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Assessing the effectiveness of policies to support renewable energy

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Assessing the Effectiveness of Policies to Support Renewable Energy

UNEP

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Contents

Summary

Close to 80% of the world's energy supply could be generated through renewables by mid-century with the right enabling public policies. Policies can play a fundamental role in promoting a sustainable energy-mix and it is key to measure their effectiveness in the medium and long run. What is the most effective way to measure and monitor this effectiveness? What can we learn from Brazil, one of the first emerging countries to refocus its national energy strategies toward renewable energy? And from South Africa, which committed to develop 42% of additional capacity in renewable by 2030? These are some of the questions addressed in the report commissioned by UNEP DTIE: *Assessing the effectiveness of policies to support renewable energy*.

The report demonstrates the importance of monitoring policy effectiveness by using the Policy Effectiveness Indicator (PEI) approach.[i] While there is no one-size-fits all approach to designing renewable policies, a number of principles of policy design exist, which can dramatically increase the effectiveness and efficiency of renewable energy policies.

Some recommendations for policy- makers include:

- assessing which of the three factors is holding back deployment,
- making sure that all three factors are robust for a high PEI score to be registered,
- implementing a detailed monitoring and reporting for all of the different aspects of renewable policy, and
- considering the entire policy framework into which incentives schemes are inserted.

1. Introduction

Scope and purpose of this report

This report summarizes, in non-technical language, the results of recent UN-sponsored studies to assess global trends in the deployment of renewable energy technologies and the effectiveness of related government policies, including detailed analyses of Brazil and South Africa, and draws out broad lessons on assessing such policies. It aims to provide guidance to policymakers in other countries seeking to better understand the potential for renewables to play a bigger role in meeting their energy needs and how to go about assessing the effectiveness of policies to exploit that potential.

As part of a project to enhance information on renewable energy technology deployment in emerging economies launched in 2010, UNEP commissioned Centro Clima – the Center for Integrated Studies on Climate Change and the Environment – in Brazil and the Energy Research Centre in South Africa to undertake detailed studies of the deployment of renewables and the effectiveness of national renewables policies, as well as the long-term prospects for renewables deployment under different scenarios, or roadmaps.[1] In both cases, the studies sought to identify the factors that encourage or impede renewables deployment and to evaluate the broader impact of different rates of deployment on investment needs, employment and greenhouse-gas emissions. The studies focused on wind and solar technologies.

These studies build on an earlier project undertaken by the International Energy Agency (IEA) to assess the effectiveness of national renewable energy policies, which used the level of renewable energy deployment to date relative to the technical and economic potential by 2030 as an indicator of policy effectiveness (IEA, 2008a). The studies of Brazil and South Africa adopted the same indicator to measure progress over the 12 years to 2009 (the last year for which full data were available). The aim was to examine the factors that have promoted or hindered the deployment of renewables in the two countries and to model various scenarios consistent with national energy policies.

Structure of the report

The next section provides a summary of the current status of and recent developments in renewables investment, deployment and policy worldwide, as well as an overview of prospects for deployment in the medium to long term. This is followed by a discussion about approaches to assessing the effectiveness of renewables policies, including the challenges in applying methodologies. The results of the case studies of Brazil and South Africa are then summarized. A concluding section presents some broad lessons learned from the case studies

[1] Centro Clima is a scientific research center established by the Brazilian Ministry of Environment and COPPE – the Institute for Research and Postgraduate Studies in Engineering of Federal University of Rio de Janeiro (UFRJ). The Energy Research Centre (ERC) is a multi-disciplinary energy research center, housed in the Faculty of Engineering and the Built Environment at the University of Cape Town.

about how to assess policy effectiveness, as well as general principles for developing effective policies.

Acknowledgements

This report was commissioned by the Division of Technology, Industry and Economics (DTIE) of UNEP. Trevor Morgan of Menecon Consulting was the principal author. Daniel Puig, now with the UNEP Risø Centre on Energy, Climate and Sustainable Development, coordinated the initial project.

Manfredi Caltagirone, Energy and Climate Change Expert in the Energy Branch of DTIE and Shannon Cowlin of the U.S. Department of Energy's National Renewable Energy Laboratory helped to bring the project to completion.

More information about UNEP Division of Technology, Industry and Economics can be found in Annex C and on the UNEP website: http://www.unep.org/dtie/

2. Renewables deployment and policy worldwide

Renewable energy sources and technologies represent a key means of lowering greenhouse-gas emissions from the combustion of fossil energy, while meeting rising global demand for energy services. By cutting reliance on imports of hydrocarbons, they can also enhance energy security and bring broader economic benefits. The supply and use worldwide of modern forms of renewable energy have been growing rapidly in recent years as a result of falling costs and rising fossil-energy prices, which have made renewables generally more competitive, as well as stronger government policies to promote their development and deployment. Even including traditional biomass, renewables still represent a small share of total primary energy use today, but their contribution is set to continue to rise briskly in the coming decades. Just how quickly depends on technological and economic factors, as well as policy developments.

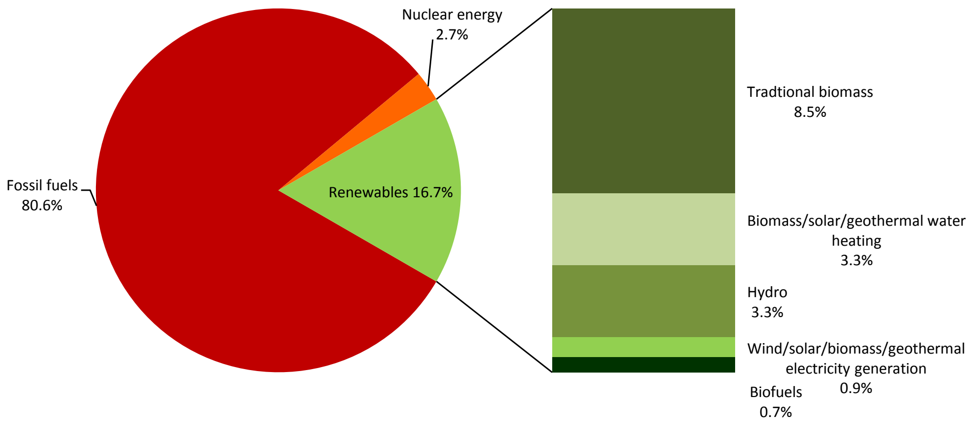
The growing importance of renewables worldwide

In 2010, renewable energy sources – biomass, biogas, liquid biofuels, wind, solar, geothermal, marine and hydro – met an estimated 16.7% of global final energy consumption (REN21, 2012) and 13.3% of primary energy supply.[2] Of final consumption, traditional biomass – wood, agricultural wastes and dung used for cooking and heating, primarily in rural areas of developing countries – accounted for 8.5% (Figure 2.1). Hydropower was the most important non-biomass renewable energy source, contributing about 3.3%.

The supply of renewables has been growing rapidly in recent years, though rate of growth vary markedly across the different sources and fuels (see Annex B for detailed tables on renewables supply and investment). The primary supply of biomass in total rose by almost one-quarter between 2000 and 2010, driven primarily by rising population in developing countries, which boosted the use of traditional fuels for cooking and heating. This more than outweighed the effect of switching by growing numbers of households in those countries to modern, commercial forms of energy, including oil products and electricity, as incomes rose. Increased consumption of biomass for heat and power generation using modern technologies in both developing and the advanced industrialized countries, as well as the use of biomass as a feedstock for producing liquid biofuels, also contributed to this increase. Globally, hydropower expanded by 24% and geothermal energy by 20% – roughly the same increase as for total primary energy supply. Most other renewable energy technologies expanded much more rapidly over the same period: wind power almost eight-fold and solar energy three-fold. However, their shares of total energy use remain small because they started from a very low base. Marine energy remains negligible.

[2] Some renewables, such as biomass, are used directly in final uses for heating, cooling or process energy; others, such as wind and solar power, are primary energy sources used to generate electricity (a form of energy transformation), which is then consumed as final energy, Biomass can also be an input to electricity generation, as well as a feedstock for the production of biofuels (another form of energy transformation). For its 2012 report, REN21 estimated the shares of primary renewable energy sources in final energy sources by using conversion factors for electricity and biofuels. Primary energy supply data is from IEA databases.

Figure 2.1: World final energy consumption, 2010



* Combustible municipal and industrial waste. ** Includes marine energy.
Source: REN21 (2012).

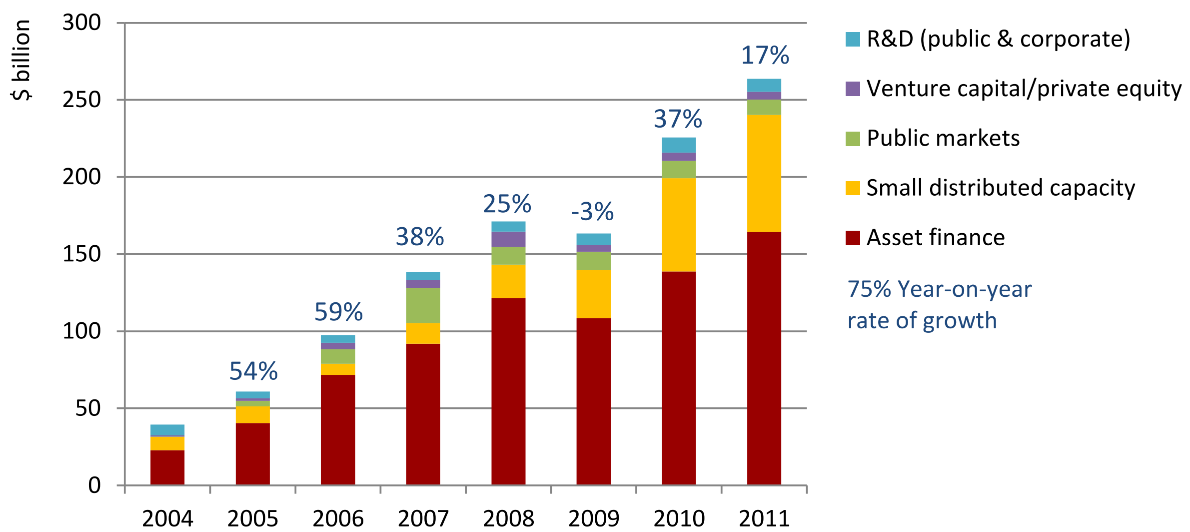
Renewables have expanded most in the power and transport sector in recent years. Between the end of 2006 and 2011, total global production capacity of solar photovoltaics (PV) grew the fastest of all renewables-based electricity generating technologies, increasing at an average of 58% per year; it was followed by concentrating solar thermal power (CSP), which increased almost 37%, from a small base, and wind power, which increased 26% (REN21, 2012). The growth in PV capacity was particularly marked in 2011, when it jumped by 74%, mainly due to a surge in installations of panels in Europe. For the first time ever, solar PV capacity increased by more than of any other renewables-based generating technology. Wind power saw the biggest increase in renewables-based electricity generating capacity in absolute terms over 2006-1011, followed by hydropower and solar PV. Renewables provided around one-fifth of global electricity supply in 2010 and almost half of the estimated 208 GW of new electric capacity installed globally in 2011. Production of ethanol and biodiesel – the two principal biofuels – expanded more than six-fold between 2000 and 2011, reaching 107 billion liters and making up 3% of the total supply of road-transport fuels.

In some countries, the recent growth in renewables has been nothing short of spectacular. In China, for example, an estimated 19 GW of grid-connected renewable capacity was added in 2011, bringing total capacity to 282 GW – an increase of 7% over 2010 and one-fifth higher than in 2009. As a result, renewables accounted for well over one-quarter of the country's total installed electric capacity by the end of 2011 and over one-fifth of total generation during the year. China now has more renewables-based capacity than any other country and also leads in several other indicators of market growth: in 2011, China again led the world in the installation of wind turbines and was the top hydropower producer and leading manufacturer and installer of solar PV modules. India and several other emerging economies are rapidly expanding many forms of rural renewables such as biogas and solar PV. Brazil produces virtually all of the world's sugar-derived ethanol and has been adding new hydroelectric facilities, biomass-based power plants and wind farms, as well as solar heating systems (see Section 4).

Among the advanced economies, Germany added almost 15 GW of solar PV capacity in 2011 and 2010, more than doubling capacity to 25 GW. Spain, Japan and Italy also saw huge increases in their PV capacity. Wind power has also been growing quickly in most European countries as well as in the United States. The latter country remains the world's leading producer of biofuels, with most of its output in the form of corn-based ethanol. Overall, the non-OECD countries now produce and use more non-biomass renewables than the OECD countries.

Reported investment in renewable energy worldwide jumped by 17% to a new record of $257 billion in 2011. This is more than six times the figure for 2004 and almost twice the level of 2007 (Figure 2.2) – the last year before the global financial crisis (UNEP, 2012). Including an estimated $10 billion of investment in solar water heaters and another $25 billion in large-scale hydropower, total investment probably exceeded $290 billion. Net investment in renewable power capacity was $40 billion higher than that in fossil-fuel-fired capacity. Asset finance of new utility-scale projects (wind farms, solar parks, and biofuel and solar thermal plants) accounted for close to two-thirds of total investment. Investment in small-scale distributed generation projects (mainly solar PV) amounted to $76 billion, making up 29%of total investment in renewable energy. Solar power and thermal heating accounted for 57% of total renewables investment and wind power for one-third in 2011. By comparison, investment in the upstream oil and gas sector in 2011 is estimated to have reached around $553 billion (IEA, 2011).

