15%.

4.5.3 Loss of load probability

The reserve margin is a known and accepted deterministic indicator of the reliability of a system. However, it does not take into account some system characteristics which are also affect the reliability of a system, such as the size of the individual units that make up a system in relation to the size of the system and their individual outage rates; random weather fluctuations that may affect both demand and supply (in the case of wind). Reliability assessments are then done by using probabilistic approaches/indicators such as LOLP (Loss of load probability). LOLP is a reliability index that indicates the probability that some portion of the load will not be satisfied by the available generating capacity. LOLP is normally expressed as a ratio of times: for example, 0.1 days per year, equals a probability of 0.0274% (i.e. 0.1/365). Each projection is designed to have a LOLP of less than 0.03%.

5. Projection outcomes

5.1 Assessing costs of projections

Total systems costs and investment costs are calculated for the different roadmaps. Systems costs are calculated by adding four different components, namely the sum of the annualised investment costs of each power plant, the fixed cost of each power plant in service, the variable costs of each power plant (based on how much electricity each plant dispatches) and the fuel cost of each plant. From these the average cost of electricity per kWh is determined. It must be noted that this not synonymous with the average electricity price (which is in any case set by the regulator), but is indicative of what price movements might result from specific technology choices.

This study assumes that the price of electricity is R 0.70/kWh more than the cost of generating electricity, based on the a calculated cost of generating electricity of R 0.11/kWh in 2010 relative to the level of price of R 0.80-0.88/kWh that should be targeted according to Eskom (2009b). The impact of a carbon tax on the price of electricity is also considered. Building on the 2 cents (Rand) per kWh environmental levy already implemented in 2009 the carbon tax is assumed to apply from 2012 at R 100 per tonne of CO_2-eq, rising to R 200 per tonne of CO_2-eq in 2016 and to R 500 per tonne of CO_2-eq in 2020.

Investment costs are calculated by distributing the overnight investment cost over the lead-time of each unit of new capacity according to ratios sourced from the South African National Integrated Resource Plan 3 (NIRP3), then adding interest during construction at a discount rate of 10%.

Renewable energy deployments are assumed to be supported through the REFIT programme, of which 90% are considered private investments until 2020. Beyond 2020 the percentage of renewable energy supported by independent power producers (IPPs) decrease steadily until it reaches 30% in 2030. All other electricity generation investments are assumed to be done by Eskom and therefore considered public. SWH spending is considered private except when subsidised by government. Until 2014, R 5,500 of each SWH is assumed to be subsidised by government, then R 3,000 till 2017, R 2,000 till 2020, and none thereafter.

5.2 Employment potential

For the six roadmaps projections of direct employment creation is determined based on literature reviewed in a study completed by Agama Energy (2003) and Kamman et al (2004), as well as newer studies such as Rutovitz & Atherton (2009), EWEA (2009) and GPI & ESTELA (2009). Table 6 below shows the job generation input values for the different energy technologies being assessed.

Operation and maintencance jobs for existing coal power plants are estimated from Eskom's current employment towards generation and ancillary jobs for generation of about 11,000 jobs (Eskom, 2009a). Assessing this relative to the Eskom's nominal capacity of 44 GW yields approximately 0.25 jobs/MW for operation and maintenance. If about 44% of the coal mined in South Africa goes to the generation of electricity (DoE, 2009c) and coal mining employs 50,000 people nationally (StatsSA, 2005) then about 0.5 jobs/MW are generated in the coal supply industry for Eskom. The operation, maintenance and fuel processing jobs for existing coal is therefore estimated at 0.75 jobs/MW (Table 6).

Table 6: Estimated job creation potential by different electricity generation technology

Energy technology	*Total jobs*		*Main Reference*
	Construction, manufacture & installation jobs (per MW) in 2009 [in 2030]	*Operation & maintenance and fuel processing jobs (per MW)*	
Existing coal	0 [0]	0.75	DoE 2009c; Eskom, 2009a
Supercritical coal	2.5 [2.3]	0.65	Agama Energy, 2003; Eskom, 2009a
OCGT	3.4 [3.4]	0.17	Rutovitz & Atherton, 2009
Nuclear	1.8 [1.8]	0.68	Rutovitz & Atherton, 2009
Biomass	8.5 [8.5]	14	Working for Energy, 2009; Kammen, 2004
Landfill gas	3.8 [3.8]	2.3	Agama Energy, 2003
Wind	15 [10.4]	1	Agama Energy, 2003; EWEA, 2009
CSP	10 [5.5 – 6.5]	0.4	GPI & ESTELA, 2009; NREL, 2006
Solar photovoltaic	30 [9.1]	0.4	Agama Energy, 2003
SWH	21 [11]	0	

Lower empolyment for fuel processing can be expected for supercritical coal because of their higher efficiency ratio. Based on Eskom's 4,800 MW Medupi plant 2000 jobs will be created for fuel processing, implying a ratio of 0.4 jobs/MW (Eskom, 2009c). Adding this to Eskom's operation and maintenance ratio yields 0.65 jobs/MW (Table 6). Construction, manufacture and installation jobs for supercritical coal are estimated from the 12,000 employment towards the construction of Medupi at a ratio of 2.5 jobs/MW (Eskom, 2009a).

Internationally, OCGT power plants are thought to generate 0.12 jobs/MW for fuel processing, 0.05 jobs/MW for operation and maintenance and 3.4 jobs/MW for construction, manufacture and installation (Rutovitz & Atherton, 2009). Nuclear operation and maintenance jobs are based on the 1,200 employees at Eskom's 1,800 MW Koeberg plant (0.67 jobs/MW), while fuel processing jobs are thought to add about 0,01 jobs/MW (Rutovitz & Atherton, 2009). The construction, manufacturing and installation job factor of 1.8 jobs/MW for South Africa is derived from the upper range of the Nuclear Energy Institute estimate, which states that building a new 1,000 MW plant would result in the creation of 1,400 to 1,800 jobs (Rutovitz & Atherton, 2009).

Biomass job factors of 8.5 jobs/MW and 14 jobs/MW are gained from Kammen et al. (2004) for construction, manufacture and installation and from the Working for Energy project proposal (DME, 2009) for operation, maintenance and fuel processing respectively. Job factors for landfill gas are based on the Agama Study (2003) at 3.8 jobs/MW and 2.3 jobs/MW.

About 15 jobs/MW are expected for the construction, manufacture and installation of wind turbines (EWEA, 2009) and about 1 job/MW for the operation and maintenance of the wind farm (Agama Energy, 2003). CSP plants require about 10 jobs/MW for construction, manufacture & installation (GPI & ESTELA , 2009) and 0.4 jobs/MW for the operation and maintenance of the plants (Stoddard, Abiecunas, & O'Connell, 2006). The photovoltaics employment factor of 30 jobs/MW for construction, manufacture and installation is based on the Agama Energy Study (2003), while a operation and maintenance factor of 0.4 jobs/MW is derived from Rutovitz & Atherton (2009).

Employment for SWH is estimated more than 700 permanent jobs in 2008, when an installation capacity to install about 120 units per day existed (Theobald & Cawood, 2009). In the study by Agama Energy (2003) the deployment of SWHs was thought to employ 21 jobs/MW for manufacture, installation and distribution in 2012, down from 30 jobs in 2002. We use 21 jobs/MW in 2010 for this study and expect it to reduce to about 11 jobs/MW by 2030 by applying a decline factor of 3%, which is similar to the rate used by Agama Energy (2003).

Construction, manufacture and installation jobs are degressed at rates similar to the learning rates for the technologies resulting in Wind jobs being 2.5 per MW in 2030 compared to 3.7 per MW in 2009, CSP being 3 per MW and 3.5 per MW for central receiver and trough technology respectively in 2030 compare to 5.7 jobs per MW in 2009 and PV installations requiring 9.1 jobs per MW in 2030 compared to 30 jobs per MW in 2009.

5.3 Greenhouse gas emissions abatement potential

Emission abatement potential is projected based on the modelling undertaken for the LTMS (Winkler (ed), 2007). Emissions abated are estimated for each roadmap projection by comparing these to the greenhouse gas emission projected for the baseline. The emission factors per fuel type used are presented in Table 7.

Table 7: Emission factors by fuel type (tonne/TJ)

Source: Winkler (2009)

	CO2	*CH4*	*N2O*	*SOx*	*NOx*	*CO*
Coal for existing plants	96.25	0.001	0.0014	0.626	0.3	0.02
Coal for new plants	96.25	0.001	0.0014	0	0.3	0.02
Natural gas	56.1	0.001	0.0001	0	0.15	0.02
Diesel	74.07	0.003	0.0006	0.253	0.2	0.015
Nuclear fuel PWR	0	0	0	0	0	0
Renewable	0	0	0	0	0	0

By the end of 2009 it is estimated that there was 214 Mt of CO_2-eq emitted from existing large coal fired power plants, 14.2 Mt CO_2-eq emitted from existing small coal fired power plants and 0.55 CO_2-eq emitted from OCGT liquid fuels power plants.

5.4 Milestones to 2030

The outcomes of the roadmaps are presented as changes in government and private spending, changes in employment and changes in GHG emissions relative to the baseline projection. Annual averages for the periods 2010 – 2014, 2015 – 2019, 2020 – 2024 and 2025 – 2030 are represented for each projection.

