Changing Climates

The Role of Renewable Energy in a Carbon-Constrained World

A Paper Prepared for
REN21
By The United Nations
Environment Programme
(UNEP)

REN21 Renewable Energy Policy Network for the 21st Century

Lead Authors
John Christensen,
Fatima Denton,
Amit Garg,
Sami Kamel,
Romeo Pacudan,
UNEP Risoe Centre
Eric Usher,
UNEP Energy

January 2006

Renewable Energy Network for the 21st Century (REN21)

REN21 is a global policy network aimed at providing a forum for international leadership on renewable energy. Its goal is to allow the rapid expansion of renewable energies in developing and industrial countries by bolstering policy development and decision-making on sub-national, national and international levels.

A dynamic policy network will increase the ability of the renewable energy community to influence national legislation and international processes. Open to a very wide variety of relevant and dedicated stakeholders, REN21 helps create an environment in which ideas and information are shared and cooperation and action are encouraged to promote renewable energy worldwide.

REN21 connects governments, international institutions and organisations, partnerships and initiatives and other stakeholders on the political level with those "on the ground". Taking into account their work, REN21 is not an actor itself but a set of evolving relationships oriented around a commitment to renewable energy.

Disclaimer

REN21 Issue Papers are released by REN21 to emphasize the importance of renewable energy, and to generate discussion of issues central to the promotion of renewable energy. While REN21 Issue Papers have benefited from the consideration and input of the REN21 community, they do not necessarily represent a consensus among Network participants on each point made in the Papers. The vision, views and information expressed are those of the authors and do not necessarily reflect the position of the REN21 network.

Further, the contents of this Paper do not necessarily reflect the views or policies of UNEP or the editors, nor are they an official record. The designations employed and the presentation do not imply the expression of any opinion whatsoever on the part of UNEP concerning the legal status of any country, territory or city or its authority, or concerning the delimitation of its frontiers or boundaries.

Acknowledgements

Contributing Authors

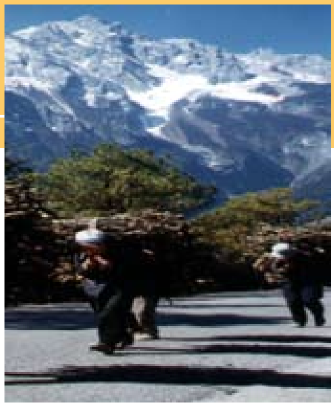
Virginia Sonntag-O'Brien, David Kline, Alia Ghandour, Douglas J. Arent, Emilio La Rovere and Andrea Felipe Simoes.

Thanks to the following for providing reviews and inputs:

REN21 Bureau and Paul Suding(GTZ), Martin Schöpe and Birgit Schwenk(BMU). Mark Radka in UNEP. Jamal Saghir and colleagues at World Bank, Members of GNESD with specific thanks to Jose Goldemberg, Ogunlade Davidson and Amit Kumar. Authors of the two other REN21 papers Molly Aeck and Eric Martinot (Worldwatch), plus individual reviewers especially Gustavo Best (FAO), Dan Kammen (UC Berkeley) and Jennifer Morgan (WWF).

Thanks to Selco for use of the photograph on page 27 and to the American Wind Energy Association for the use of their chart on wind power additions, page 2 and 17.

Table of Contents



Executive Summary

Climate change is recognized as a major issue of global concern

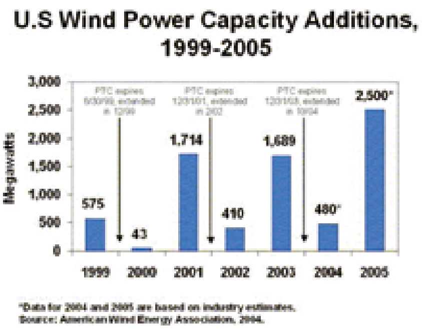
There is increasing consensus in both the scientific and political communities that significant reductions in greenhouse gas emissions are necessary to limit the magnitude and extent of climate change. Even with a stabilized atmospheric carbon dioxide concentration of 450 parts per million, the emerging consensus is that the current politically discussed target of a maximum change of 2°C will likely be exceeded.

Fossil fuels are the major contributor

The majority of greenhouse gas (GHG) emissions come from the use of fossil fuels to power a growing US$60 trillion world economy. Industrialized countries are responsible for the majority of current and historic emissions, but many developing countries are significantly increasing their share as their economies expand. This is especially true in some of the large emerging economies, such as China and India, that have sustained high economic growth.