Figure 2.1: World new investment in renewables



Note: Asset finance is adjusted for reinvested equity. Total values include estimates for undisclosed deals.
Source: UNEP (2012).

The five leading countries for renewables investment in 2011 were China, which led the world for the third year in a row, followed closely by the United States, and by Germany, Italy and India (UNEP, 2012). US investment jumped by 57% in 2011, mainly as the result of developers rushing to take advantage of federal support policies that were coming to an end. India saw the fastest expansion in investment of any large renewables market in the world, with 62% growth. The share of the developing countries in renewables investment worldwide, which has been increasing steadily since the mid-2000s, fell back in 2011. They invested $89 billion, or 35% of the total, compared with $168 billion, or 65%, in developed countries.

Rapid declines in production costs as a result of technology learning and economies of scale have boosted the deployment of renewables. Solar energy has enjoyed the biggest falls in production cost over the last three years, the price of PV modules per kW having dropped by 50% and onshore wind turbine prices by between 5% and 10% in 2011 alone (UNEP, 2012). In some countries, solar and wind power are now close to being competitive with fossil-energy-based generating options without subsidy.

Policy developments

Supportive government policies remain the main driving force behind the increasing penetration of renewable energy, despite increased uncertainty about future policy directions in some countries. There are four main reasons why governments encourage renewables: to reduce reliance on fossil energy as a way of curbing greenhouse-gas emissions; to cut imports of oil and gas to enhance energy security and to improve the trade balance; to provide a source of energy in places where it is costly to supply fossil fuels; and to stimulate domestic economic activity and employment. Some types of renewables can also reduce local pollution problems. In developing countries, energy access and social and economic development have been the main policy drivers. In the advanced industrialized countries, climate change is the main driver of renewables policies, though the potential for job creation is an increasingly important justification, especially where those policies lead to higher energy prices for consumers. An estimated 5 million people work in renewable energy industries worldwide, about 30% of them in the biofuels industry; employment has quadrupled since 2004, when only about 1.3 million renewables-related jobs existed (REN21, 2012). The industry also supports many other jobs in related industries that provide materials, equipment and services.

The focus of renewables policies used to be on electricity generation, but is now broadening to include heating and cooling and transportation. There has been a sharp increase in both the number of countries that have adopted some kind of target or measure to support the deployment of renewables and the overall strength of policy action in recent years. By early 2012, 118 countries had introduced some kind of support policy at the national level – the same number as a year earlier but up from only 55 countries in early 2005 and 109 in 2010 (REN21, 2012). Policies at state/provincial and local levels have also become more widespread and have generally been strengthened. Renewables policies can be categorized according to whether they target price or quantity, as well as investment or production (Table 2.1).

Table 2.1: Main types of policies to support renewable energy

	Price	Quantity
Investment	Grants Tax credits Low-interest/soft loans Public funding of research and development	Tendering system for investment grants Direct public investment Public funding of research and development
Production	Feed-in tariffs (fixed price for defined period) Net metering and premium feed-in tariffs (for households/small-scale producers surplus power) Tax exemptions/rebates Favorable grid-access terms	Renewables portfolios standards/quotas Blending mandates (biofuels) Tendering system for long-term supply contracts Green purchasing and labeling

Source: Menecon Consulting analysis based on Haas *et al.* (2008).

All the industrialized countries and a growing number of emerging economies and developing countries have adopted quantified targets for renewables, covering the share of renewables in total primary energy supply, electricity generation and/or road transport fuels. In some cases, they concern the amount of installed production capacity. Within those countries that have adopted renewables policies, the number of official renewable energy targets and measures in place to support investments in renewable energy continued to increase in 2011 and early 2012, though at a slower rate than in previous years. Several countries overhauled their renewables policies, in some cases resulting in reduced support – either because of the increasing competitiveness of certain technologies or as part of austerity packages to rein in government budget deficits.

The most widely used measure for encouraging renewables-based electricity generation is feed-in tariffs, which were in place in at least 65 countries and 27 states/provinces around the world in early 2012. A feed-in tariff is applied to the power supplied by renewable energy producers to the grid under a long-term contract, whereby the tariff is typically based on the cost of generation of each technology. The higher costs of renewables-based power generation are usually recovered through a surcharge that is charged to all electricity consumers by the utilities that are obliged to sign such contracts. In this way, the cost of the scheme is passed onto final consumers in the form of higher electricity prices. Some countries have reduced the levels of tariffs over the last couple of years in response to falling unit costs of generation and the unexpectedly strong growth in supply under feed-in tariff contracts, which has increased overall program costs and led to higher electricity prices.

Another increasingly popular approach is the Renewable Portfolio Standard (RPS), which requires that a minimum percentage of power generated (or installed capacity) is based on renewable energy sources. Often, generators can meet the RPS, which often increases over time, either from their own plants or from contracted supplies from renewables-based plants owned by other companies; failure to meet the RPS incurs a financial penalty. As of 2012, 18 countries and 53 other jurisdictions (including 31 US states) had introduced an RPS.

There are several other types of policies that can be used to support renewables-based power generation, including priority access to the grid on favorable terms; direct subsidies in the form of tax credits and rebates or grants to capital investment; other types of tax incentive or production credits; and direct public financing of renewables projects, as well as research and development. Net metering arrangements, whereby private generators of renewables-based electricity are compensated for any excess power they generate and export to the grid at retail rates, have been introduced in at least 20 countries, including Italy, Japan, Jordan, and Mexico, and in almost all US states (REN21, 2012). Green energy purchasing and labeling programs are also growing in importance in many parts of the world. Broader policies aimed at reducing greenhouse emissions, including cap-and-trade schemes, may also encourage renewables-based electricity.

The most common type of policy to support biofuels is blending mandates, whereby transport fuel suppliers are obliged to blend in a minimum percentage volume of biofuel (ethanol into gasoline or biodiesel into diesel). This type of measure was in place in at least 46 countries at the national level and in 26 states and provinces in early 2012, with three countries enacting new mandates during 2011 and at least six increasing existing mandates. However, support in Brazil and the United States – the two biggest biofuel-producing countries – was scaled back in 2011. In at least 19 countries, subsidies and excise-tax exemptions are also used to promote biofuels.

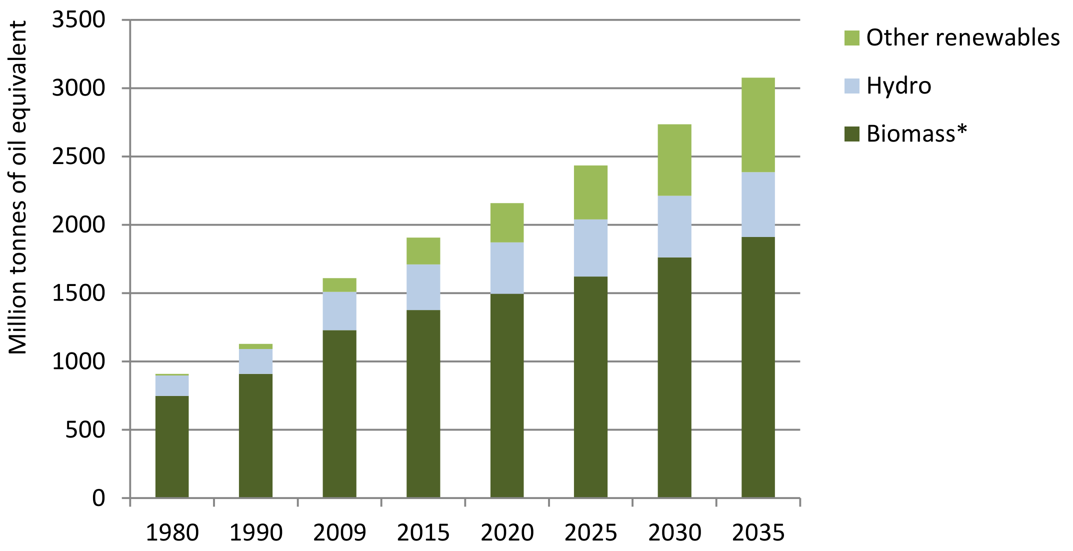
Some governments have also introduced policies to promote renewable heating and cooling in recent years, though they remain less widespread and aggressive than those in the power and transport sectors. The most common type of measure is direct grants and tax credits for investment, but there is a growing emphasis on approaches that do not increase the burden on the public budget, such as mandates on solar water heating covering new construction projects. By early 2012, at least 19 countries had specific renewable heating/cooling targets in place and at least 17 countries and states had obligations/mandates to promote renewables-based heat. Measures are most common in Europe, but interest is expanding to other regions. New policies introduced since the beginning of 2010 include the United Kingdom's innovative Renewable Heat Incentive and a grant program in South Africa (REN21, 2011).

Global prospects for renewables

Renewables are likely to play an increasingly important role in global energy supply in the coming decades, though just how rapidly they expand hinges critically on government policies, technological advances and their cost *vis-à-vis* conventional fuels. In the IEA's most recent *World Energy Outlook*, renewables as a whole expand at a rate of 2.5% per year between 2009 and 2035 in a central New Polices Scenario, which takes account of policy commitments and plans that have been announced but not always formally adopted (IEA, 2011). Excluding biomass, they grow by 4.4% per year, with solar and wind power expanding most rapidly

(Figure 2.3). In a 450 Scenario, which assumes radical policies to put energy use on a trajectory that is consistent with limiting the global increase in average global temperature to 2°C, renewables expand much more quickly, averaging 3.6% per year and reaching a level in 2035 that is 30% higher than in the New Policies Scenario.

Figure 2.3: World primary supply of energy from renewable sources in the IEA's New Policies Scenario

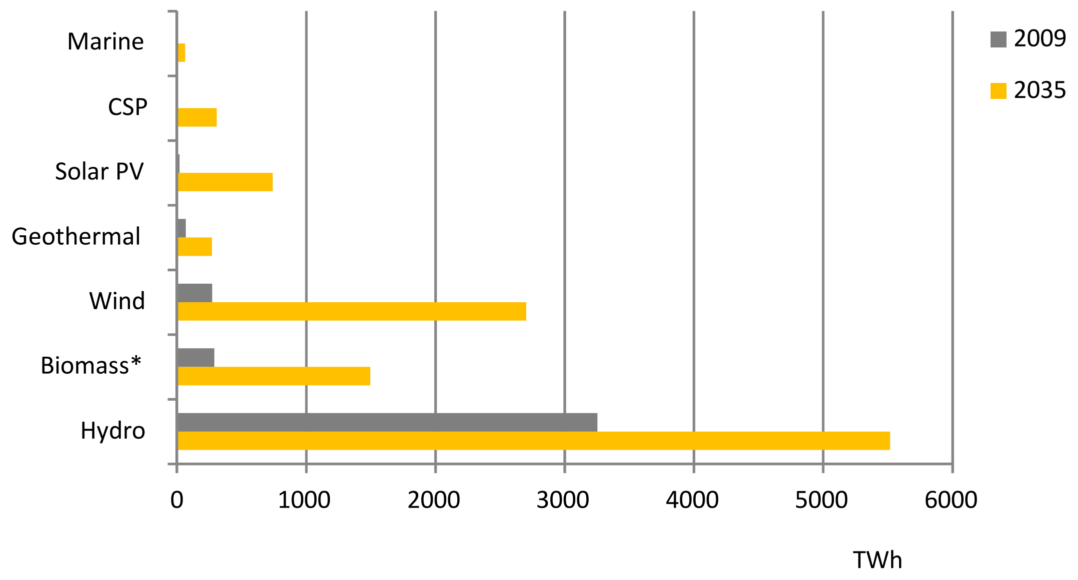


* Includes waste.
Source: IEA (2011).

A growing share of biomass is projected to be used for making liquid biofuels for use as a transport fuel: in the New Policies Scenario, total biofuels supply increases from 1.3 million barrels per day (mb/d) in 2010 to 4.4 mb/d in 2035 while its share of total liquid transport fuel use increases from 4% to 11% over the same period. The use of biomass for electricity and heat generation in modern plants also grows significantly, its share of total biomass use rising from 8% in 2009 to 22% in 2035. Among the different electricity-generating technologies, wind power expands the most between 2009 and 2035, followed by hydropower (Figure 2.4).

Further penetration of renewables in global energy supply is likely in the longer term. More than 50% of the scenarios from a number of different organizations reviewed recently by the Intergovernmental Panel on Climate Change in 2012 project a contribution from renewables in excess of 27% in 2050 (IPCC, 2012). Renewables are expected to expand even under baseline scenarios, in which no change in policy is assumed. By 2050, renewables deployment reaches more than 2.4 million tonnes of oil equivalent in many baseline scenarios and up to about 6 Mtoe in some cases, compared with 1.6 Mtoe in 2009. Unsurprisingly, deployment is generally much higher in scenarios that assume strong policy action to achieve stabilization of the concentration of greenhouse gases at low levels. In the two-degrees scenario in the IEA's latest *Energy Technology Perspectives*, in which the greenhouse-gas emissions trajectory is consistent with an 80% chance of limiting long-term global temperature increase to 2⁰ Celsius, the share of total average world electricity generation increases six-fold from 19% currently to 57% by 2050 (IEA, 2012).

Figure 2.4: World electricity generation from renewables by source in the IEA's New Policies Scenario



* Includes waste.
Source: IEA (2011).