6. South Africa electricity projections

6.1 Baseline projection

The baseline to which different renewable energy roadmaps are compared is modelled on the baseline developed for the long-term mitigation scenarios (LTMS) for South Africa (Winkler (ed), 2007). In the LTMS the baseline is called the 'Growth without constraint' scenario (GWC) and it runs from 2003 to 2050, though for this study we will only consider the period 2010 – 2030. GWC represents a scenario where there is no change from the country's current trends; where not even existing policy is implemented; and where no SWHs are installed to reduce the electricity system demand.

Existing generation capacity at the end of 2009 is made up of 30.5 GW large coal, 6.1 GW small coal, 2.4 GW OCGT liquid fuel, 1.8 PWR nuclear, 0.7 GW hydro, 0.1 GW landfill gas and 0.2 GW biomass, totalling 43.3 GW generation capacity (Eskom, 2009a).

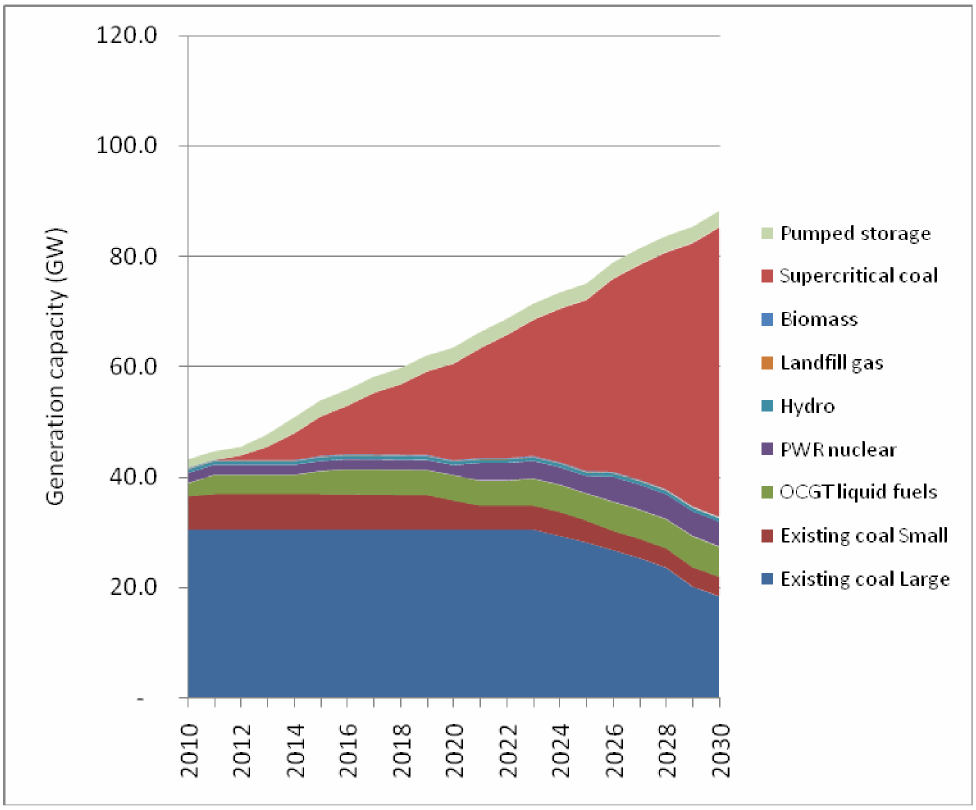


Figure 4: Projected generation capacity under GWC baseline

In the baseline scenario electricity generation continues to be predominantly from coal, with all new coal-fired plants using supercritical steam technology comes into the generation mix from 2012, when Medupi is expected to come online (Figure 4). A unit of PWR nuclear generation capacity (1350 MW) is brought online in 2021 and again in 2026. Every few years 3 or 6 units of OCGT plants, each at 120 MW are also installed to reduce the loss of load probability. Renewables remain limited to a 2% share of capacity, and do not enter the generation mix in a significant way in the GWC scenario.

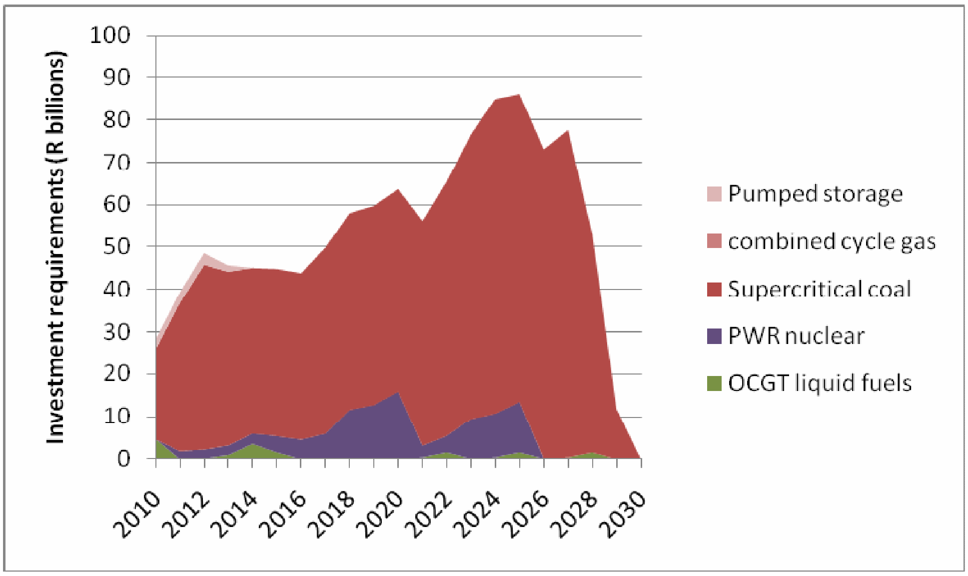


Figure 5: Annual investment requirements for the baseline projection

Annual investment requirements peak in 2025 at R86 billion. More than 80% of the investments go towards the construction of supercritical coal plants except in years before the two nuclear plants come online when more of the investment requirements are directed at these (Figure 5). The drop off in investment requirements by 2030 is due the end of the modelling period.

Electricity production continues to be more than 90% from coal-fired power stations, which can be run 88% of the time. The gas-fired power stations are suitable for peak generation, and thus do not run as much. Renewable energy technologies will run when the resource is available and thus have smaller shares of electricity generated. However, some designs improve availability factors, such as the use of molten salt in the solar power tower.

The baseline projection results in an electricity supply system instability in 2012 when the reserve margin (AF) for that year is below 15%. The reserve margin for 2011, 2012 and 2013 is also below 15% and the LOLP is higher than 0.03% for 2010, 2011, 2012, 2013 and 2014. This is largely due to the fact that Medupi will only be able to bring its first unit online by 2012 and no other coal-fired power plants can be constructed in the time before that. The Department of Energy hopes to alleviate some of the instability through connecting additional renewable energy and co-generation capacity of 343 MW in 2010, 518 MW in 2011, 284 MW in 2012 and another 300MW in 2013 as outlined in the Integrated Resource Plan 1 (IRP1) signed off by the Minister of Energy on 16 December 2009 (DoE, 2010).

Electricity is generated from renewable energy technologies contribute very little to the national mix, only 1.2% in 2010 and declining to 0.6% in 2030. The electricity is generated from the existing hydro, biomass (mainly bagasse), and a small amount of landfill gas with no new renewable energy capacity added.

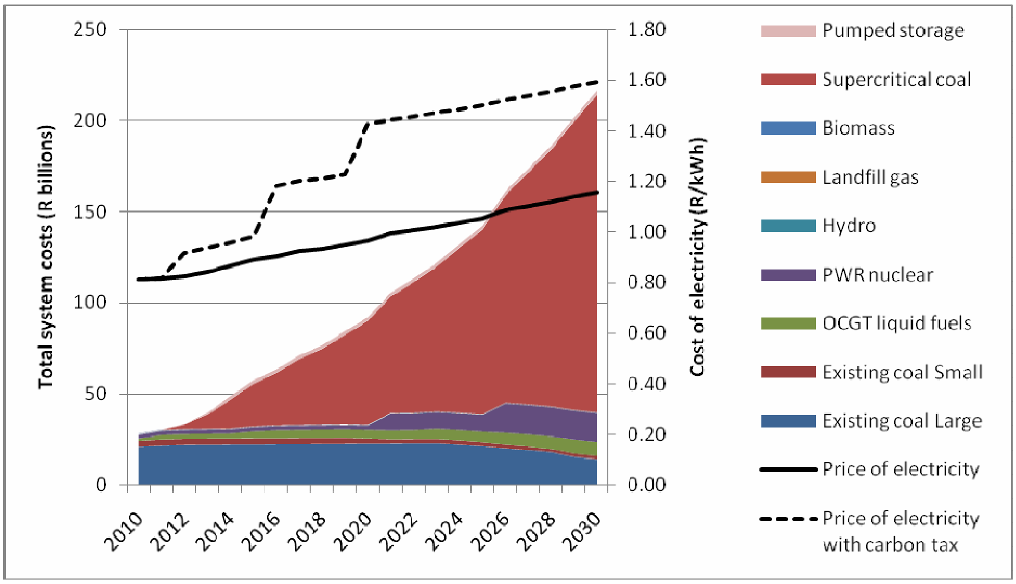


Figure 6: Total system cost and average cost of electricity for the baseline scenario

The baseline scenario results in a total system cost close to R200 billion by 2030 rising from a production cost of about R30 billion in 2010. This results in an expected increase in the average price for electricity from R0.81/kWh to about R1.10/kWh (Figure 6). If a carbon tax is applied, rising from R100 per tonne in 2012 to R200 in 2016 and R500 in 2020, the price of electricity may rise to R1.54/kWh by 2030. The price of electricity assumes an additional cost of R0.70/kWh to be added to the cost of generating electricity.