3. Measuring policy effectiveness

In most cases, the deployment of modern renewable energy sources and technologies can only take off within the framework of supportive long-term government policies aimed at overcoming market and non-market barriers. Careful and regular monitoring of pro-renewables policies is vital in order to continually improve their design so as to make them more effective in stimulating investment, while minimising their economic cost. Indicators of policy effectiveness need to take account of local market conditions and circumstances, including the underlying potential for renewables to contribute to meeting energy needs.

Ways of assessing the effectiveness of renewable policies

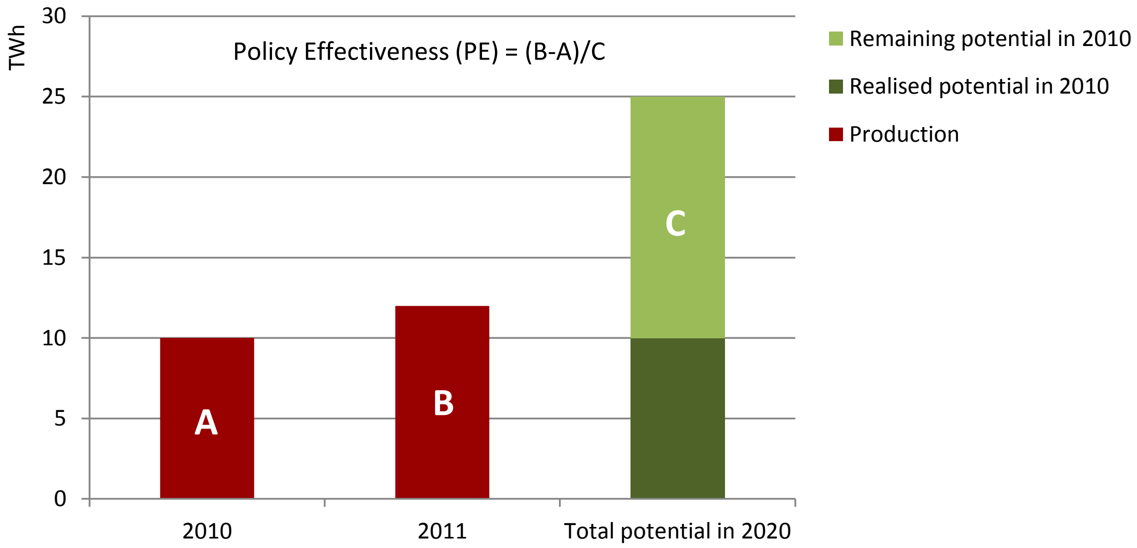
The penetration of renewable energy sources and technologies varies widely across countries and regions, reflecting both differences in local production potential and in policies to encourage them. Yet the existence of policies and measures – including quantified targets – does not guarantee that renewables will actually be deployed on a large scale. Even where considerable potential exists, those policies may be unsuccessful if they fail to address adequately economic and other (non-market) barriers to the deployment of renewables.

The success of renewables policies is generally measured in two ways: their impact on market growth (policy effectiveness) and their cost. Combining the two provides a measure of policy- or cost-efficiency. Assessing the effectiveness and efficiency of renewables policies in a regular manner is essential to enable policymakers to continuously improve the design of those policies and ensure that broad energy policy, environmental and socio-economic goals are being met at an acceptable cost. Quantitative indicators provide a means of evaluating these criteria in a systematic and reliable manner. In practice, policy effectiveness can be measured in several different ways. Possible parameters or indicators include consumption, production, installed production capacity, energy access (in the case of developing countries), employment and added value in manufacturing (direct and indirect). The appropriate parameter(s) will depend on the predefined objectives of the policy in question.

The work undertaken by the IEA and the case studies of Brazil and South Africa commissioned by UNEP focus on the effectiveness of renewables policies, adopting a standard indicator that measures the share of the potential that is achieved for a given technology in a given year. The main reason for choosing this indicator is that it enables the success of policies to be compared across countries of different sizes, starting levels of renewables deployment and levels of ambition of renewables policies and targets, since it takes into consideration country-specific factors that affect the potential for producing renewables (IEA, 2008). The realizable potential is estimated based on a long-term view of the technical potential, adjusted to take account of unavoidable medium-term constraints, such as maximum market growth rates and planning constraints, on the rate of change. The realizable potentials for each renewable energy technology are derived from the estimated resources of each country, taking account of expected developments in technology.

The Policy Effectiveness Indicator (PEI), is expressed as a percentage of the remaining production potential that can be realized by the end of the pre-defined medium-term period as measured at the start of that period (Figure 3.1). Thus, if the remaining potential for a renewables-based electricity generating technology to 2020 was 15 TWh in the base year, 2010, and production increased by 2 TWh in 2011, the PEI for the latter year would be 0.133 (2/15). Of course, if production were to fall in any given year, the PEI in that year would be negative. Measuring the PEI in cumulative terms over a period of several years provides a better indication of the long-term effectiveness of policy.

Figure 3.1: Illustrative example of the Policy Effectiveness Indicator (base year = 2010)



Source: Based on Steinhilber (2011).

Other indicators can be used, the most obvious ones being the share of any target that is achieved and the annual rate of growth or the absolute rate of growth in production/use (Table 3.1). These alternatives are easier to calculate as they make use of data that is generally available, but they suffer from important drawbacks: measuring effectiveness in terms of the degree to which a targeted level of deployment is achieved makes cross-country comparisons difficult as it does not take into account the ambitiousness of the target; this creates a bias in favor of less ambitious countries. The absolute increase in renewables production provides a measure of the policy effort to boost renewables, but clearly favors large countries, while the rate of growth favors countries starting from a low level of deployed renewables.

The PEI, as defined in the IEA and UNEP work, has been used in several studies. The EU research project, OPTRES, developed the indicator initially and subsequently applied it to monitor the effectiveness of renewables support schemes in Europe. The results were included in the 2008 impact assessment of the proposed Renewable Energy Directive, which set legally-binding targets for each member state for the share of renewable energy in gross final energy consumption of each member state by 2020 equating to 20% for the Union as a whole; the directive was subsequently adopted in 2009 (European Commission, 2008). This and other indicators were updated and extended as part of the RE-Shaping project (Steinhilber, 2011). The 2008 IEA study used the PEI to assess the effectiveness of renewables policies in all OECD countries, as well as in Brazil, Russia, India, China and South Africa (BRICS). It reviewed progress over 2000-2005 for all the main types of renewables in the electricity generation, heating and transport sectors, using the period to 2020 as the medium term to establish potentials.

Table 3.1: Alternative indicators of policy effectiveness

Indicator	Formula	Advantage	Disadvantage
Share of target	$S = G^i_n/T^i_n$	Based on empirical values	Depends on ambitiousness of target making cross-country comparisons difficult
Average annual growth rate	$g^i_n = \left(\frac{G^i_n}{G^i_{n-t}}\right)^{\frac{1}{t}} - 1$	Based on empirical values	No consideration of country-specific factors
Absolute annual growth	$a^i_n = \frac{G^i_n - G^i_{n-1}}{n}$	Based on empirical values	No consideration of country-specific factors
Share of potential (the chosen Effectiveness Policy Indicator)	$E^i_n = \frac{G^i_n - G^i_{n-1}}{ADDPOT^i_n} = \frac{G^i_n - G^i_{n-1}}{POT^i_{2020} - G^i_{n-1}}$	Country-specific factors taken into consideration	Difficult to identify additional mid-term potential

Note: G^i_n = production by renewables technology i in year n; $ADDPOT^i_n$ = additional production potential of technology i in year n until 2020; POT^i_{2020} is the total production potential of technology i in year 2020.

Source: Based on IEA (2008); Ragwitz and Held (2007).

It is important to bear in mind that the PEI measures only the effectiveness of overall renewables policy in increasing the production or consumption of renewables; it does not measure the impact of individual policies or measures, nor does it provide any insights into why a particular national policy is effective or ineffective relative to the potential or to performance in other sectors or countries. Clearly, the type of policy instrument or measure chosen to encourage the supply and use of renewables, as well as the strength or size of the incentive put in place, is crucial to policy effectiveness. Other factors affect policy success, including non-economic barriers to their deployment. Administrative hurdles, such as planning restrictions, lack of co-ordination between different authorities and delays in issuing permits and authorizations, for example, can lead to delays in launching and completing projects, increase their cost and undermine their profitability. Public resistance, for example to wind farms, can accentuate such barriers. Thus, application of the PEI needs to be accompanied by an assessment of the factors promoting of hindering the deployment of renewables (see Section 5).

Estimating renewables potentials

Calculating PEIs for a given country requires an estimate of the realizable potential of renewable energy. This potential varies among the different renewable technologies and sources, across countries and over time as technology develops and understanding of the resource base improves. There is considerable discussion of renewable-energy potentials in the literature. In line with the IEA, the case studies of Brazil and South Africa adopted the following definitions of the different types of potential to ensure consistency of terminology and facilitate cross-country comparisons:

- *Theoretical potential:* This represents the theoretical upper limit of the amount of energy that can be produced or generated from a specific technology or resource, over a defined area, based on current scientific knowledge. It depends solely on physical flows or resources (for example, the average solar irradiation across a certain area).

- *Technical potential:* The technical potential, a sub-set of the theoretical potential, is the amount of renewable energy that can be produced given technical constraints. It can be derived based on assumptions about technical boundary conditions, such as the thermal efficiency of conversion technologies or overall technical limitations such as available land area for installing wind turbines. For most resources, the technical potential is dynamic; in other words, it varies over time with technological advances (resulting from research and development) and changes in land use (which may restrict or free up land for renewables production).

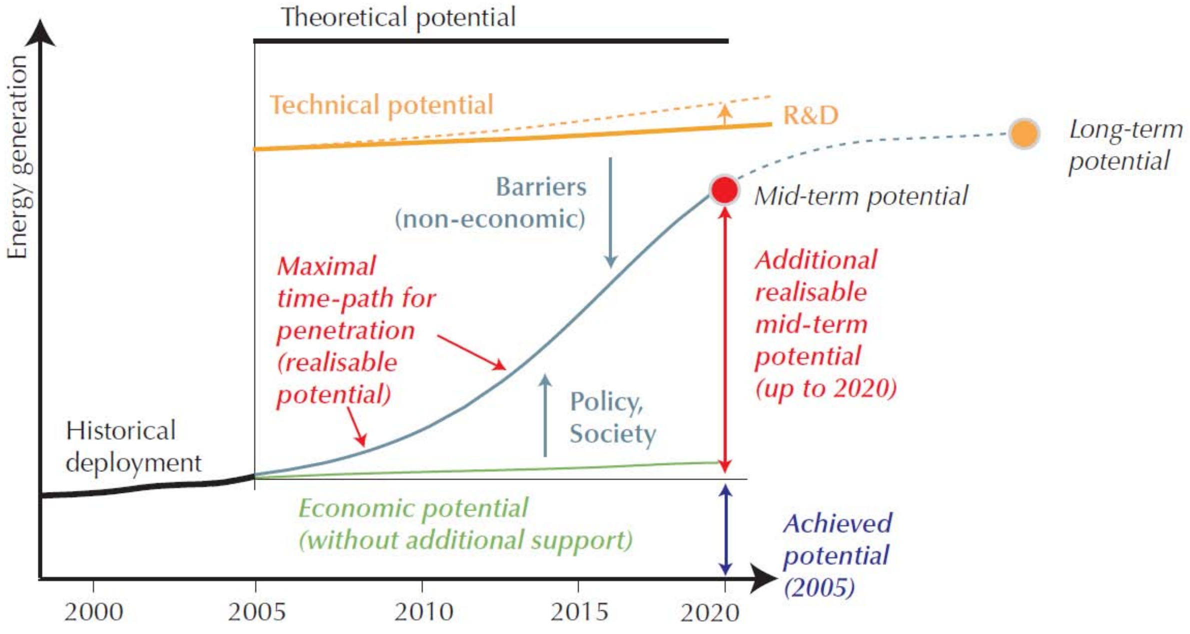
- *Realizable potential:* This represents the maximum achievable potential, assuming that all existing non-economic market barriers can be overcome and that "all development drivers are active" (i.e. that policy adequately addresses all economic barriers to deployment). In determining this potential, general parameters such as feasible rates of market growth and planning constraints are taken into account. The realisable potential is time-dependent; i.e. it must relate to a certain year. In the long run, the realizable potential tends towards the technical potential as non-economic barriers are gradually overcome. For any given year, the total realizable potential is the achieved potential to date (actual installed production capacity) plus the additional realizable potential in the remaining part of the timeframe.

- *Mid-term potential:* In the case study of Brazil, the mid-term potential is defined as the realizable potential in 2020; in the South African study, it relates to 2030.The difference in the timeframe is explained by differences in official policy goals and the way each country was modeled.

- *Economic potential:* The economic potential is defined as the part of the realizable potential that can be produced profitably without the need for government support, i.e. the amount of renewables production with a cost of production that is competitive with existing conventional non-renewable technologies.

The relationships between the different types of potential and their evolution over time are depicted in Figure 3.1.

Figure 3.1: Stylized representation of different types of renewable-energy potentials over time (base year = 2005)



Sources: Based on IEA (2008) and Resch *et al.*(2008).

For the studies of Brazil and South Africa, the PEI was calculated for each year from 1998 to 2009 as the increase in production of renewables over and above that in the base year (1997) divided by the additional realizable mid-term potential (up to 2020 in the case of Brazil and 2030 in the case of South Africa).