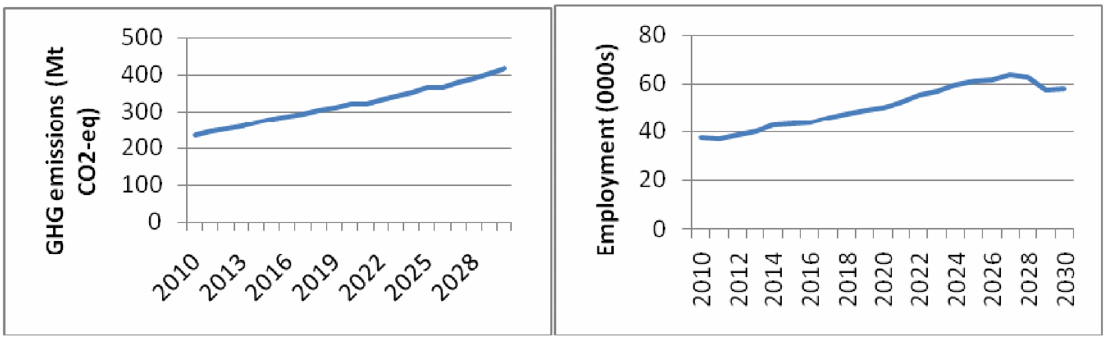


Figure 7: GHG emissions and jobs generated from the baseline projection

From a base of 237 Mt CO_2-eq GHG emissions in 2010 GHG emissions steadily increase in the baseline projection reaching 416 Mt CO_2-eq in 2030, see Figure 7. Jobs generated in the energy sector in 2010 are estimated at 38 000 and with the deployment of electricity generators under the baseline projection the number of people employed in 2030 is expected to be 58 000. Peak employment is expected in 2027 with 63 000 jobs generated (Figure 7).

6.2 Renewable energy policy roadmaps

The renewable policy roadmaps are a combination of targets for electricity generation from renewables and targets for SWH rollout. Electricity generated from renewables is supported with the REFIT programme until the technologies become competitive with other non-renewable technologies, such as nuclear and different coal technologies. SWHs are supported by a decreasing government subsidy until 2020.

6.2.1 Capacity deployed to 2030

Two Roadmaps (1 and 2) present scenarios where the deployment of renewables for electricity generation is unrestricted by policy, but rather by the resources available. Two further roadmaps (3 and 4) present scenarios where renewables for electricity generation are deployed to reach a target of 27% renewable electricity sent out by 2030. The last two roadmaps (5 and 6) present scenarios where renewables for electricity generation are deployed to reach a target of 15% renewable electricity sent out by 2030. Deployment scenarios for electricity generation capacity for the roadmaps are presented in Figure 9.

Certain restrictions on new capacity deployment are established dependent on resource availability and realistic rates of deployment. Landfill gas is restricted to 60 MW of new capacity, biomass to 160 MW of new capacity, and hydro to 190 MW of new capacity. Eight units, each of 333MW, of pump storage are allowed to be built. Nuclear capacity is only allowed to be built after 2020. No more than 1000 MW of wind is allowed to be built per year until 2025, after which 2000 MW can be built per year, and wind with a 30% availability factor is restricted to 10 GW. CSP and PV are not allowed to more than double in deployment year on year with no specific restriction on the maximum deployment per year or in total.

In Roadmaps 1, 3 and 5 the SWH rollout is high, in line with targets set by the draft national SWH framework, where one million units are installed by 2014, another four million by 2020 and approaching the theoretical limit of 10 million by 2030 (DoE, 2009b). The deployment of SWH peak between 2014 and 2020 when more than 600 thousand units are installed annually (Figure 8).

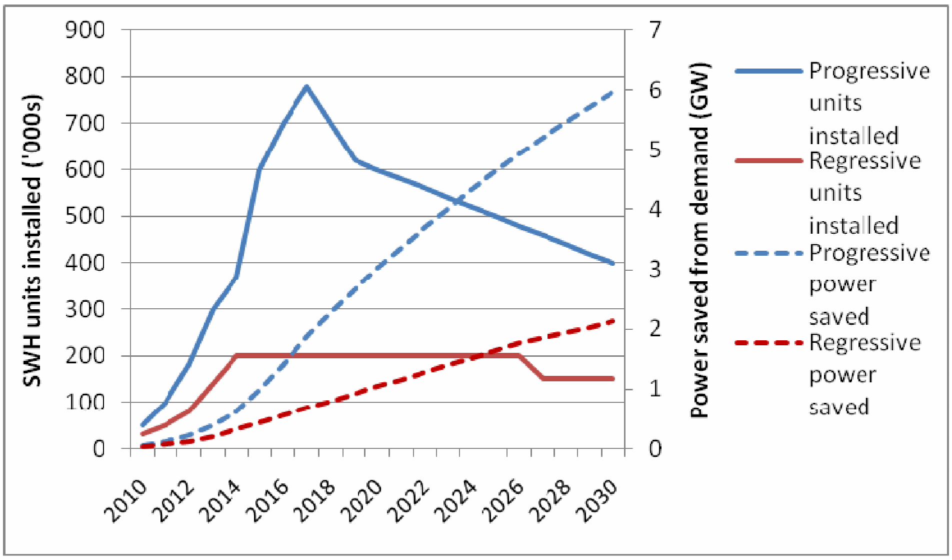


Figure 8: High and low SWH rollout as applied to roadmaps 1, 3 & 5 and 2, 4 & 6 respectively.

By contrast, Roadmaps 2, 4 and 6 represent a low scenario for SWH deployment. By 2014 only 500 thousand units are installed and in total by 2030 only 3.5 million units get deployed at a maximum rate of 200 thousand units per year (Figure 8). By 2030 about 6 GW of electricity generating capacity is saved with the high SWH strategy, while the low SWH projection only results in 2 GW of electricity generation capacity saved.

All projections achieve the maximum of 10 GW wind 30% deployment. Roadmaps 5 and 6 do not deploy any more wind beyond this by 2030, while the others start to deploy wind plants with a capacity factor of 25%. The most wind 25% capacity deployed by 2030 is in Roadmap 2 at 15 GW, while in Roadmaps 1, 3 and 4 about 9 GW of wind 25% are deployed by 2030, see Figure 9.