Challenges in applying methodologies

In practice, estimating the various potentials is far from straightforward. It involves a combination of scientific measurement and modeling of the economic and technical dynamics of investment in renewables and other energy sources and technologies. In particular, estimating the economic potentials requires modeling technological learning (cost reductions as technology manufacturers accumulate experience) and investment behavior, incorporating assumptions about energy prices and other factors, such as broader investment conditions. Estimating mid-term potentials requires modeling deployment rates, taking account of various technical constraints. Producing reliable estimates requires considerable effort and resources.

The 2008 IEA study assessed the realizable mid-term potential of RETs up to 2020 using the Green-X model, an independent computer program developed for an EU research project, for European countries and the WorldRES model for all other OECD countries and the BRICS, both of which were developed by the Energy Economics Group at Vienna University of Technology (World RES was originally built to provide input the IEA's *World Energy Outlook*). The analysis of Brazil's renewables potential was based largely on independent assessments, while the analysis of South Africa was based on a combination of third-party assessments and use of a MARKAL model[3] developed specifically for South Africa to prepare long-term climate policy scenarios.

Another challenge concerns the volatility of renewables production from one year to another caused by weather-related factors. Wind and hydropower are particularly sensitive to weather conditions in many locations as a result of wide annual variations in precipitation and wind speeds. For the PEI to provide a reliable indication of policy effectiveness, reported production levels need to be adjusted for these weather-related factors and any other external circumstances that hide the real effect of policy. The best way of normalizing production data depends on the renewable technology and the maturity of the market. For example, an effective technique for normalizing hydropower is to use the ratio between electricity generation and the installed capacity averaged a long period, for example 15 years, to even out annual fluctuations; for solar heat, production can be adjusted using heating degree days (Steinhilber *et al.*, 2011).

In most cases, the primary aim of renewables policy is to increase the consumption of renewable energy so as to displace the use of fossil fuels for both environmental and energy-security reasons. In the case of electricity, which is rarely traded across international borders as transmission over long distances is costly, this is generally achieved through incentives or obligations on generators to opt for renewables-based technologies in building capacity and producing electricity. Thus, for renewables-based electricity generation, it is appropriate to calculate the PEI based on production data. However, in the case of solid biomass and liquid biofuels, adjustments to the PEI need to be made to take account of trade, as these fuels can be transported conveniently and at relatively low cost across country borders, such that a country can easily consume more biofuels than it is able to produce domestically. Using domestic production potential in calculating the PEI would not lead to meaningful indicator values in this case, as the appropriate parameter for measuring the effectiveness of policy is consumption. In the case of extensive trade in bioenergy, the share of consumption in final energy demand in each sector may be a better indicator of policy effectiveness.

[3] MARKAL is an energy-technology optimization model, developed under an IEA implementing agreement, used to carry out economic analysis of different energy-related systems at the country level to project their evolution over the long term (typically up to 40-50 years).

4. Case studies: Brazil and South Africa

Renewables deployment and policy effectiveness were assessed in Brazil and South Africa. The assessments focused on solar (water heaters, PV and CSP) and wind power, and covered the period 1998-2009. In both cases, the studies sought to identify the factors that encourage or impede renewables deployment and to develop roadmaps in order to simulate the impact of different rates of deployment of these renewable energy technologies on public and private investment needs, greenhouse-gas emissions and employment. In each case, the PEI scores were lowest in South Africa, reflecting low initial levels of deployment, slow rates of market penetration and the sizeable mid-term potentials for all technologies. Policies have been most effective for solar water heaters and PV in Brazil, though considerable potential remains. In both countries, an expanded role for wind and solar to 2030 would involve relatively modest increases in investment, yet provide a major boost to employment while helping to curb emissions.

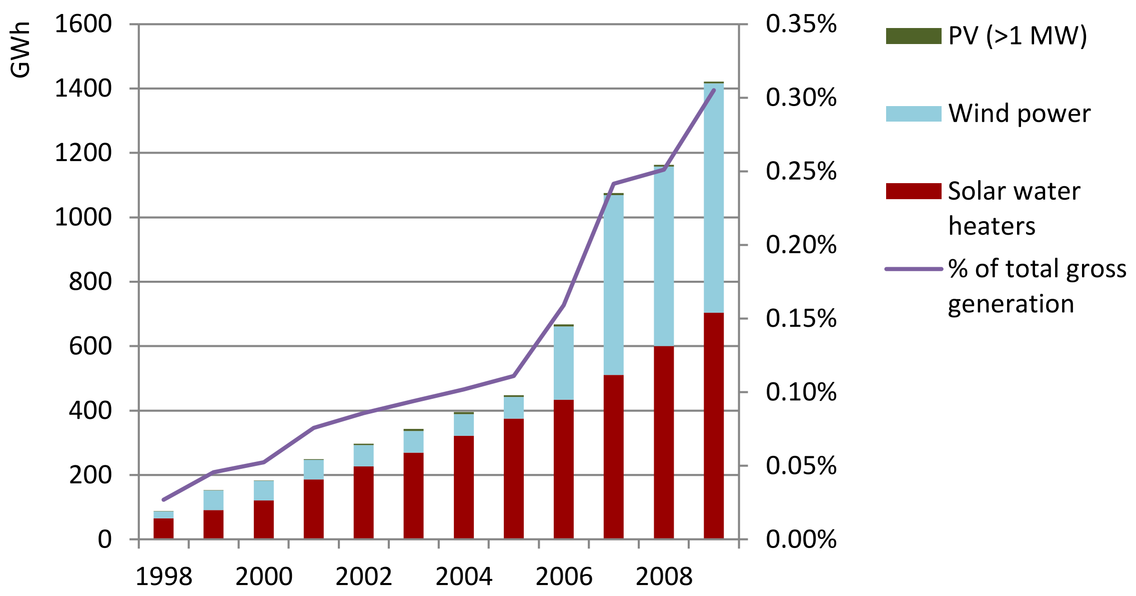
Brazil

Status of renewables policy and deployment

Renewables meet the bulk of Brazil's electricity needs, thanks mainly to the country's large endowment of hydropower and biomass resources. In 2010, hydropower accounted for 78% of gross power generation in Brazil and biomass and waste for a further 6%. The share of hydropower in total generation has fallen steadily in recent years, as a growing share of rapidly rising demand has been met by thermal power plants using natural gas, biomass or nuclear power. Brazil currently uses only about 30% of its hydropower potential, but the remainder is located mostly in the Amazon region. Environmental concerns make development of this potential difficult, while the long distances to the main demand centers mean that large investments in high-tension transmission lines are required. Wind power accounted for a mere 0.4% of generation in 2010, despite a steady increase in production since the mid-2000s, while the contribution of solar power was negligible at just 0.001%. There is as yet minimal use of solar water heaters, which would help to curb demand for electricity and other non-renewable forms of energy, though installations have been increasing thanks to various public policy initiatives and a favorable climate. In total solar and wind power production reached about 1.5 TWh in 2009 (Figure 4.1).

The first measure taken in the country to encourage the use of wind energy and other renewable sources was the Incentive Program for Alternative Sources (Programa de Incentivo às Fontes Alternativas de Energia Elétrica – "PROINFA"), established by law in 2002 and launched in 2004. PROINFA's long-term goal is to increase the share of wind, biomass, and small and medium-sized hydroelectric facilities to 10% of electricity generation by 2020. It set a first phase target of 3.3 GW of installed capacity by end-2006, divided equally between the three sources. The Brazilian government designated Eletrobrás, the national power utility, as the primary buyer of electricity generated by PROINFA projects, entering into long-term (20-year) power purchase agreements at a guaranteed feed-in tariff, differentiated by source. The Brazilian government later adopted a goal of 11.5 GW of wind, 6.4 GW of small-scale hydro and 9.1 GW of biomass capacity by 2020. PROINFA achieved its overall phase 1 goal much later than originally planned, while generation from biomass fell short of its 1. 1 GW quota. A total of 3.299 GW of capacity was contracted, 1.191 GW of hydropower, 1.423 GW of wind power and 0.685 GW of biomass-fired power plants.

Figure 4.1: Production of solar and wind power in Brazil, 1998-2009



Source: Centro Clima analysis, based on national sources.

In the case of wind, the entry into operation of most projects was delayed for several reasons, including delays in setting up the program, determining tariffs and in obtaining environmental licenses, rising costs due to increases in raw materials prices and the legal requirement to source at least 60% of capital inputs from domestic suppliers, and the fact that there was initially only one manufacturer of turbines in the country. As a result of these delays, the government decided to postpone the deadline for entry into operation of the PROFINA wind projects to December 2008 and subsequently to December 2010, and to temporarily suspend the 14% import tax on turbines.

The Brazilian government has been seeking to promote wind power generation through reserve energy auctions (Leilão de Energia de Reserva, or LER) – a mechanism created to ensure that sufficient capacity is held in reserve in the National Interconnected System (NIS). In 2009, an arrangement was established to share the costs of connection between different wind farms, to help wind power compete better with other sources of generation. As a result, a significant amount of new wind capacity was contracted at rates well below the PROINFA feed-in tariffs, which took effect in July 2012.

Policies to promote solar PV and CSP have been less ambitious. Historically, PV was seen largely as a component of rural development programs to provide access to electricity in remote parts of the country. One of the first such initiatives was PRODEEM (the Program of Energy Development of States and Cities) – a federal program launched in 1994 involving the installation of 8 956 PV systems with a total capacity of 5.1 MW. This was followed in 2002 by the PRODEEM Revitalizing and Capacitating Program (PRC – PRODEEM), which was incorporated into the federal "Light for All" program launched in 2003. The electric utilities charged with serving the communities in their concession areas subsequently took on responsibility for operating and maintaining the PRODEEM PV systems.

More recently, interest has been growing in promoting PV more generally, in response to the falling costs of panels and growing concerns about climate change. However, the federal government remains of the view that generating costs are too high for solar to be competitive and has resisted calls for a tender and feed-in tariffs for PV. At the state level, the most prominent initiative is the creation in 2009 of the Solar Energy Incentive Fund (FEI) in Ceará, which offers a premium tariff similar to a feed-in tariff for PV-based power sold to the grid. Despite the country's large solar resources, CSP has not yet got off the ground in Brazil though some utilities are assessing its potential.

Some initiatives have been launched at the federal and state levels to promote the use of solar water heaters. In 2009, the federal government launched the program, "Minha casa, minha vida" (My House, My Life), targeting 300 000 – 400 000 solar water heaters in social housing projects. This projects has since been stepped up under the second stage of the growth acceleration program (Aceleração do Crescimento, or PAC 2), which involves spending on infrastructure, social and energy projects over 2011-2014. The aim now is to build two million low-income dwellings, all of which will be equipped with solar heaters. The budget for this program has been doubled to R$72 billion, or $44 billion. Funding comes from federal, state and municipal governments, as well as from private and state companies. In addition, a number of initiatives are under way in state and municipal legislatures to encourage or require the installation or preparation of solar heating installations. For example, São Paulo adopted a program in 2008, causing market growth to jump from 11% per year to 30% in 2009 (Soares and Rodrigues, 2010).

Analysis of policy effectiveness

The PEI was calculated for wind, PV and solar water heaters for the period 1998-2009 based on actual rates of deployment and estimated mid-term potentials. It was not possible to calculate a PEI for CSP, as no commercial plants have yet been brought into operation, though the theoretical potential was estimated. Among the four renewable technologies, wind power was found to have by far the largest technical and economic potential, though the mid-term potential is greatest for solar water heaters (Table 4.1). In total, the mid-term potential (2020) for solar water heaters, PV and wind combined amounts to 26.4 TWh – equal to about 5% of Brazil's current total power generation.

Table 4.1: Renewable energy potential in Brazil (TWh/year)

	Technical (2030)	Additional mid-term (2020) in 1998	Total mid-term (2020)	Economic (2030)
Solar water heaters	57.8	16.4	17.1	11.3
Wind	272.2	8.6	9.3	25.4
CSP	27.0	-		-
PV (>1 MW)	-	0.003	00.9	0.074
Total	***357.0***	***25.0***	***26.4***	***36.8***

Source: Centro Clima analysis, based on national sources.

The resulting PEIs scores for the three technologies assessed based on their mid-term potentials are relatively low because of the low initial levels of deployment, slow rates of market penetration and the significant mid-term potentials for all technologies (Table 4.2). The scores were highest for PV, though no increase in the cumulative score was recorded after 2003, with deployment standing at around 11% of the mid-term potential. PV production leveled off at 5.8 GWh. The cumulative score for solar water heaters rose steadily between 1999 and 2009, reaching almost 6%, with output reaching more than 700 GWh; the score for wind power was flat at 0.2% through to 2005, but jumped to 2.7% in 2009 as deployment took off under the PROINFA program, boosting production to 712 GWh.