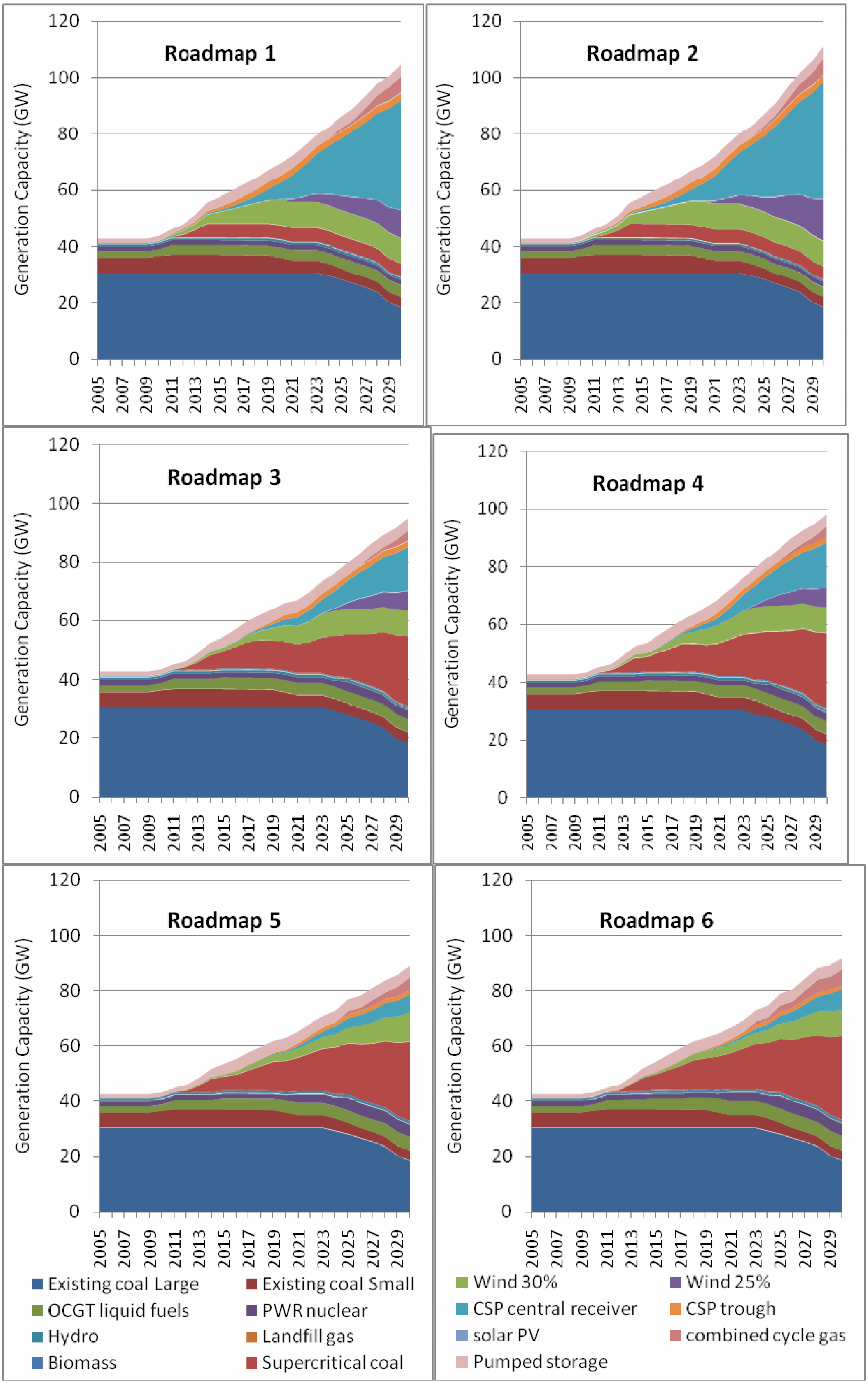


Figure 9: Capacity deployment for the different roadmaps

Initially a few units of CSP parabolic trough and central receivers are deployed with central receivers becoming the preferred technology. In roadmaps 1 and 3 CSP is deployed reaching about 40 GW by 2030, while in roadmaps 3 and 4 about 15 GW are deployed by 2030 and in roadmaps 5 and 6 less than 10 GW are deployed for 2030. PV plants are only deployed in Roadmaps 1 and 2 after 2020 to diversify the electricity supply mix, though this contributed to no more than 200 MW by 2030.

Roadmap 2 requires a larger deployment of renewable energy plants for electricity generation than Roadmap 1 because of the lower electricity demand in 2030 by Roadmap 1 due to the high rollout of SWHs. Due to the lower capacity availability factors of renewable energy generation plants Roadmaps 1 and 2 have to deploy more than 100 GW of capacity by 2030, while the other Roadmaps (3, 4, 5 & 6) only need to achieve electrical capacity below 100 GW by 2030 without creating instability in the electricity system (Figure 9).

6.2.2 Electricity generation

Starting from the same base in 2010 Roadmap 1 is projected to produce the most renewable energy by 2030, namely 290 TWh which is 60% of the energy demand (Table 8). It generates more than Roadmap 2 (264 TWh in 2030) because it has a higher electricity demand profile due to the lower rollout of SWH, which is met by the large-scale rollout of wind and CSP after 2020. Comparing Roadmaps 3, 4, 5 and 6 indicates that the progressive SWH rollout (Roadmaps 3 & 5) achieves higher renewable energy deployment than a regressive SWH rollout even if in the regressive projections (Roadmaps 4 & 6) the electricity deployed by CSP and wind is slightly more, see Table 8.

Table 8: Renewable energy generated in 2030 from the different roadmaps

Roadmap	*Wind (TWh)*	*CSP (TWh)*	*PV (TWh)*	*SHW (TWh)*	*Total (TWh)*	*% energy produced*
1: Unrestricted; high SWH strategy	45	196	0.4	23	264	55
2: Unrestricted; low SWH strategy	56	226	0.4	8	290	60
3: 27% target; high SWH strategy	37	88	0	23	148	30
4: 27% target; low SWH strategy	38	90	0	8	136	28
5: 15% target; high SWH strategy	26	40	0	23	91	20
6: 15% target; low SWH strategy	26	42	0	8	76	16

Electricity generated from wind is highest in the unrestricted Roadmaps 1 and 2, at 45 TWh and 56 TWh respectively by 2030. Roadmaps 3 and 4 generate 37-38 TWh of wind powered electricity and Roadmaps 5 and 6 only generate about 26 TWh or wind-powered electricity. The most solar powered electricity is also generated with the unrestricted renewable energy roadmaps at more than 200 TWh from CSP, PV and SWH by 2030. The 27% target roadmaps result in less than 100 TWh of solar energy produced and the 15% targets in less than 70 TWh by 2030 (Table 8).

Although all the policy roadmaps are projected to achieve adequate reserve margins and reserve margin AF values for the whole period the probability of a loss of load for 2010-2013 are mainly above the threshold of 0.03%, as is the case for the baseline projection. Only roadmaps 1 and 2, in support of unlimited deployment of renewables, achieve a LOLP below 0.03% in 2013 and lower LOLP values for 2011 and 2012 than the other roadmaps. This is largely due to the fact that 2000 MW of wind capacity generating 5.3 TWh of electricity and 800 MW of CSP capacity generating 3.7 TWh of electricity come online by the end of 2013.

6.2.3 Levelised price of electricity and investment requirements

The average price of electricity, calculated by adding R 0.70/kWh to the projected cost of generating electricity, increases the most for the Roadmap 1 and 2 projections and least for the Baseline and Roadmap 5 and 6 projections, from R 0.81/kWh to R 1.36/kWh and R 1.16/kWh in 2030 respectively. The cost projections for Roadmaps 1 and 2 are very similar, as are those for the Baseline and Roadmaps 5 and 6. This implies that reaching a 15% renewable electricity target by 2030 will not cost any more than the Baseline projection, while higher renewable electricity targets would. Roadmaps 3 and 4, which achieve a target of 27% of electricity output from renewable energy sources, result in a price for electricity of R 1.20/kWh and R 1.21/kWh in 2030 (Figure 10).

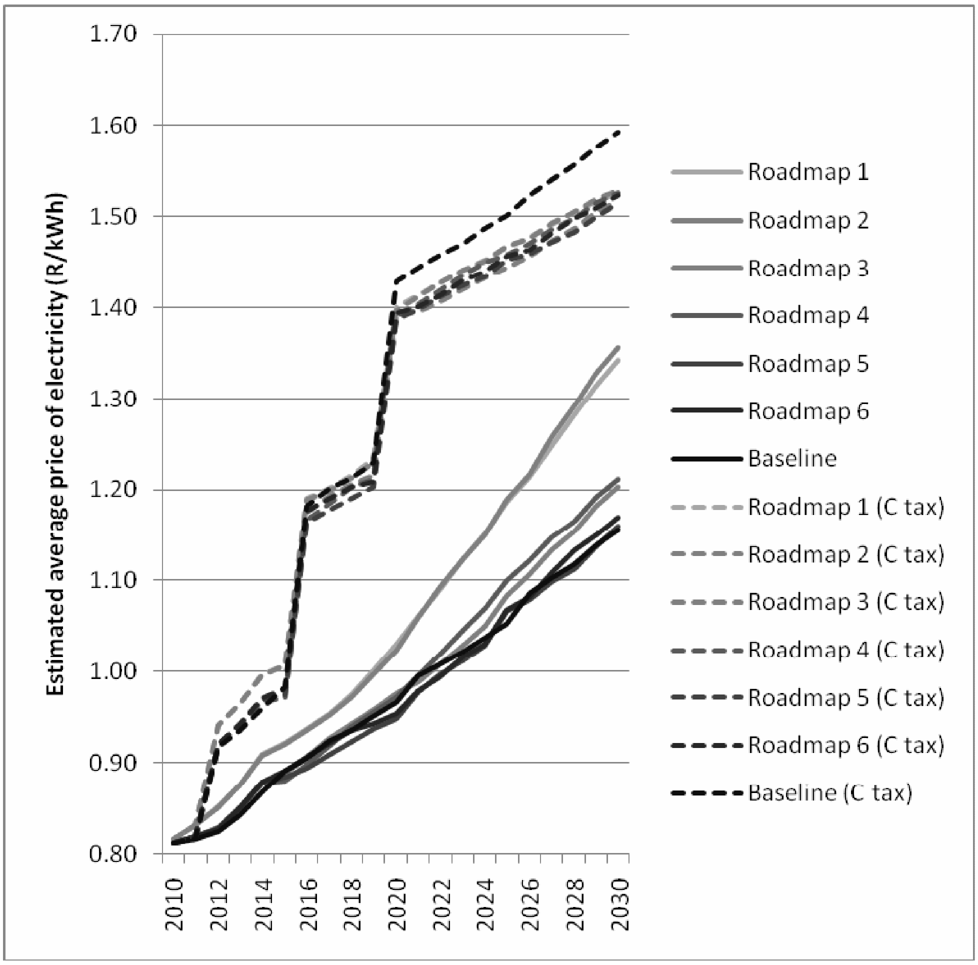


Figure 10: Projected average price of electricity generated with and without a carbon tax for the baseline projection and the six roadmaps.

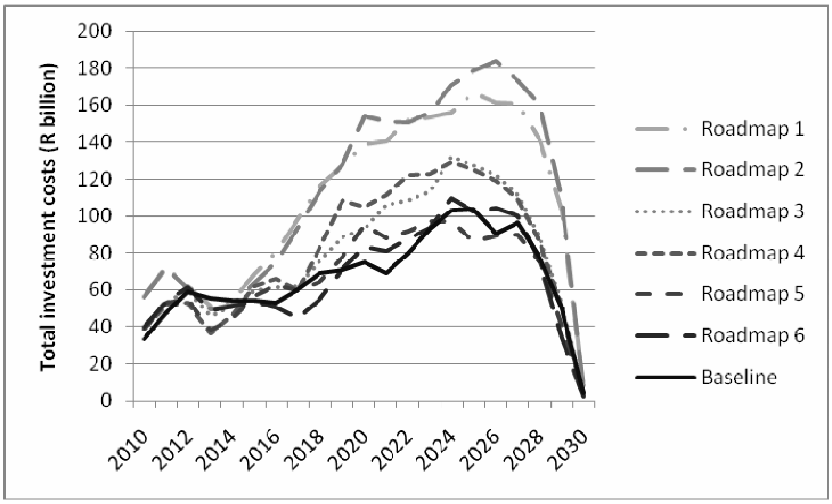


Figure 11: Total investment costs for the Baseline projection and the Roadmaps.

By contrast, if a rising carbon tax is applied from 2012, reaching R500 per tonne of CO_2-eq after 2020, the price of electricity for the Baseline projection becomes the highest in 2030 at R 1.59/kWh. The renewable energy policy Roadmaps achieve electricity prices of R 1.51 – 1.53/kWh in 2030.

This would imply that the true cost of generating electricity in South Africa, whereby the external cost of carbon emissions are defined by the carbon tax, is cheaper if the expansion of electricity from renewable energy sources is supported. It is notable that achieving a 55%, a 27%, or a 15% of renewable electricity by 2030 hardly makes any difference to the price of electricity.

The differences in electricity prices are largely based on the investment requirements of the different scenarios, whereby in the Baseline scenario no investment costs are realised from renewable energy technologies. Roadmaps 5 and 6 have total investment profiles without accounting for the cost of carbon closest to the baseline peaking at about R 100 billion in 2024 (Figure 11). Roadmap 2 shows the highest total investment requirements peaking at R184 billion in 2026, which is twice the highest annual investment requirement in the Baseline, not accounting for carbon taxes.

6.2.4 Employment created

All renewable energy policy Roadmaps result in creating a lot more employment than the baseline scenario. Between a third and more than twice the amount of jobs generated in the baseline scenario are projected for different renewable energy policy interventions.

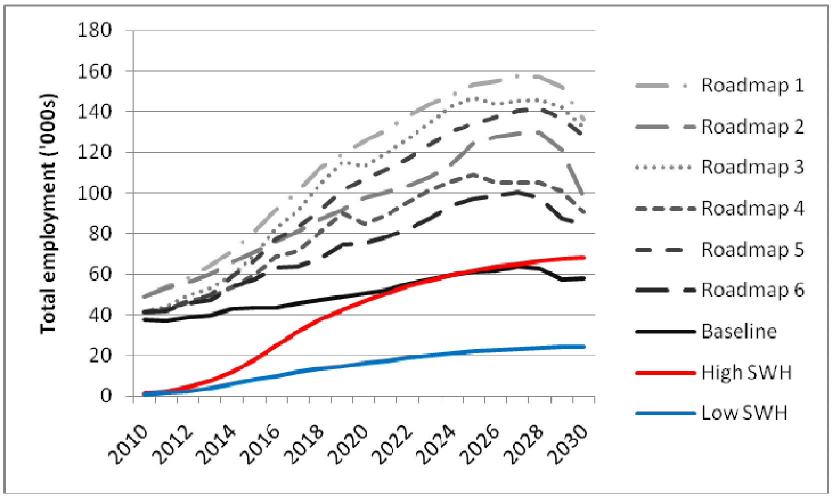


Figure 12: Jobs created by the different projections

The Roadmaps supporting a high SWH rollout (1, 3 & 5) generate a lot more jobs than the Roadmaps with low SWH rollouts (2, 4 &6), whereby jobs only from SWHs are 68,000 and 24,000 respectively by 2030. Interestingly the Roadmap projecting the most jobs generated is not the one achieving the highest percentage of energy generated from renewables (Roadmap 2), but rather one that encourages SWH deployment over electricity production from enewables (Roadmap 1) peaking at more than 150,000 people employed (Figure 12). This would imply that reducing electricity consumption through the rollout of SWHs is favourable over supplying that electricity from renewables.

6.2.5 GHG emissions

All Roadmaps result in lower GHG emission than the baseline projection. In Roadmaps 5 and 6, where a 15% renewable energy target is achieved by 2030, GHG emissions still increase, though at a lower rate than the baseline projection. GHG emissions stabilise around 300 Mt CO_2-eq if a 27% target of electricity generation is achieved in 2030 as in roadmaps 3 and 4, while with maximum renewable energy deployment for electricity generation, as in roadmaps 1 and 2, GHG emissions peak in 2018 and are projected to reduce to 170 Mt CO_2-eq in 2030 (Figure 13). In the next section we consider how a renewable energy target may be married with a nuclear energy deployment plan.

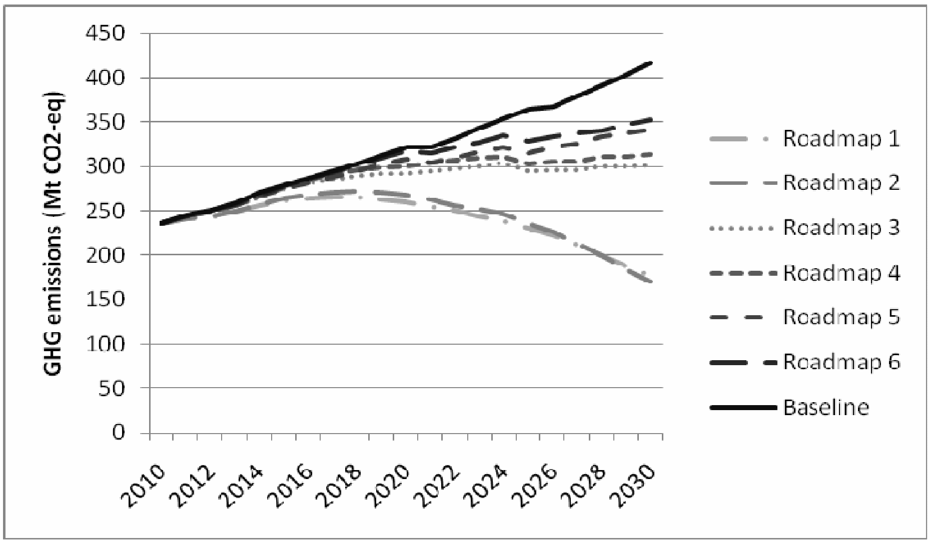


Figure 13: GHG emissions projected for the different roadmaps

6.2.6 Relative change in investments, employment and GHG emissions

The projected investment requirements, employment creation and GHG emissions for the six renewable energy policy Roadmaps can also be assessed as percentage change from the Baseline projection, as see in Figure 14 below.

The greatest percentage change is seen in employment numbers where Roadmaps 1, 2, 3 and 5 record more than 100% increases in employment. Achieving a high level of SWH rollout, in line with the targets of one million units by 2014, five million by 2020 and 10 million by 2030, results in a greater relative increase of employment compared to a renewable energy policy projection that supports a low SWH rollout. This is particularly noticeable when comparing Roadmaps 5 and 6, where the GHG emissions, and public and private investments are similar to the Baseline projection, but where Roadmap 5 with a high SWH rollout results in more than 100% increase in employment per year from 2020. In conclusion a renewable energy policy Roadmap should support as high a rollout of SWHs as possible.

GHG emission savings are projected in all Roadmaps, while the greatest reductions are for Roadmaps 1 and 2 where more than 40% reductions are achieved per year between 2025 and 2030. This is because no new supercritical coal plants are built under these scenarios after the last unit of Eskom's Medupi power plant comes online in 2015. Both scenarios deploy 9 GW of 30% wind, while Roadmap 2 deploys 15 GW of 25% wind and Roadmap 1 only 10 GW by 2030. 2.6 GW of CSP parabolic troughs are deployed in both Roadmaps while Roadmap 2 deploys more than 40 GW and Roadmap 1 less than 40 GW of CSP central receiver plants by 2030, and both have 200 MW of PV plants installed by 2030 (Figure 9).

The high GHG emission reductions associated with the unrestricted rollout of renewable energy generation capacity is only achievable with high investment costs. The REFIT programme could encourage more than a 80% increase in private investments per year in 2015-2019 and 2020-2024 (Figure 14). As more public investments start financing the renewable energy generation capacity the percentage of these rises towards 2030 in Roadmaps 1 and 2.Futhermore, the resultant true price of electricity, with a carbon tax calculated in is the same for all Roadmaps, and less than that for the Baseline projection, implying that the highest possible renewable energy targets should be pursued.

Achieving a 15 % electricity generation target from renewable energy sources by 2030, as presented in roadmaps 5 and 6, is possible with hardly any change in public and private investments. In most periods actually a saving is projected, except for possibly the 2020 – 2025 period where investment costs are slightly higher. Comparing the two Roadmaps shows that slightly more investments are required in support of the high SHW rollout strategy under Roadmap 5, thought the employment benefits of this would probably pay itself off. The change in GHG emissions hardly shift more than 10% below the baseline, except towards the end of Roadmap 5 where less fossil fuel powered electricity generators are built due to the decreased demand for electricity achieved through the high SWH rollout.