Table 4.2: PEIs for renewables in Brazil, 1998-2009

	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Solar water heaters												
Production (GWh)	65.5	91.0	120.5	185.9	226.3	269.8	322.0	374.9	433.2	510.1	600.1	703.7
PEI – annual (%)	-	0.2	0.3	0.6	0.4	0.4	0.5	0.5	0.5	0.7	0.8	1.0
PEI – cumulative (%)	-	0.2	0.5	1.1	1.5	1.9	2.4	2.9	3.4	4.1	4.9	5.9
Wind power												
Production (GWh)	21	61	61	61	67	67	67	67	228	559	557	712
PEI – annual (%)	-	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.6	1.3	0.0	0.6
PEI – cumulative (%)	-	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.8	2.1	2.1	2.7
PV (>1 MW)												
Production (GWh)	0.2	0.7	1.5	1.7	3.4	5.8	5.8	5.8	5.8	5.8	5.8	5.8
PEI – annual (%)	-	0.66	1.08	3.70	2.29	3.58	0.00	0.00	0.00	0.00	0.00	0.00
PEI – cumulative (%)	-	0.66	1.74	5.44	7.73	11.31	11.31	11.31	11.31	11.31	11.31	11.31

Source: Centro Clima analysis.

Assessment of barriers to deploying renewables

The main barrier to the deployment of the technologies assessed is the higher upfront cost of construction of production facilities relative to alternatives and, in the case of PV, solar and, to a lesser extent, wind power, the lower return on investment for power generators. Government policies have so far been inadequate in compensating for these factors by encouraging or mandating large-scale investments in non-hydro generating technologies, though plans are afoot to push up significantly the use of solar water heaters, mainly by mandating their installation in new social housing.

In the case of wind power, the establishment of PROINFA and the LER auctions gave a boost to investment, but the share of the country's potential being exploited remains very low, largely because the technology is unable to compete against hydropower and gas-fired capacity without subsidy. This has been exacerbated by the requirement for 60% of the investment to have local content and import duties on imported turbines, together with the fact there was initially only one manufacturer of wind turbines in the country; these factors contributed to higher installation costs. The success of the LER led some foreign manufacturers of turbines to set up operations in Brazil, helping to lower costs.

The deployment of solar water heaters has benefited from policy initiatives specifically aimed at the sector, as well as the financial and economic attractiveness of the technology. The majority of Brazilian households heat water for washing, with the load coinciding to a large degree with peak evening and morning load. Solar water heaters are significantly more expensive to install than simple electric immersion heaters, but are much cheaper to operate, yielding a payback of typically two to three years. For electricity utilities, they represent a cost-effective means of reducing peak load, which can be very expensive to supply. Higher electricity tariffs, especially for the residential sector, which followed the privatization of publicly owned electricity companies in the mid-1990s, have helped to make solar water heaters more financially attractive. Nonetheless, the legal restriction on vertical integration in the electricity-supply industry under the new regulatory model that was introduced in 2004 has hindered the development of voluntary demand-side management programs, which would probably have favored solar water heaters.

The failure of PV and CSP to establish themselves in Brazil stems mainly from their high production cost, especially relative to low-cost hydropower, which has discouraged private investment and limited policy initiatives. PRODEEM is the only significant government program that supports PV deployment. The effectiveness of that program was hindered by a lack of capacity-building in isolated areas, which led many of the PV modules that were installed to be scrapped, though the subsequent launch of PRC-PRODEEM in 2002 helped to address this problem. The absence of producers of PV panels or components has also led to high prices of panels and held back growth of the market.

National roadmap for renewables

Five separate roadmaps, or scenarios, were prepared for rapid deployment of wind (replacing coal and all fossil fuels), CSP, PV and solar heat waters. The results were compared with a baseline scenario derived from two recent studies: the government's Ten Year Energy Plan (PDE-2019), which provided the basis for the nationally appropriate mitigation actions in the power sector to which the Brazilian government has committed itself to under the Copenhagen Accord in 2009, as well as the 2030 National Energy Plan (PNE-2030). PDE-2019 covers the period to 2019 and PNE-2030 the period 2020-2030. In this scenario, peak electricity demand increases from 112.2 GW in 2010 to 263.9 GW in 2030.

Among the five roadmaps, the biggest impact on employment and greenhouse-gas emissions occurs in the two wind and the solar water heater roadmaps; investment needs are smallest in the wind roadmaps (Figure 4.2):

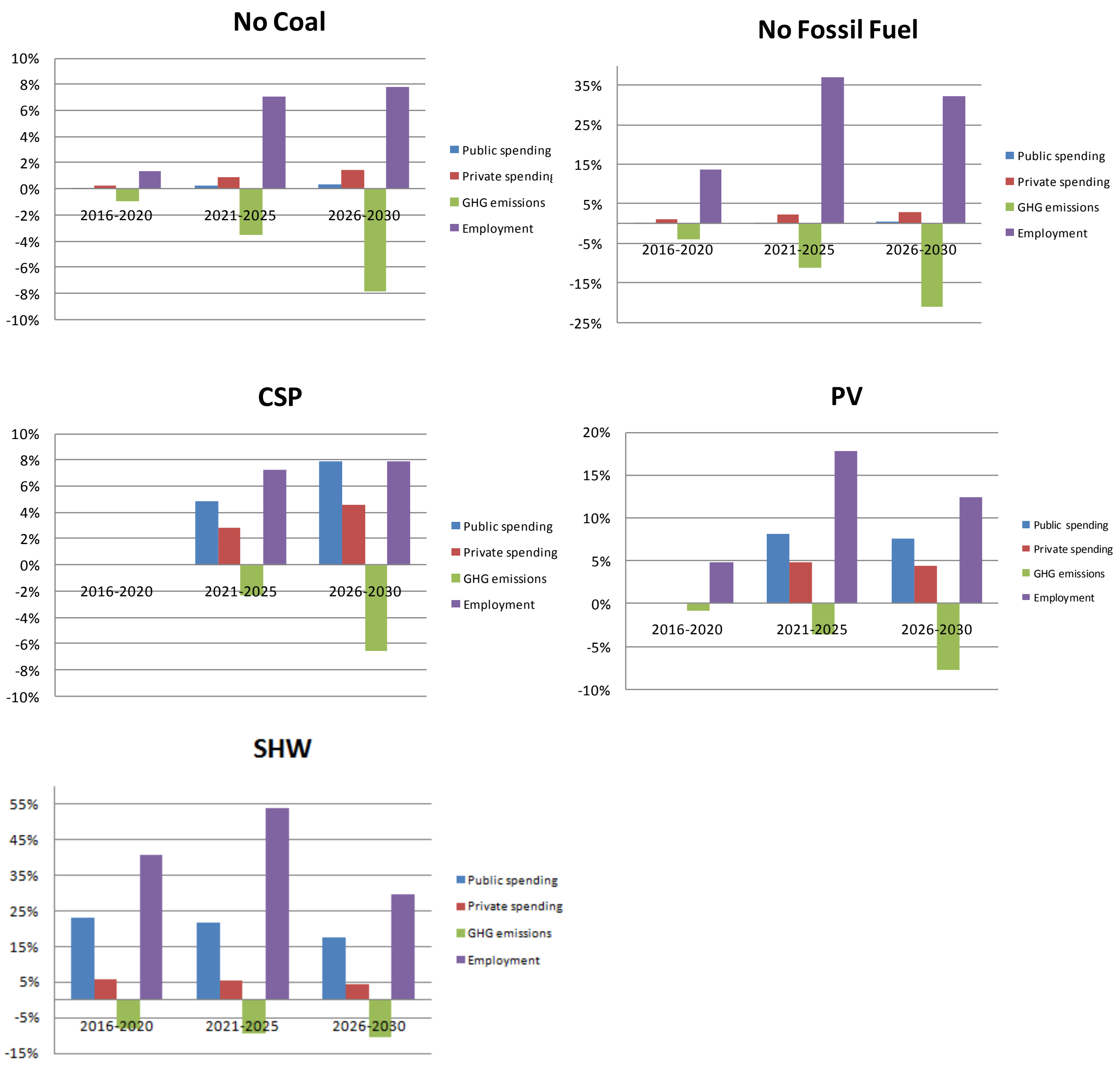
- *No coal (wind):* This roadmap assumes that the planned expansion of coal-based thermal power generation after 2015 would be replaced by wind farms as a result of the government providing tax breaks for buyers of green certificates. This leads to a significant impact on emissions and net job creation, particularly after 2020: by 2026-2030, emissions are lowered by around 8% and employment increased by a similar amount. The very small increase in investment *vis-à-vis* the baseline scenario reflects the maturity of the technology, which is already almost competitive with coal for baseload generation.

- *No fossil fuel (wind):* This roadmap assumes that wind replaces natural gas-fired as well as coal-fired generation, again thanks to tax breaks for buyers of green certificates. The impact on emissions and job creation is correspondingly significantly greater than in the No coal roadmap, while the increase in investment needs remains modest.

- *CSP:* In this roadmap, CSP replaces the expansion of coal-fired capacity after 2025 on the assumption that it will take that long for the technology to evolve and costs to fall sufficiently for it to be considered viable. Investment is assumed to be incentivized by means of a feed-in tariff. This leads to an increase in net employment of 8% and a reduction in emissions of over 6% by 2026-2030, but this comes at the expense of a large increase in investment needs – especially in the private sector, where they grow by 8%.

- *PV:* Given the current high cost of PV, it is assumed in this roadmap that the government introduces a feed-in tariff or some other form of support for this technology in 2015, when costs are assumed to have fallen to a level that makes it viable. It is assumed that deployment reaches 8.2 GW in 2030. As with CSP, PV replaces coal-fired generation, following the CSP example. Job creation and emissions savings are significant, but investment needs are relatively high reflecting high unit costs.

Table 4.2: Changes in capital spending, greenhouse-gas emissions and employment relative to the baseline projection in roadmaps for Brazil



Source: Centro Clima analysis.

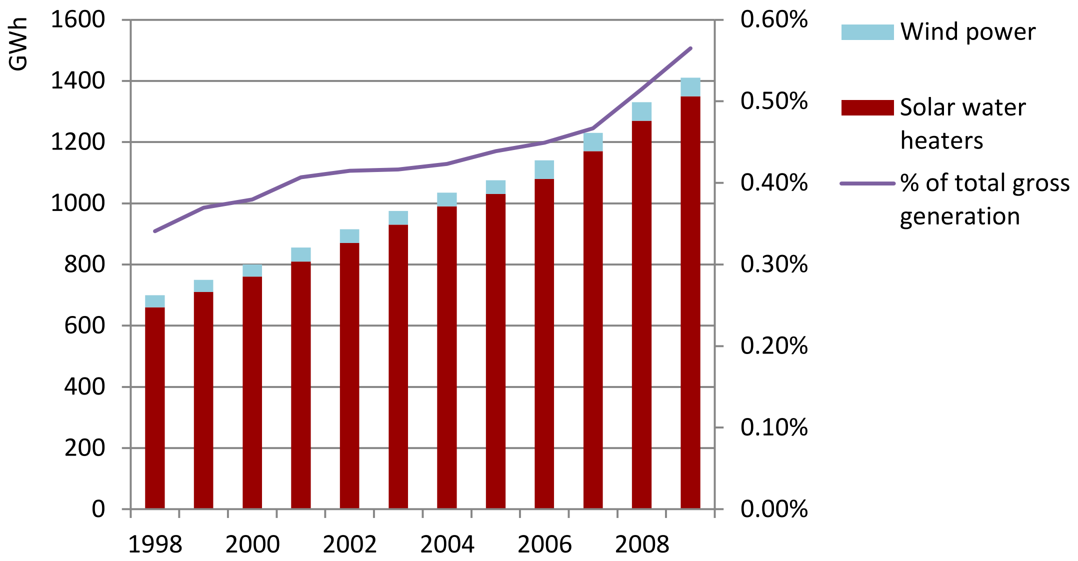
- *Solar hot water (SHW):* This roadmap assumes that the government implements a program to expand the installation of flexible solar water heaters in social housing (a less expensive system, which does not involve the installation of a large tank and is combined with electric water heating for times when solar energy is insufficient). Consequently, around 10 million more homes are equipped with such heaters by 2030 than in the baseline scenario, boosting total capacity to just over 5 GW. On the assumption that this capacity effectively reduces the need for coal-fired capacity, greenhouse-gas emissions are reduced by almost 8% by 2026-2030. Employment is boosted by more than in any other roadmap – by well over 50% in the first half of the 2020s – thanks to the highly labor-intensive nature of such installations. The increase in investment is also highest, especially in the private sector, though the increase could be lower in practice if bigger cost reductions than assumed were realized thanks to technology learning and economies of scale.

South Africa

Status of renewables policy and deployment

Although South Africa has very good solar and wind resources, the deployment of renewable energy technologies has been slow to take off. According to IEA databases, renewables accounted for only 10% of primary energy supply in 2010; of those renewables, all but 1% was biomass (mainly traditional). More than 90% of South Africa's electricity is generated from the burning of low-cost indigenous coal, with nuclear power making up most of the rest. Only 1% of electricity was generated from renewable energy sources, amounting to just over 2 TWh, the vast bulk of which was hydropower. Output of wind power and solar water heaters combined doubled between 1998 and 2009, but remains minimal at just 1.4 TWh, almost of all of it solar (Figure 4.3).

Figure 4.3: Production of solar and wind power in South Africa, 1998-2009



Source: Energy Research Centre (University of Cape Town) analysis, based on national sources.

Until recently, the country had the lowest electricity prices in the world, averaging less than 0.25 rand (R)/kWh in 2008/9. However, prices have risen sharply since then to cover the cost of building new capacity. In 2008, demand for electricity outstripped supply and the national power company, Eskom, had to resort to load shedding. To alleviate the electricity shortfall, Eskom subsequently embarked on a major program of capacity expansion, involving the addition of about 10 GW of capacity from coal, 1.2 GW from the Ingula pumped storage scheme and about 150 MW of renewable energy (a 50 MW CSP plant and 100 MW of wind-turbine capacity). Total capacity reached 43.5 GW in 2010, up from abput 42 GW in 2005. To cover the cost of building this capacity, the National Energy Regulator (NERSA) granted sharp increases in electricity prices, which have more than doubled since 2008/9 to an average of R0.53/kWh in 2011/12; they are set to rise by another 26% in 2012/13.

Renewables are due to play a much bigger role in power generation in the longer term. In March 2011, the South African government adopted an Integrated Resource Plan (IRP), outlining the government's strategy for electricity generation in the country for 2010-2030 (RSA DOE, 2011). The plan calls for 42.6 GW of new capacity (net of capacity required to replace decommissioned plant and plants currently under construction) over the 20 years to 2030. Of this new capacity, 17.8 GW, or 42%, are to be based on renewable technologies: 8.4 GW each of solar PV and wind power, and 1 GW of CSP. Under this plan, renewables would account for 9% of total generating capacity of 96.6 GW in 2030. Independent power producers are expected to contribute a growing share of generation.

Overcoming energy poverty still remains a major strategic development objective for South Africa. Despite considerable progress since the 1990s, around 30% of the country's households are still not connected to the electricity network and large numbers of households in remote rural areas continue to rely heavily on traditional biomass for cooking and heating. It was estimated in 2007 that more than 1.5 million households located in remote areas were still unlikely to be connected to the grid in the near future (Lemaire, 2007).

Analysis of policy effectiveness

As in Brazil, the scores for the PEI in South Africa are very low for the renewable technologies assessed, reflecting slow rates of deployment and substantial mid-term potential. The potentials in 2030 for renewables vary enormously across the four technologies assessed and the types of potential (Table 4.4).

Table 4.4: Renewable energy potential in South Africa in 2030 (TWh/year)

	Theoretical	Technical	Mid-term	Mid-term (additional) in 1998	Economic
Solar water heaters	70	47	31	28	17
Wind	184	80	28	28	23
CSP	2 361 300	1 000	121	121	52
PV (>1 MW)	2 361 300	1 000	2	2	0
Total	***2 361 484***	***1 127***	***182***	***179***	***92***

Source: Energy Research Centre (University of Cape Town) analysis, based on national sources.

The theoretical and technical potentials for CSP and PV are enormous, dwarfing those of wind power and solar water heaters. South Africa has 24% of the world's best winter sunshine, as well as some of the best annual irradiation, particularly in the Northern and Western Cape provinces (Holm et al., 2008). However, the mid-term and economic potentials of solar resources are much smaller. Among the four technologies, the mid-term potential is highest for CSP, of which about 40% is estimated to be economic. There is significant mid-term potential for solar water heaters and wind power too, while that of PV is minimal. In total, the mid-term potential of all the technologies combined is estimated at 182 TWh – equal to about 85% of final consumption of electricity in South Africa in 2011. Roughly half of this is economic. The share of the mid-term potential that is economic is highest for wind power, while PV is not economic at all without policy incentives to encourage its deployment.

The PEIs were calculated based on the additional mid-term potential for solar water heaters, which obtained the highest score, and wind power (Table 4.5). They were not calculated for CSP or PV (of more than 1 MW) as no plants have yet been built, though several are planned under the IRP. There are a few small-scale PV installations in South Africa, mostly used to provide electricity for telecommunications and electronic media in areas remote from the grid, but total capacity is minimal.

Table 4.5: PEIs for renewables in South Africa, 1998-2009

	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Solar water heaters												
Production (TWh)	0.66	0.71	0.76	0.81	0.87	0.93	0.99	1.03	1.08	1.17	1.27	1.35
PEI – annual (%)	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.1	0.2	0.3	0.3	0.3
PEI – cumulative (%)	0.2	0.4	0.6	0.8	1	1.2	1.4	1.5	1.7	2	2.3	2.6
Wind power												
Production (TWh)	0.040	0.040	0.040	0.045	0.045	0.045	0.045	0.045	0.060	0.060	0.060	0.060
PEI – annual (%)	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.2	0.2	0.2	0.2
PEI – cumulative (%)	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	1.0	1.2	1.4	1.6

Source: Energy Research Centre (University of Cape Town) analysis.

The cumulative PEI for solar water heaters reached 2.6% in 2009, with an estimated 7.9% of the country's total economic potential exploited. The deployment of heaters entered a period of rapid growth in 2007, having experienced only modest growth since the last surge in the early 1980s. In 2009, there were an estimated 1.4 million square meters of heating panels in use throughout South Africa, producing an estimated 1.35 TWh of heat. Installations were boosted by the power crisis of 2008, when Eskom launched a demand-side management program to reduce peak load. Originally, Eskom planned to support the deployment of 1 million heaters over five years, but by August 2009, only 1 612 had been installed under the scheme.

By 2009, the cumulative PEI for wind power was just 1.6%, with output of 60 GWh, or about 0.03% of total electricity generation. Only 2.6% of the country's estimated economic potential was being exploited in 2009. To date, just two pilot wind-farm projects have been developed – Eskom's 3.2 MW Klipheuwel Wind Energy Demonstration Facility and the independent 5.2 MW Darling Wind Farm – with a combined output of about 18 TWh. The remaining 42 TWh came from wind-powered water pumps.

Assessment of barriers to deploying renewables

A number of policies were put in place over the 12 years to 2009 to incentivize the deployment of renewables, but these were generally far from adequate to spark a boom in any of the leading technologies. The White Paper on Energy Policy of 1998, the overarching document that established the government's official policy on energy supply for the next decade, provided some early support to renewables-based power generation in South Africa. In addition, the Renewable Energy White Paper of 2003 set a target of 10 TWh of renewable energy production in 2013, made up largely of bagasse with small contributions from landfill gas, hydropower, solar water heaters, other biomass and wind; no targets were set for PV or CSP. In 1999, the South African government launched the solar household concessions program, which started to be rolled-out in 2002 with the aim of providing off-grid PV systems to 300 000 households lacking electricity. More recently, the government introduced a 2 cent/kWh environmental levy on non-renewable generation effective from 1 July 2009. These measures have met with some success, but the deployment of renewables – especially solar and wind power – has been held back by a combination of market and non-market barriers.

Among the market barriers, the low price of electricity – the result of generation being based largely on low-cost coal in South – was the most important. Until the recent price hike, renewables, with high upfront investment costs, were simply unable to compete. The government established the Renewable Energy Fund and Subsidy Office (REFSO) in 2005, but the subsidies offered were not large enough to stimulate much investment. By 2009, a total of only R15 million had been allocated to six projects with a total installed capacity of 23.9 MW. The non-market barriers to renewables investment include institutional, legal and financing hurdles, prominent among which are the difficulties facing project developers in obtaining approvals and licenses (Table 4.6). These problems have led to delays in getting projects off the ground and driven up costs.

The deployment of solar water heaters has faced specific obstacles. In 2008, Eskom launched a nationwide Demand Side Management program in response to the power crisis, which included a target for the roll-out of 1 million heaters by 2014 (RSA DME, 2008). Eskom subsidies for these heaters are dependent on the efficiency of the collectors. Already in 2008, the number of companies supplying heaters in South Africa jumped from 20 to more than 200, resulting in the deployment of more than 100 000 m^2 of heater surface area (0.1 TWh) that year. However, deployment could have been faster, had it not been for constraints on the supply of the heaters, as national production is limited. Furthermore, delays in testing new heaters by the South African Board of Standards (SABS) led to a backlog of orders; for a heater installation to receive the Eskom subsidy, the technology must be approved by the SABS testing facility. In 2010, the South African Department of Energy announced its intention to offer 200 000 individual grants for a mass roll-out of the national solar water heating program under the Industrial Policy Action Plan (REN21, 2012).

Table 4.6: Non-market barriers to the deployment of renewables in South Africa

Type	Barrier
Institutional	Too many agencies involved in approvals (DME, DEAT, DME and NERSA, the Department of Water Affairs and Forestry, and the provincial and local authority). Time taken to process approvals for licenses, EIAs or negotiation of PPA. Identifying the right public sector finance partner. CDM process is expensive and long. Approval of the right tariff.
Legal	EIA laws, planning legislation, the Public Finance Management Act (PFMA), MFMA, wheeling rights and power purchase agreements (PPAs). Rights of access to property or resource.
Financial	Identifying institutions that offer development grants. Identifying suitable lenders (soft and commercial). Securing equity partners. Insurance.

Source: Energy Research Centre (University of Cape Town) analysis.

The government responded to the slow pace of renewables deployment by introducing in 2009 feed-in tariffs for projects of more than 1 MW; different tariffs were established for wind, landfill gas, biogas, solid biomass (direct combustion), small hydro, CSP and PV projects. However, the feed-in tariff was subsequently abandoned before being promulgated in favor of a competitive bidding process, which was launched in August 2011. Under this bidding process, the South African government plans to procure 3 750 MW of renewable energy: 1 850 MW of onshore wind, 1 450 MW of solar PV, 200 MW of CSP, 75 MW of small hydro, 25 MW of landfill gas, 12.5 MW of biogas, 12.5 MW of biomass, and 100 MW of small projects. All projects are due to be commissioned by June 2014, with the exception of CSP projects, which are planned to be brought on-line by June 2015. Under a first tender held in November 2011, the Department of Energy awarded contracts to 28 bidders for a total of 1.42GW of capacity. A second tender held in May 2012 led to approvals for a further 1.04 GW of capacity, including 563 MW of wind power, 417 MW of large-scale PV capacity and a single 50-MW CSP project.

National roadmaps for renewables

For this case study, six national roadmaps, or scenarios, were developed for the deployment of wind power, CSP and PV to 2030, corresponding to three different targets for renewables penetration (15% of total electricity generation, 27% and unlimited, in which the maximum level of government support is provided until the technologies become cost-competitive), each of which were combined with low and high roll-out programs for solar water heaters to reduce demand for electricity (Table 4.7). The high heater deployment target results in a saving of at least 6 GW of electricity generation capacity, while the low target reduces capacity needs by only 2 GW. These roadmaps were compared with a baseline projection in which only supercritical coal-fired plants are built and no new heaters are installed.

Table 4.7: Roadmaps for the accelerated deployment of renewables in South Africa, 2030

Roadmap	Targeted renewables share of electricity generation	Pace of roll-out of solar water heaters	Renewables-based generation (TWh)					
			Wind	CSP	PV	Solar water heaters	Total	Share of total generation
1	Maximized	High	45	196	0.4	23	264	55%
2	Maximized	Low	56	226	0.4	8	290	60%
3	27%	High	37	88	0.0	23	148	30%
4	27%	Low	38	90	0.0	8	136	28%
5	15%	High	26	40	0.0	23	91	20%
6	15%	Low	26	42	0.0	8	76	16%

Note: Solar water heater deployment reaches 10 million by 2030 in the high case and 3.5 million in the low case. The generation from electricity from solar water heaters represents the saving in generation that results from their installation.

Source: Energy Research Centre (University of Cape Town) analysis.

The outcomes of the roadmaps are presented as changes in employment in the sectors covered, greenhouse-gas emissions, and government and private capital spending on generating capacity relative to the baseline projection (Figure 4.4). Unsurprisingly, the largest employment benefits are recorded for the roadmaps supporting a high solar water heater rollout and the highest level of penetration of renewables; employment increases by more than 150% in 2030 in roadmap 1, compared with less than 60% in roadmap 6. The unlimited renewable energy target projections (roadmaps 1 and 2) result in the highest savings in greenhouse-gas emissions from electricity, amounting to 40% between 2025 and 2030, while the 27% target projections (3 and 4) stabilize emissions at a level 20% lower than in the baseline projection in 2030.

Investment needs increase most, by over 20% in 2025-2030, where the penetration of renewables is highest (roadmaps 1 and 2), reflecting their higher capital costs. Achieving a 27 % electricity generation target from renewable energy sources by 2030 (roadmaps 5 and 6) involves only a marginal increase in investment over 2010-2030 (averaging well under 10%). The 15% target (roadmaps 5 and 6) is achieved with hardly any change in public and private investments; by 2030, investment is actually lower than in the baseline projection. The higher investment costs in roadmaps 1 and 2 need to be balanced against the higher employment levels and emissions savings.

Table 4.4: Changes in capital spending, greenhouse-gas emissions and employment relative to the baseline projection in roadmaps for South Africa

Source: Energy Research Centre (University of Cape Town) analysis.

This analysis suggests that roadmap 3, with a target of at least 27% electricity supply from renewable sources and a rapid roll-out of solar water heaters may be the most favorable option for South Africa. It would create a significant number of new jobs at relatively limited additional capital cost (less than 20% for both the private and public sectors), while bringing forth sizeable reductions in greenhouse-gas emissions, resulting in a stabilization of emissions in absolute terms by the early 2020s. CSP contributes 70% of the increase in renewables-based generating capacity and wind for the remaining 30%.

Comparison with other countries

The deployment to date of emerging non-hydro renewable energy sources and technologies in Brazil and South Africa is well below the average for most other countries. On average, the penetration of non-hydro renewables (excluding biomass) was 0.9% in 2010 in non-OECD countries (weighted by production), compared with only 0.2% in Brazil and 0.1% in South Africa. In the OECD, penetration was markedly higher, at 1.2%. Globally, the average was 0.9%.