Figure 14: Percentage change in private and public spending, GHG emissions and employment for the six renewable energy policy roadmaps relative to the baseline projection

Achieving a 27% target for electricity generation from renewable energy sources by 2030, as achieved in Roadmaps 3 and 4, results in GHG emission savings of 20% less per year in 2025-2030.

This is associated with an increase in investments of less than 20% compared to the Baseline projection in both the public and private sector, though interestingly the increases in investments are less for Roadmap 3 than for Roadmap 4, even though a greater change in employment is achieved in Roadmap 3 (Figure 14).

Reviewing the renewable energy policy roadmaps shows that the renewable energy policy supported by Roadmap 3 the most appealing. A high SWH rollout with the aim of achieving targets of 1 million units by 2014, 4 million units by 2020 and tending to 10 million units by 2030, and a target of 27% electricity generation from renewables creates great employment benefits and stabilise GHG emissions without costing more than 18% per year above the baseline projection for either the private or public sector, the later being supported by the REFIT programme.

7. Choosing a 27% target by 2030

Supporting a renewable energy policy of achieving 27% electricity from renewables by 2030 and achieving a high SWH rollout results in the second most jobs generated of all projections. Peaking at almost 150,000 jobs only Roadmap 1 beats Roadmap 3 in the amount of jobs generated. The renewable energy policies presented under Roadmap 3 would also result in stabilising GHG emissions around 300 Mt CO_2-eq from the electricity sector.

If, however, South Africa aims to reduce GHG emissions in absolute terms beyond 300 Mt CO_2-eq higher targets for electricity generation from renewable energy sources should be adopted or a nuclear programme should also be pursued. Immediate GHG emission savings could be achieved through the high initial deployment of wind and CSP capacity, in the region of 1,800 MW and 800 MW respectively by 2013 as under Roadmaps 1 and 2. IPPs in South Africa have announced that this would be possible. Assuming 90% of these developments are driven by private investments supported by the REFIT would mean about 20% increases in investments relative to the baseline projection.

Considering the fragile state of the South African electricity supply system such immediate renewable energy developments may be necessary. Only Roadmaps 1 and 2 show some ability in minimising the loss of load probability and increasing the reserve margin for electricity supply in 2011 and 2012.

7.1 The makeup of Roadmap 3

Roadmap 3 is only achievable by encouraging wind power developments to come online in 2011 and CSP in 2012, while both Medupi and Kusile power plants are built between 2012 and 2018. Additional suppercirital coal capacity is built from 2022 onwards to make up the electricity supply shortfall until resulting in a total 26GW of new coal capacity by 2030.

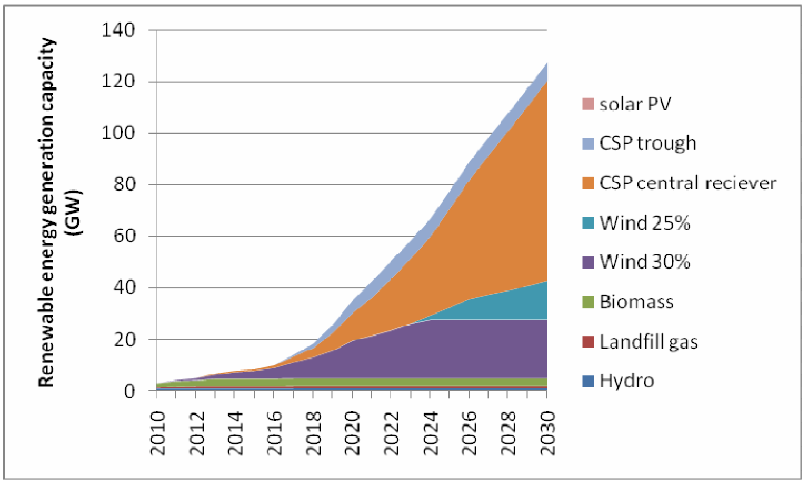


Figure 15: Renewable energy generation capacity development to 2030 under Roadmap 3

CSP deployments increase annually from the first 100 MW in 2012, to more than 500 MW after 2015, reaching 1.2 GW per year from 2020 and about 1.5 GW per year from 2025. No PV plants are built over the period 2010-2030. Wind capacity is developed at the best sites (30% availability factor) until about 10 GW is established by 2024, rising from the first plant in 2011, to the first GW after 2014 and about 5 GW by 2020. Wind capacity with a 25% availability factor is developed from 2024 deploying an additional 7 GW by 2030, making the total wind capacity deployed about 17 GW (Figure 15).

Therefore 125 TWh of electricity is supplied from renewable energy sources by 2030, 37 TWh (30%) from wind technology and 88 TWh (70%) from CSP technology (Table 9). With about 23 TWh of electricity equivalent energy generated by the high SWH rollout about 30% of the electrical energy demand in 2030 is expected to come from renewable sources. Although PV did not enter the electricity generation mix to any large extent this would change if the learning rate for this technology is experienced, and the cap for this technology is removed under the current South African REFIT.

Table 9: Sensitivity analyses of Roadmap 3

Roadmap 3 sensitivities	Wind (TWh)	CSP (TWh)	PV (TWh)	SHW (TWh)	Total RE (TWh)	Coal (TWh)	Nuclear (TWh)
Original	37	88	0	23	148	44	0
PV encouraged	37	35	53	23	148	44	0
Nuclear instead of coal	37	88	0	23	148	0	44
Nuclear and PV encouraged	37	35	53	23	148	0	44

The Roadmap 3 projected requires annual investments that steadily rise to peak at R 125 billion in 2024, relative to the Baseline scenario a maximum of about 18% increase in public and private spending per year for 2020 – 2025. The price of electricity is expected to stay under R 1.20/kWh by 2030, which is still higher than the Baseline projection of the price of electricity. But if a carbon tax is applied the Roadmap 3 projection results electricity priced well below the true price of electricity from the Baseline projection (Figure 10).

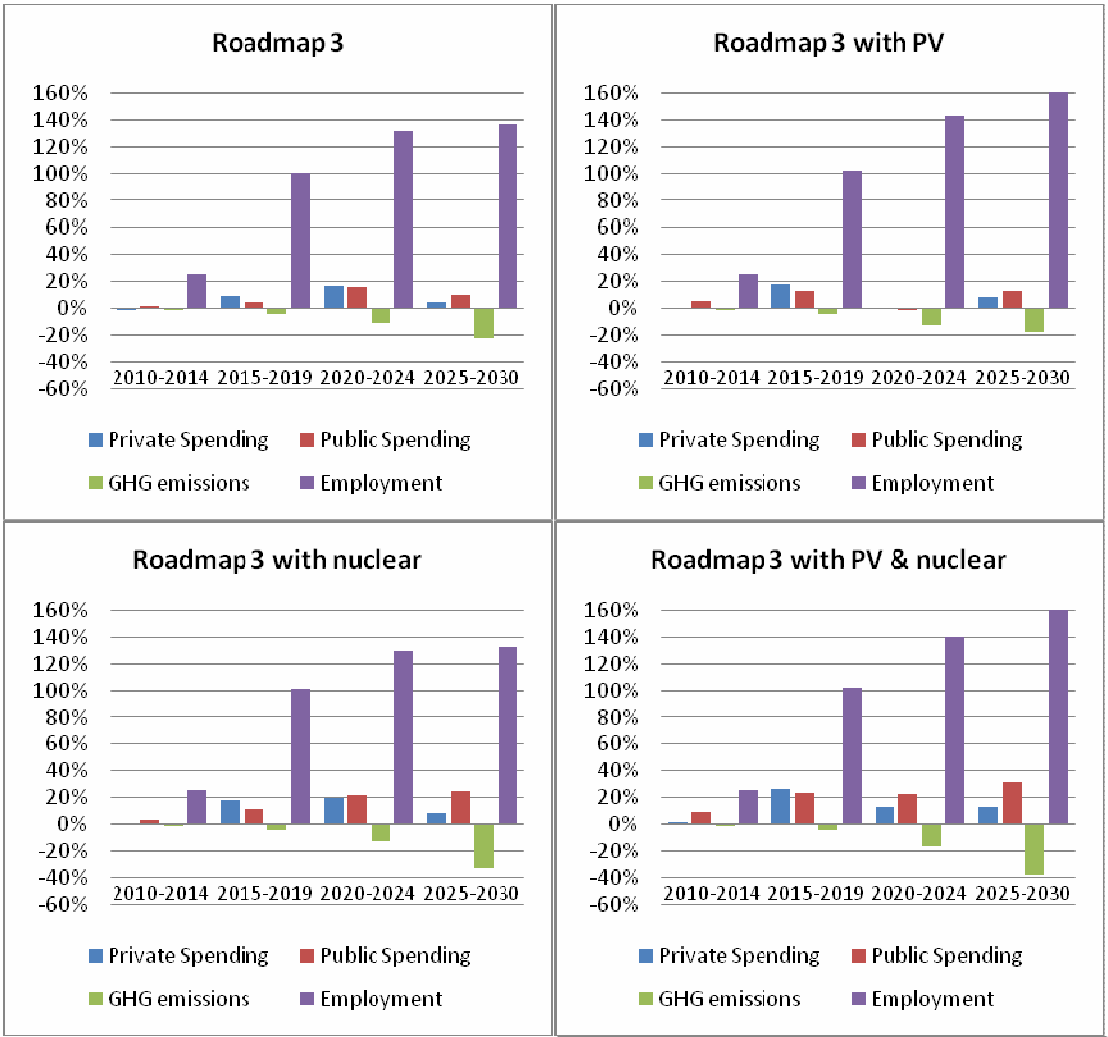
Besides the SWH subsidy programme aimed at achieving the high SWH targets the deployment of renewables for electricity generation is thought to be achieved with the support of the REFIT. Key to facilitating this renewable energy policy is for allowing the REFIT to progress towards achieving the 27% by 2030 and not being capped below this, as is currently the case in South Africa. The current cap on the REFIT at 725 MW capacity renewable energy deployments by 2013 (DoE, 2010) should rise to at least 1,200 MW by 2013 and the next IRP 2 should emphasise renewable energy targets in line with the Roadmap 3 projection.

7.2 Roadmap 3 sensitivities

While a 27% renewable electricity target by 2030 seems to be the most appealing, this can be achieved with different technologies. Whereas small hydro, biomass and landfill gas can probably play a larger role in South Africa's future energy mix, beyond the 95 MW, 160 MW and 60 MW modelled, PV could probably also realise much greater deployment by 2030. Large-scale PV farms are already considered under South Africa's REFIT but are thought to remain rather expensive and therefore considered to contribute little to the Roadmap 3 projection. If however the technology experiences higher learning rates than the 25% assumed for this study, more in the region of 40 – 50%, then the levelised cost of electricity provided from this technology decreases dramatically by 2030 and becomes competitive with nuclear by 2025 (Figure 3).

The REFIT for solar PV technology could possibly encourage such higher learning rates as the technology evolves. If this were so PV systems would be preferred over CSP after 2020 and the share of electricity generated from PV by 2030 would shift in favour of PV, see Table 9. A policy

Roadmap encouraging such technology learning for PV would benefit in lower investment costs as seen compared to the original Roadmap 3 (Figure 16).



For comparison:

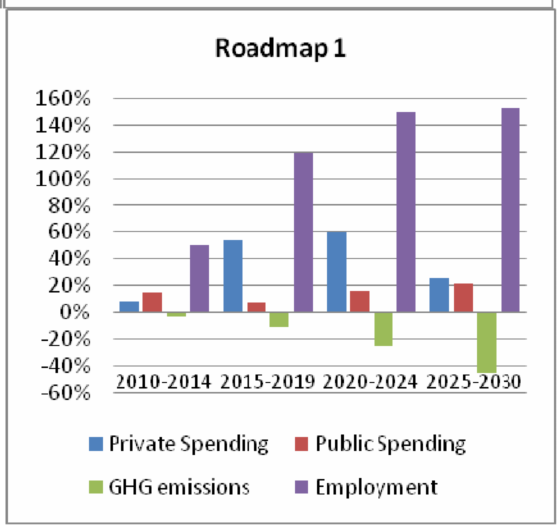


Figure 16: Relative change in investments, employment and GHG emissions from Roadmap 3 sensitivity studies.

Furthermore, the electricity demand not covered with renewables, which is about 44 TWh, could be generated from nuclear power instead of more supercritical coal from 2020 as is the case for the original Roadmap 3 (Table 9). This would facilitate high GHG emission reductions, almost on par with those seen in Roadmap 1 (Figure 16) because all new generation capacity after Medupi and Kusile would be low carbon technologies. Relative to the original Roadmap 3 slightly higher public and private investments are required reaching above 20% from the baseline in 2020 – 2025 and 2025 – 2030.

A final sensitivity analysis of Roadmap 3 is one whereby the excess electricity demand is supplied by nuclear and the REFIT is implemented to encourage higher technology learning rates for PV. This results in greater GHG savings, almost similar to those of Roadmap 1, though less because Kusile is allowed to be built, and investment requirements of up to 30% above those of the Baseline projection in the final period due to the large nuclear rollout programme.

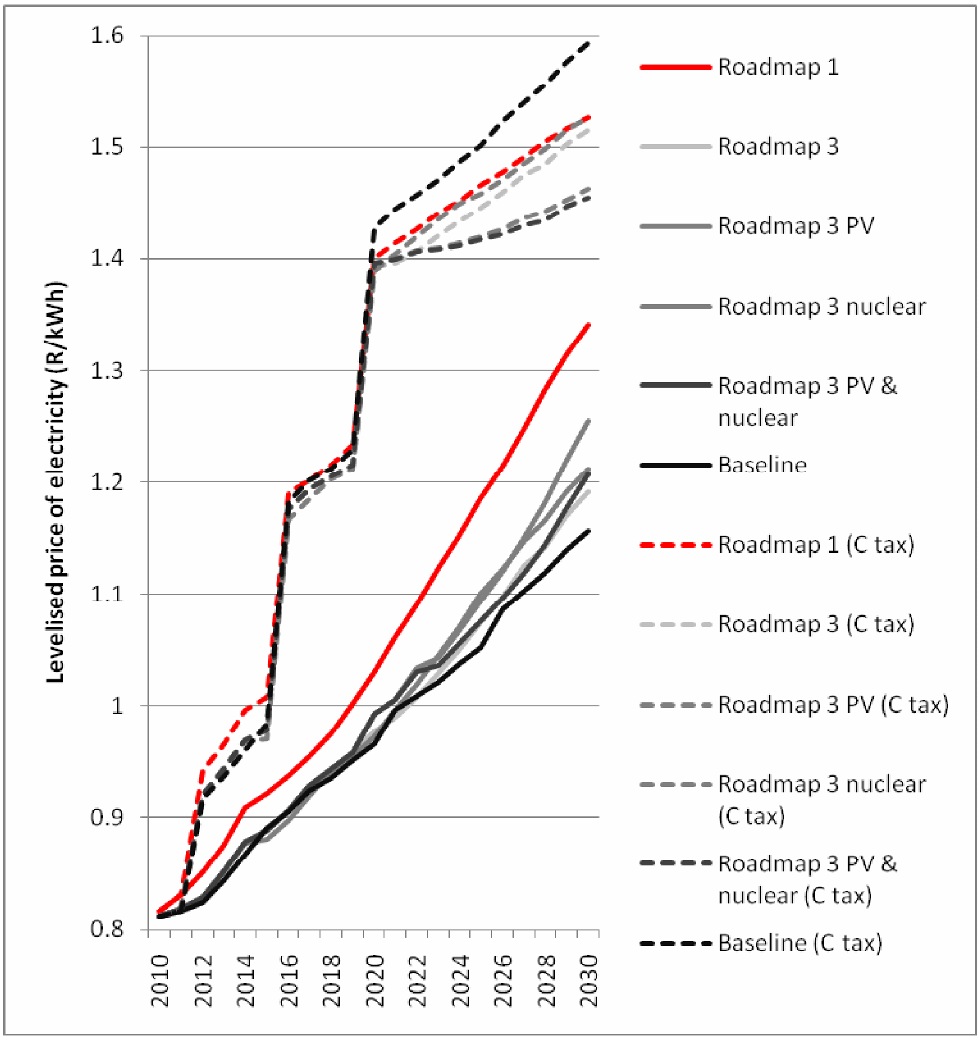


Figure 17: Price of electricity estimates for the sensitivity analyses of Roadmap 3 compared to Roadmap 1

Assessing the Roadmap 3 sensitivities shows that the price of electricity from these projections is slightly higher by 2030 compared to the original Roadmap 3 (Figure 17). If, however, the external cost of GHG emissions is considered through a rising carbon tax then the Roadmap 3 sensitivity projections supporting nuclear instead of coal as the source of additional capacity then the price of electricity is markedly below that of the original Roadmap 3, expected at about R 1.45/kWh in 2030. These nuclear sensitivity analyses achieve GHG emission reductions at a level almost comparable to Roadmap 1, but at a lower cost, indicating that a future electricity mix of both nuclear and renewables in South Africa may indeed be the most effective solution, assuming the cost of nuclear to not increase above those reported today.

Conclusion

South Africa should support the rollout of renewable energy technologies with policy options as identified in this study. Ideally a REFIT should be coupled with a renewable electricity target, which is well above that of the present 10,000 GWh target for 2013. Judging by the past experience of renewable energy project developments in South Africa it seems that renewable energy policy has been in-effective, while with the publication of the REFIT in 2009 the interest in developing projects has grown dramatically. Although the SWH market developed after nation-wide electricity blackouts in 2008 this technology will certainly still require subsidy support aimed at high rollout targets of reaching about 10 million units by 2030.

This study reviewed renewable energy Rroadmaps which resulted in different deployment projections for wind, CSP and PV and SWH. In total six policy Roadmaps were developed. Electricity targets of 15% (Roadmaps 5 & 6), 27% (Roadmaps 3 & 4) and unlimited (Roadmaps 1 & 2) by 2030 were assessed, as well as high (Roadmaps 1, 3 & 5) and low SWH (Roadmaps 2, 4 & 6) strategies. There were compared to a Baseline projection which only deployed supercritical coal-fired power plants, similar to those currently under construction in South Africa, to meet the demand for electricity.