The relatively limited penetration for Brazil and South Africa reflects mainly the limited policy action that has been taken so far, in turn the consequence of low-cost conventional alternatives for power generation (hydropower in the case of Brazil and coal in South Africa). This is starting to change, as the government in both countries has recently launched new policy initiatives, largely in support of climate goals, though it will take time for them to catch up with other non-OECD countries. Certainly, there is large potential for much higher production in the medium term – especially for wind power and solar water heaters. Only 1.6-2.7% of the additional mid-term potential for wind had been exploited by 2009 in the two countries. Solar heaters scored better, at 2.6% in South Africa and 5.9% in Brazil. There is even bigger potential for PV in South Africa, where virtually none the potential had been exploited; the score for PV in Brazil is highest among all the technologies assessed, with more than 11% of the mid-term potential having being exploited between 1998 and 2009.

Direct comparisons of policy effectiveness with other countries are difficult, as other studies that have been carried out using different base years and periods. Nonetheless, the 2008 IEA study, which covered all OECD countries and the BRICS, shows clearly that the indicator is generally much higher for OECD countries: for example, 11% of the total mid-term realizable potential for onshore wind was exploited between 2000 and 2005, compared with only 0.2% in Brazil and 0.8% in South Africa. Wind and solar policy effectiveness is also relatively high in the European Union according to 2011 study carried out on behalf of the European Commission (Steinhilber, 2011).

These studies – and the case studies presented here – demonstrate a strong correlation between policy effectiveness and the use of feed-in tariffs for electricity-generating technologies (though a minimum level of remuneration is necessary). For example, the countries with the highest effectiveness – Germany, Spain, Denmark and Portugal – successfully used feed-in tariffs to encourage the deployment of wind. The absence of effective feed-in tariffs in Brazil and South Africa explains the policy effectiveness scores for wind and solar power. The studies also suggest that the presence of non-economic barriers, notably administrative hurdles, significantly undermines the effectiveness of policies to develop wind and solar power (see the next section).

5. Lesson learned

Assessing policy effectiveness

The two case studies presented here illustrate how the effectiveness of policies to support specific renewable energy sources and technologies can diverge markedly in practice, and so demonstrate the importance of monitoring policy effectiveness. The principal indicator used – the Policy Effectiveness Indicator (PEI) – serves as a measure for the degree to which a predefined goal can be achieved. As such, it can be a useful tool for understanding the true rate of progress in deploying renewables by comparing the expansion of production over a given period with the mid-term realizable potential.

In fact, the PEI measures the combined impact of three driving factors (IEA, 2008):

- The strength of a country's policy ambition, which may be expressed in terms of a quantified target.
- The existence of well-designed and effective measures, such as incentive schemes (that effectively make the price of renewable attractive) or quotas/mandates (that guarantee a level of production regardless of cost).
- The capability of overcoming non-market barriers to investment in renewables.

In any country, all three factors need to be robust for a high PEI score to be registered; a policy can fail if just one factor is weak – for example, if ambition is strong but effective measures are not introduced or if non-market barriers impede investment. The generally low scores for solar and wind policies in Brazil and South Africa stem from all of these factors: over the time period considered, there was an absence of both a formal target for any of these technologies – with the exception of wind power in Brazil – and any effective measures to encourage a high level of investment; there were also considerable non-market hurdles (for example, the lack of wind power equipment manufacturers in Brazil).

The general lesson that one can take from this is that, in seeking to boost policy effectiveness, policymakers need to carefully assess which of the three factors is holding back deployment: is there a need for more ambitious policy targets? Are stronger incentive mechanisms needed, including bigger financial incentives to compensate for the higher cost of renewables compared with conventional energy sources? And do specific non-market barriers need to be addressed?

The PEI should be seen as a starting point for measuring policy effectiveness and for comparing national performance with other countries. Other indicators and approaches are needed to provide a full evaluation of renewables policy. For example, a number of different indicators have been developed under the European Commission monitoring program for renewables policy and the OPTRES and RE-Shaping research projects, such as the Economic Incentives and

Conversion Costs indicator and a comparison of the economic incentives provided for specific technologies and average generation costs, which helps to monitor whether financial support levels are well suited to the actual support requirements of a technology (Ragwitz, 2007; Steinhilber et al., 2011).

One shortcoming of the PEI approach is that it does not take account of the dynamics of technology diffusion; using it to compare countries does not allow for the fact that technological transformation cannot proceed at the same pace in all countries given differences in existing experience in deploying new technologies, learning rates, institutional capacity and saturation effects. In practice, it is possible to integrate different aspects of technology diffusion directly in the design of the effectiveness indicator. For example, diffusion curves can be modeled by using regression runs over different data sets in order to adjust the mid-term potentials for different technologies (Steinhilber *et al.*, 2011).

The PEI approach effectively defines the effectiveness of a policy by reference to the policy outputs, rather than the policy's ultimate objectives, such as the climate benefits from reduced emissions of CO_2 or reductions in the cost of the technologies themselves. The results are useful from the perspective of a policymaker already committed to supporting renewable energy, as they can help identify actions that will increase effectiveness. But other indicators are needed to answer the larger question of the extent to which renewable policies are cost-effective. In other words, do the benefits from the policy justify the related costs?

In reality, a comprehensive assessment of the cost-effectiveness of renewables policy can be resource-intensive and technically complex, involving large amounts of data and measurement of many different types of economic, environmental and social impacts – often using computerized general equilibrium and partial equilibrium models. Estimating some types of impact inevitably involves considerable uncertainty, such that no decisive conclusions can be drawn. Nonetheless, some impacts can be measured and evaluated relatively easily, such as the direct impact of fuel switching on emissions. There appears to be a need for further work to understand better the methodological challenges in identifying the impacts of renewable energy deployment, including on energy security and technological and economic development.

One clear lesson that can be drawn from the case studies and the whole body of work that has been carried out on renewables policy is that detailed monitoring and reporting of all of the different aspects of renewables policy, including indirect impacts, greatly aids the analysis of policy effectiveness and its overall costs and benefits. Important areas for reporting include the full range of support mechanisms for renewables; the deployment of sub-technologies within any given category of technology (for example, roof-mounted PV within the category of solar PV); annual financial transfers being made to different categories of installations under the various schemes; effective subsidies, taking into account the difference between transfers and the power price; the technologies being offset by each type of renewable energy installation; and factors such as $CO2$ emissions per kWh and job years per MW and per kWh, disaggregated by domestic manufacturing, export manufacturing, installation and operations and maintenance (Wooders *et al.*, 2012).

Finally, the assessment of the effectiveness of renewables policy must consider the entire policy framework into which incentive schemes are inserted, rather than focusing on which specific incentive scheme functions best. For example, the apparent failure of a policy to boost deployment of a particular type of renewable relative to potential may stem from a measure that favors a competing conventional energy sources or technology. Similarly, the impact of a carbon pricing on renewables deployment needs to be taken into account when assessing the impact of renewables-specific policies.

Principles of renewables policy design

Experience of energy policy around the world demonstrates the critical importance of policy design. Setting a policy goal is not enough: it must be backed up by effective mechanisms and instruments. In practice, there is no one-size-fits-all approach to designing renewables policy. Ultimately, the policy must be designed to meet the specific goals that have been set, taking account of local market conditions and national circumstances, including the availability of resources, supply costs, institutional and societal factors, the existing policy framework, the size of non-market barriers, the degree of market liberalization and existing energy-system infrastructure. As described in section 2, there is a wide variety of incentive schemes that can be applied effectively depending on the specific technology and country. The appropriate mix of instrument and their design for one country will not necessarily be right for others.

Nonetheless, there are a number of principles of policy design, which, when applied sensibly, can increase the effectiveness and efficiency of renewable energy policies. According to the IEA (2008a), renewable energy policy design should reflect five fundamental principles:

- The removal of non-market barriers in order to improve the way markets and policy function.
- The need for a predictable and transparent support framework to attract investments.
- The introduction of transitional incentives, decreasing over time, to foster and monitor technological innovation and move technologies quickly towards market competitiveness.
- The development and implementation of appropriate incentives guaranteeing a specific level of support to different technologies based on their degree of technology maturity, in order to exploit the significant potential of the large basket of renewable energy technologies over time.
- Due consideration of the impact of the large-scale penetration of renewable energy technologies on the overall energy system, especially in liberalized energy markets, with regard to overall cost efficiency and system reliability.

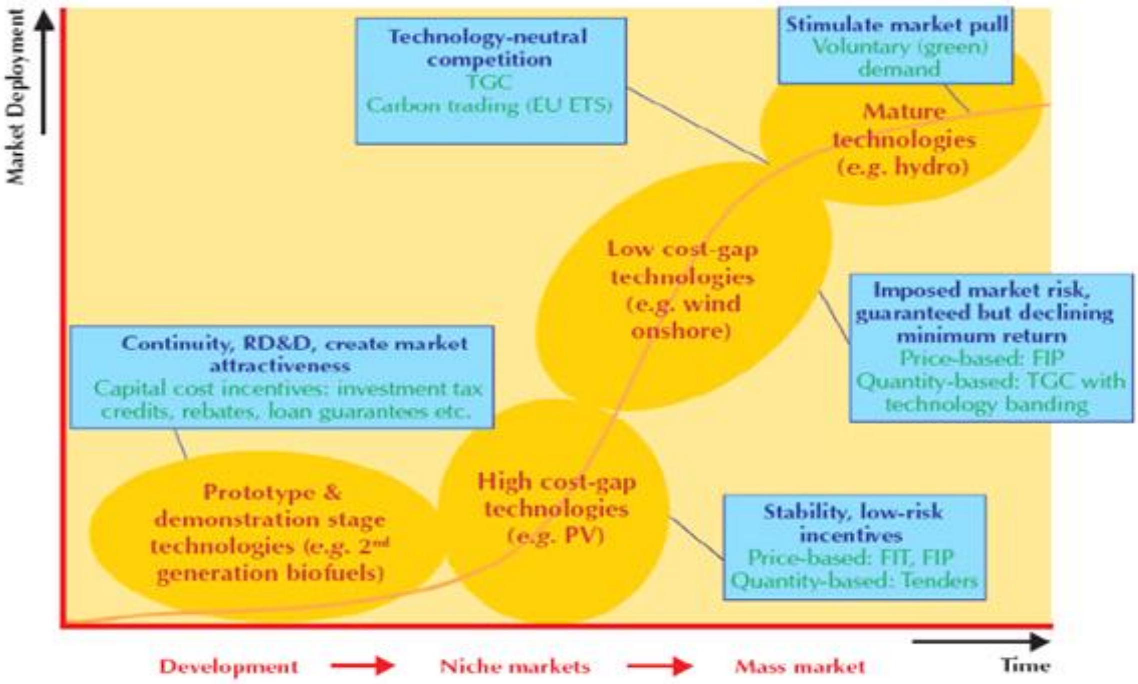
The slow rate of deployment of wind power in Brazil illustrates the critical importance of making sure that non-market factors do not drive up costs and hold back investment, irrespective of the target or the type of incentive scheme put in place. They include administrative hurdles (including planning delays and restrictions, and long lead times in obtaining authorizations), impediments to renewables producers to gain access to the grid, poor electricity market design (which systematically favors centralized producers), lack of information and training, and a lack of acceptance of renewables projects by the public. For example, long and bureaucratic authorization and permitting procedures can increase significantly investment risk and lead to a project failing, as can long and non-transparent procedures for grid connection. Difficulties in gaining access to the electricity network can also hinder the development of distributed renewables-based electricity generating technologies. And local opposition on the grounds of visual pollution and other types of nuisance – the so-called "Not-In-My-Backyard (NIMBY)" syndrome – can lead to costly public enquiries, delays and even project cancellation.

As a rule, the least mature technologies that are furthest from economic competitiveness need continued public support for research and development, as well as stable low-risk incentives, such as investment grants, feed-in tariffs or tenders (Figure 5.1). For those technologies that are closest to being competitive with conventional ones, such as onshore wind or biomass combustion, other more market-oriented instruments like feed-in-premiums and tradable green certificate systems may be more appropriate. Once the technology is competitive (with carbon pricing in place), non-market barriers are adequately addressed and deployment on a large scale is about to begin, support to renewables can be phased out altogether as they should be able to compete on a level playing field with other energy technologies (IEA, 2008a).

Policy frameworks which combine different technology-specific support schemes according to the maturity of each technology may be best suited to fostering the widespread deployment of renewables. All types of renewable technology are continuing to evolve rapidly, with the potential in some cases for major advances in performance and significant cost reductions. Research and development will need to play an important part of this process in parallel with market deployment.

In practice, balancing the need for a predictable and transparent policy framework and lowering incentives progressively over time as technological innovation, learning and economies of scale help to move renewables technologies towards market competitiveness is challenging, especially in view of political factors and shifting macroeconomic conditions. Sudden changes in policy can be extremely detrimental to the deployment of renewables. For example, the sudden reduction in feed-in tariffs for some types of renewables in several European countries in the last year or two – prompted mainly by a desire to limit their impact on final electricity prices – has led to sharp falls in investment. Ideally, reductions should be programmed in a transparent manner, to avoid market upheavals and encourage cost reductions.

Figure 5.1: Framework of policy incentives as a function of technology maturity and deployment



Source: IEA (2008).