The most employment benefits are recorded for the Roadmaps supporting a high SWH rollout, with targets of deploying 1 million units by 2014, another 4 million by 2020 and reaching 10 million by 2030. The unlimited renewable energy target projections result in the highest GHG savings, while the 27% target projections stabilise GHG emissions form electricity. Reaching a 15% renewable electricity target does not result in any price increased above those projected for the Baseline and if a carbon tax is considered in all renewable projections the Baseline projection results in the highest price estimates by 2030.

The renewable energy policy Roadmap 3, with a target of at least 27% electricity supply from renewable sources and a high SWH rollout strategy, is identified as the most favoured strategy for South Africa. The strategy would create the most possible employment, well above 100% change from the baseline from 2015, and would stabilises the GHG emissions from the electricity sector. A mixture of wind (30%) and CSP (70%) would be the largest contributors to achieving this target in 2030, supported by the REFIT.

By completing sensitivity analyses on Roadmap 3 it is seen that PV can play a more important role if higher technology learning rates are encouraged by an effective REFIT with sensible tariff degression. Furthermore, higher GHG emission reductions can be achieved at a lower cost compared to a renewables only strategy (Roadmap 1) by encouraging nuclear to supply the additional electricity demand from 2020. The price of electricity under this sensitivity projection is also below the original Roadmaps 1and 3, and the Baseline projection if carbon taxes are considered in the analysis, indicating that it may be the most economical strategy on the assumption that the cost of nuclear will not rise into the future.

A further assessment of renewable energy policy in South Africa would have to incorporate a more detailed analysis of possible energy efficiency policy and targets, as these will have a notable influence on the electricity demand in the country. Furthermore, a more detailed review of the maco-economic impacts beyond employment generation should be completed for South Africa’s renewable energy policy options.

Nonetheless, this study was able to show that renewable energy policies, in particular the REFIT, aimed at substantial renewable energy targets can encourage GHG savings and employment without requiring too much additional private and public investment above the Baseline projection.

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Appendix: Build plan for reference scenarios and roadmaps

Reference scenario

Plant Description	Unit Size MW	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Existing coal Large	564	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Existing coal Small	114	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
OCGT liquid fuels	120	0	9	0	0	0	6	3	0	0	0	0	0	0	3	0	0	3	0	0	3	0
PWR nuclear	1350	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0
Hydro	95	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Landfill gas	30	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Biomass	80	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Supercritical coal	794	0	0	1	2	3	3	2	3	2	3	3	3	3	3	4	4	5	5	5	6	6
Wind 30%	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Wind 25%	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
CSP central receiver	100	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
CSP trough	100	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
solar PV	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
combined cycle gas	387	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pumped storage	333	0	0	0	2	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Roadmap 1: Unrestricted; high SWH strategy

Plant Description	Unit Size MW	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Existing coal Large	564	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Existing coal Small	114	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
OCGT liquid fuels	120	0	9	0	0	0	0	0	0	0	0	3	0	0	0	0	0	3	0	0	0	0
PWR nuclear	1350	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Hydro	95	0	0	0	0	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0
Landfill gas	30	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Biomass	80	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Supercritical coal	794	0	0	1	2	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Wind 30%	1	200	400	600	800	1000	1000	1000	1000	1000	1000	1000	0	0	0	0	0	0	0	0	0	0
Wind 25%	1	0	0	0	0	0	0	0	0	0	0	0	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000
CSP central receiver	100	1	1	1	0	1	2	4	5	10	15	20	25	25	30	30	30	35	35	40	40	40
CSP trough	100	0	2	3	1	2	3	4	5	3	3	0	0	0	0	0	0	0	0	0	0	0
solar PV	5	0	0	0	0	0	0	0	0	0	0	0	1	0	0	2	2	5	5	5	10	10
Combined cycle gas	387	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	3	3	3	3
Pumped storage	333	0	0	0	2	2	2	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Roadmap 2: Unrestricted; low SWH strategy

Plant Description	Unit Size MW	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Existing coal Large	564	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Existing coal Small	114	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
OCGT liquid fuels	120	0	9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
PWR nuclear	1350	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Hydro	95	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Landfill gas	30	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Biomass	80	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Supercritical coal	794	0	0	1	2	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Wind 30%	1	200	400	600	800	1000	1000	1000	1000	1000	1000	1000	0	0	0	0	0	0	0	0	0	0
Wind 25%	1	0	0	0	0	0	0	0	0	0	0	0	1000	1000	1000	1000	1000	2000	2000	2000	2000	2000
CSP central receiver	100	1	1	1	0	1	2	4	5	10	15	20	30	30	30	30	35	35	40	40	45	40
CSP trough	100	0	2	3	1	2	3	4	5	3	3	0	0	0	0	0	0	0	0	0	0	0
solar PV	5	0	0	0	0	0	0	0	0	0	0	0	1	0	0	2	2	5	5	5	10	10
Combined cycle gas	387	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	3	3	3	3
Pumped storage	333	0	0	0	2	2	2	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Roadmap 3: 27% target REFIT; high SWH strategy

Plant Description	Unit Size MW	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Existing coal Large	564	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Existing coal Small	114	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
OCGT liquid fuels	120	0	9	0	0	0	3	0	0	0	0	3	0	0	0	0	0	3	0	0	0	0
PWR nuclear	1350	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
Hydro	95	0	0	0	0	0	0	0	1	0		1	0	0	0	0	0	0	0	0	0	0
Landfill gas	30	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Biomass	80	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Supercritical coal	794	0	0	1	2	3	1	2	2	1	0	0	0	1	2	2	1	2	2	3	3	2
Wind 30%	1	0	100	200	300	400	200	400	800	700	1000	1500	700	800	1000	600	0	0	0	0	0	0
Wind 25%	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	700	1400	1500	800	700	800	900
CSP central receiver	100	0	0	1	1	0	1	1	2	3	6	7	8	10	10	10	15	15	15	15	15	15
CSP trough	100	0	0	0	1	0	1	0	2	3	4	5	4	2	0	0	0	0	0	0	0	0
solar PV	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Combined cycle gas	387	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	3	3
Pumped storage	333	0	0	0	2	2	2	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Roadmap 4: 27% target REFIT; low SWH strategy

Plant Description	Unit Size MW	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Existing coal Large	564	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Existing coal Small	114	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
OCGT liquid fuels	120	0	9	0	0	0	3	0	0	0	0	3	0	0	0	0	0	3	0	0	0	0
PWR nuclear	1350	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
Hydro	95	0	0	0	0	0	0	0	1	0		1	0	0	0	0	0	0	0	0	0	0
Landfill gas	30	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Biomass	80	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Supercritical coal	794	0	0	1	2	3	0	2	2	2	0	0	2	2	2	2	1	2	2	3	3	2
Wind 30%	1	0	100	200	300	400	200	400	800	700	1000	1500	700	800	1000	600	0	0	0	0	0	0
Wind 25%	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	700	1400	1500	800	700	800	900
CSP central receiver	100	0	0	1	1	0	1	1	2	3	6	7	8	10	15	15	15	15	15	15	15	15
CSP trough	100	0	0	0	1	0	1	0	2	3	4	5	4	2	0	0	0	0	0	0	0	0
solar PV	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Combined cycle gas	387	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	3	3
Pumped storage	333	0	0	0	2	2	2	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Roadmap 5: 15% target REFIT; high SWH strategy

Plant Description	Unit Size MW	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Existing coal Large	564	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Existing coal Small	114	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
OCGT liquid fuels	120	0	9	0	0	0	6	0	0	0	0	3	0	0	0	0	0	0	0	3	3	0
PWR nuclear	1350	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	0	0	0	0	0
Hydro	95	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
Landfill gas	30	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Biomass	80	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Supercritical coal	794	0	0	1	2	3	0	1	2	2	2	1	1	2	2	2	2	2	2	3	3	3
Wind 30%	1	0	100	100	100	100	100	400	800	400	400	400	400	400	400	600	1000	1000	1000	1000	1000	1000
Wind 25%	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
CSP central receiver	100	0	0	0	1	1	0	0	0	0	1	2	4	6	6	8	6	6	5	5	6	8
CSP trough	100	0	0	0	0	1	2	0	0	0	1	2	4	3	2	0	0	0	0	0	0	0
solar PV	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Combined cycle gas	387	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	3	0	3	3
Pumped storage	333	0	0	0	2	2	2	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Roadmap 6: 15% target REFIT; low SWH strategy

Plant Description	Unit Size MW	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Existing coal Large	564	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Existing coal Small	114	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
OCGT liquid fuels	120	0	9	0	3	0	3	0	0	3	0	6	0	0	0	0	0	0	0	0	3	0
PWR nuclear	1350	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	0	0	0	0	0
Hydro	95	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
Landfill gas	30	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Biomass	80	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Supercritical coal	794	0	0	1	2	3	1	2	2	2	1	1	1	2	2	2	2	2	3	3	3	3
Wind 30%	1	0	100	100	100	100	100	400	800	400	400	400	400	400	400	600	1000	1000	1000	1000	800	0
Wind 25%	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
CSP central receiver	100	0	0	0	1	1	0	0	0	0	1	2	2	4	4	6	8	8	8	10	10	10
CSP trough	100	0	0	0	0	1	2	0	0	0	1	2	4	3	2	0	0	0	0	0	0	0
solar PV	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Combined cycle gas	387	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	3	0	3	3	0	3
Pumped storage	333	0	0	0	2	2	2	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0