The renewables policy debate has often focused on the relative merits of feed-in tariffs, differentiated by technology, and renewable portfolio standards (quota obligations) with renewable green certificates. Neither approach is always better than the other: in practice, the best approach depends on country- and technology-specific factors. Precise design criteria and fine-tuning of the incentive scheme are key factors (IEA, 2008a). The last few years have seen a degree of convergence between the two approaches. For instance, technology-banding, whereby an obligation is imposed on utilities or generators to procure a minimum percentages of renewable energy from specific technologies or technology tiers, has been introduced into renewable portfolio standards in some countries, for example in the Non-Fossil Fuel Obligation in the United Kingdom. In any case, feed-in tariffs can complement portfolio standards, by providing assurances to investors and encouraging the development of projects (Cory *et al.*, 2009).

In designing renewables policies, policymakers need to adopt an integrated approach to evaluating all options in the context of broader energy, climate, economic and social policymaking. Renewables are a means to end; they form one of several paths to lowering CO_2 emissions, enhancing energy security and promoting economic and social development. Practical tools are available to help government do this: for example the MCA4climate policy evaluation tool developed by UNEP – a practical step-by-step tool for identifying and prioritizing mitigation and adaptation policies, consistent with developmental goals (UNEP, 2011).[4]

Whatever the approach adopted, policymakers need to recognize that what is needed is to set in motion a profound transformation of energy-supply system, involving a long-term transition towards a low-carbon energy system in which renewables play a central role in meeting energy needs. For that to happen, the market will need to place an appropriate price on carbon and other externalities and infrastructure will need to develop in a way that allows renewables to compete with other energy technologies on a level playing field and accommodates their deployment on a large scale. Once this is achieved, there should be no further need for any other type of support or subsidy, with their further development and deployment being driven by market forces.

[4] More information about this tool can be found at http://www.mca4climate.info/.

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Annex B: Data tables

Table B.1: Renewable energy capacity and biofuel production, 2011

	Added during 2011	Capacity at end year/annual production
Power generation capacity (GW)		
Biomass	5.9	72
Geothermal	0.1	11.2
Hydropower	25	970
Ocean power	0.3	0.5
Solar PV	30	70
CSP	0.5	1.8
Wind power	40	238
Hot water/heating capacity (GW_{th})		
Modern biomass	10	290
Geothermal	7	58
Solar water heaters*	>49	232
Transport fuels production (billion liters/year)		
Biodiesel	2.9	21.4
Ethanol	-0.4	86.1

* Glazed systems only (net additions only).

Note: Numbers are rounded to nearest GW/GWth/billion liter, except for relatively low numbers and biofuels, which are rounded to the nearest decimal point.

Source: REN21 (2012).

Table B.2: Renewable electric power capacity by leading regions/countries, end-2011

	EU	BRICS	China	US	Germany	Spain	Italy	India	Japan	World
Biomass	26	17.5	4.4	13.7	7.2	0.8	2.1	3.8	3.3	72
Geothermal	0.9	0.1	~0	3.1	~0	0	0.8	0	0.5	11.2
Ocean power	0.2	~0	~0	~0	0	~0	0	0	0	0.5
Solar PV	51	3.7	3.1	4	25	4.5	13	0.5	4.9	70
CSP	1.1	~0	0	0.5	0	1.1	~0	~0	0	1.8
Wind power	94	80	62	47	29	22	6.7	16	2.5	238
Total non-hydro	***174***	***101***	***70***	***68***	***61***	***28***	***22***	***20***	***11***	***390***
Per capita	*0.35*	*0.03*	*0.05*	*0.22*	*0.75*	*0.60*	*0.37*	*0.02*	*0.09*	*0.06*
Hydropower	120	383	212	79	4.4	20	18	42	28	970
Total capacity	***294***	***484***	***282***	***147***	***65***	***48***	***40***	***62***	***39***	***1 360***

* Glazed systems only (net additions only).

Note: Numbers are rounded to nearest GW, except for relatively low numbers, which are rounded to the nearest decimal point.

Source: REN21 (2012).

Table B.3: Global investment in renewable energy, $ billion

		2004	2005	2006	2007	2008	2009	2010	2011	2010-2011 (%)	2004-2011 (%)*
1	***Total investment***										
1.1	New investment	39.5	60.8	96.5	132.8	166.6	160.9	219.8	257.5	17%	31%
1.2	Total transactions	48.6	85.2	132.2	191.9	231.2	226.1	285.1	325.9	14%	31%
2	***New investment by value chain***										
2.1	Technology development										
2.1.1	Venture capital	0.4	0.6	1.2	2.1	3	1.5	2.4	2.5	5%	30%
2.1.2	Government R&D	1.9	2	2.2	2.5	2.6	3.5	5.3	4.6	-13%	14%
2.1.3	Corporate RD&D	5.1	2.5	2.9	2.7	3.9	4	4.6	3.7	-19%	-5%
2.2	Equipment manufacturing										
2.2.1	Private equity expansion capital	0.3	1	3	3.2	6.9	2.8	2.9	2.5	-15%	33%
2.2.2	Public markets	0.3	3.5	9.4	22.7	11.6	11.7	11.3	10.1	-10%	69%
2.3	Projects										
2.3.1	Asset finance	22.8	40.5	71.7	92	121.5	108.6	138.8	164.4	18%	33%
	of which reinvested equity	*0*	*0*	*1.1*	*5.7*	*4.5*	*2.4*	*6*	*6.1*	*3%*	
2.3.3	Small distributed capacity	8.6	10.8	7.2	13.4	21.6	31.2	60.4	75.8	25%	36%
	Total financial investment	***23.8***	***45.5***	***84.3***	***114.2***	***138.5***	***122.2***	***149.5***	***173.4***	***16%***	***33%***
	Govt R&D, corporate RD&D & small projects	15.6	15.3	12.2	18.5	28.1	38.7	70.3	84.1	20%	27%
	Total new investment	***39.5***	***60.8***	***96.5***	***132.8***	***166.6***	***160.9***	***219.8***	***257.5***	***17%***	***31%***
3	***M&A transactions***										
3.1	Private equity buy-outs	0.9	3.8	1.7	3.6	5.6	2.6	1.9	3.4	77%	21%
3.2	Public markets investor exits	0	1.3	2.7	4.3	1.2	2.6	5.3	0.2	-97%	-
3.3	Corporate M&A	2.6	6.9	12.9	20.2	18.7	21.7	21.1	28.4	34%	40%
3.4	Project acquisition & refinancing	5.5	12.3	18.5	31	39	38.3	37	36.5	-1%	31%
4	***New investment by sector***										
4.1	Wind	13.3	22.9	32	51.1	67.7	74.6	95.5	83.8	-12%	30%
4.2	Solar	13.8	16.4	19.5	37.7	57.4	58	96.9	147.4	52%	40%
4.3	Biofuels	3.5	8.2	26.6	24.5	19.2	9.1	8.5	6.8	-20%	10%
4.4	Biomass & waste	6.1	7.8	10.8	11.8	13.6	12.2	12	10.6	-12%	8%
4.5	Small hydro	1.4	4.4	5.4	5.5	6.6	4.7	3.6	5.8	59%	22%
4.6	Geothermal	1.4	1	1.4	1.4	1.9	2	3.1	2.9	-5%	12%
4.7	Marine	0	0	0.9	0.7	0.2	0.3	0.3	0.2	-5%	30%
	Total	***39.5***	***60.8***	***96.5***	***132.8***	***166.6***	***160.9***	***219.8***	***257.5***	***17%***	***31%***
5	***New investment by geography***										
5.1	United States	7.4	11.2	27.2	28.5	37.7	22.5	32.5	50.8	57%	32%
5.2	Brazil	0.4	1.9	4.3	9.3	12.7	7.3	6.9	7.5	8%	51%
5.3	Other America	1.3	3.3	3.3	4.7	5.4	6.4	11	7	-36%	27%
5.4	Europe	18.6	27.7	37.4	57.8	67.1	67.9	92.3	101	10%	27%
5.5	Middle East & Africa	0.3	0.4	1.6	1.9	3.7	3.1	6.7	5.5	-18%	50%
5.6	China	2.2	5.4	10	14.9	24.3	37.4	44.5	52.2	17%	57%
5.7	India	2	2.9	4.7	5.6	4.7	4.2	7.6	12.3	62%	29%
5.8	Other Asia-Pacific	7.2	8	8	10.1	11	12.1	18.4	21.1	15%	17%
	Total	***39.5***	***60.8***	***96.5***	***132.8***	***166.6***	***160.9***	***219.8***	***257.5***	***17%***	***31%***

* Compound average annual growth rate.

Note: New investment volume adjusts for re-invested equity. Total values include estimates for undisclosed deals.

Source: UNEP (2012).

Annex C: About the UNEP Division of Technology, Industry and Economics

The UNEP Division of Technology, Industry and Economics (DTIE) helps governments, local authorities and decision-makers in business and industry to develop and implement policies and practices focusing on environmental protection and sustainable development. In 2008, UNEP's new Medium Term Strategy (MTS) was adopted along six strategic priorities: climate change, disasters and conflicts, ecosystem management, environmental governance, harmful substances and hazardous waste, and resource efficiency. The selection of these six themes was guided by scientific evidence, the UNEP mandate, and priorities emerging from global and regional forums. UNEP's mandate has five main interrelated areas:

- **Keeping the world environmental situation under review.** UNEP provides access to environmental data notably through the Global Environment Outlook, which regularly assesses environmental change and its impact on people's security, health, well-being and development.

- **Providing policy advice and early warning information, based upon sound science and assessments.** UNEP has created several international scientific panels such as the Intergovernmental Panel on Climate Change, jointly established with the World Meteorological Organization in 1988 to assess the state of existing knowledge about climate change. The IPCC's reports helped raise awareness among the media and the general public about the human-made nature of climate change. UNEP also set up the International Panel for Sustainable Resource Management in 2007 and the Intergovernmental Platform on Biodiversity and Ecosystem Services in 2008. These complementary initiatives are aimed at providing policymakers with the science on which to base their decisions.

- **Facilitating the development, implementation and evolution of norms and standards and developing coherent links between international environmental conventions.** UNEP has helped establish and implement many international environmental agreements – such as the Montreal Protocol to restore the ozone layer, a growing number of treaties that governs the production, transportation, use, release and disposal of chemicals, and the family of treaties that protects global biodiversity.

- **Catalyzing international co-operation and action and strengthening technology support and capacity in line with country needs and priorities.** UNEP encourages decision-makers in governments, industries and businesses to develop and adopt environmentally sound policies, strategies, practices and technologies. This involves raising awareness, building international consensus, developing codes of practice and economic instruments, strengthening capabilities, exchanging information and initiating demonstration projects.

- **Raising awareness and promoting public participation.** UNEP publications and outreach activities help disseminate scientific information to decision-makers and provide them with policy guidance. Moreover, special public events like the World Environment Day (every 5 June) or the Billion Tree Campaign stimulate worldwide awareness of environmental issues, encourage political action and promote behavioural change.

The Division works to promote:

- Sustainable consumption and production.
- Efficient use of renewable energy.
- Adequate management of chemicals.
- The integration of environmental costs in development policies.

The Office of the Director, located in Paris, co-ordinates activities through:

- The International Environmental Technology Centre – IETC (Osaka, Shiga), which implements integrated waste, water and disaster management programmes, focusing in particular on Asia.
- Production and Consumption (Paris), which promotes sustainable consumption and production patterns as a contribution to human development through global markets.
- Chemicals (Geneva), which catalyzes global actions to bring about the sound management of chemicals and the improvement of chemical safety worldwide.
- Energy (Paris), which fosters energy and transport policies for sustainable development and encourages investment in renewable energy and energy e!ciency.
- OzonAction (Paris), which supports the phase-out of ozone depleting substances in developing countries and countries with economies in transition to ensure implementation of the Montreal Protocol.
- Economics and Trade (Geneva), which helps countries to integrate environmental considerations into economic and trade policies, and works with the finance sector to incorporate sustainable development policies.

Set up in 1975, three years after UNEP was created, the Division of Technology, Economics (DTIE) provides solutions to policymakers and helps change the business environment by offering platforms for dialogue and co-operation, innovative policy options, pilot projects and creative market mechanisms.

DTIE plays a leading role in three of the six UNEP strategic priorities: climate change, harmful substances and hazardous waste, resource efficiency.

DTIE is also actively contributing to the Green Economy Initiative launched by UNEP in 2008. This aims to shift national and world economies on to a new path, in which jobs and output growth are driven by increased investment in green sectors, and by a switch of consumers' preferences towards environmentally friendly goods and services.

Moreover, DTIE is responsible for fulfilling UNEP's mandate as an implementing agency for the Montreal Protocol Multilateral Fund and plays an executing role for a number of UNEP projects financed by the Global Environment Facility.

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[i] The PEI measures the combined impact of three driving factors (IEA,2008):
- The strength of a country's policy ambition, which may be expressed in terms of quantified target.
- The existence of well- designated and effective measures, such as incentive schemes or quotas/ mandates.
- The capability of overcoming non- market barriers to investment in renewables.

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This report summarizes, in non-technical language, the results of recent UN- sponsored studies to assess global trends in the deployment of renewable energy technologies and the effectiveness of related government policies, including detailed analyses of Brazil and South Africa, and draws out broad lessons on assessing such policies. It aims to provide guidance to policymakers in other countries seeking to better understand the potential for renewables to play a bigger role in meeting their energy needs and how to go about assessing the effectiveness of policies to exploit that potential.

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