The Kyoto Protocol is just a first step

The United Nations Framework Convention on Climate Change (UNFCCC) has established an international framework for action on climate change. With the ratification of the Kyoto Protocol, a first step has been taken to reduce the emissions up to 2012, although all emission scenarios indicate that these reductions will not be enough to significantly reduce the threat of climate change. The Kyoto Protocol was intentionally designed as a process with progressively increasing reduction requirements and participation by all countries. How these intentions will be met is the main focus of negotiations for the post-2012 period.



Renewable energy has evolved rapidly as costs continue to decline

The term *renewable energy* covers a number of sources and technologies at different stages of development. By their nature, renewable energy sources are generally carbon-free or carbon neutral. Many renewable energy technologies have matured over the last decade and moved from being a passion for the dedicated few to a major economic sector attracting large industrial companies and financial institutions. Renewable energy technologies such as windpower and solar photovoltaic (PV) devices have achieved major cost reductions over the last decades, which are expected to continue in the medium term as large global companies enter new energy markets for wind, solar and biomass technologies.

The traditional finance community is also gradually including renewable energy projects into their mainstream lending portfolios. The REN21 *Global Status Report* notes that in 2004, about US$30 billion was invested in a renewable energy sector that contributes 160 GW, or approximately 4% of global power capacity.

Although modest today, renewable energy will grow to a major role

Renewable energy systems already reduce GHG emissions from the energy sector, although on a modest scale. Most long-term energy projections show that renewable energy will play a major role in the global energy supply in the second half of the century, with capacity increasing gradually in the first three decades. The analysis presented in Chapter 3 concludes that:

- Global energy demand will continue to grow, increasing by approximately 50%-60% by 2030 unless major efforts are successful at increasing energy efficiency and reducing overall energy use.
- The domination of fossil fuels in current energy supplies will not automatically change in the next

decades unless renewable energy becomes more cost competitive, or prices for oil and gas remain or surpass current levels above US$50 barrel.

A limit to global warming of 2°C above pre-industrial levels can avoid the most serious climate change threats. However, this level can only be reached with major long-term emission reductions from many different and combined options, including larger renewable energy markets, efficiency improvements, and cleaner fossil fuels.

> *"Due to the long time lags, the next 10 to 20 years are the decisive window of opportunity for transforming energy systems. If this transformation is initiated later, disproportionately high costs must be expected."*
>
> *German Advisory Council on Global Change (WBGU)*

Basic policy questions remain

Basic policy questions include how to ensure continued technological progress, overcome implementation barriers, and accelerate the shift to renewable energy. Although there are many good political, economic and social reasons for stimulating a more rapid development of renewable energy, the sector is hampered by a number of market distortions and institutional, financial, and economic barriers.

Overcoming these barriers and accelerating the current gradual transition to renewable energy can be accomplished with the right policy mix as an important and necessary action to mitigate potential impacts of climate change.

Recent increases in the price of oil and gas have also stimulated concerns about longer-term prices and supply security. These concerns, and environmental impacts from the use of fossil fuels, can be addressed through greater penetration of renewable energy into expanding energy markets.

Chapter 4 shows there is already significant policy experience in many countries, which can create significant and sustained growth of renewable energy markets in both developed and developing countries. Successful examples all are characterised by an approach that:

- Combines different policies, rather than just a single policy,
- Applies long-term and predictable policy support, and
- Adapts and uses the power of markets.

Economic policy can create the right signals

Creating cost competitive renewable energy systems and technologies is the most important challenge, and an area where economic policy instruments can quickly make a difference. With an energy sector that is increasingly deregulated and market orientated, the use of economic policy instruments has proven to be an effective strategy to stimulate change. The evolving experiences with carbon finance and emissions trading also show promising results to provide strong, longer-term incentives for developing renewable energy markets.

R&D is essential

Analysis of R&D expenditure shows that the recent increased commercial interest in renewable energy has not resulted in higher R & D investment, which is still predominantly oriented towards nuclear and fossil technologies. It is, however, fundamentally important to reduce costs in the medium and longer term by increasing and targeting R & D programmes. Education and broader efforts will also be needed to increase the necessary technical and economic expertise for scaling-up the industrial production and use of renewable energy technology.

And most importantly. . . .

To accelerate both the development of better renewable energy technology and markets in the next decades, policy action is required at both national and international levels. The specific policy tools need to fit local circumstances, but significant experience is already available to guide the development of these policies. Targets and timetables at the global level to reduce emissions – such as those established under the Kyoto Protocol – or develop technologies can be important instruments to ensure and accelerate national action and to guide private investment decisions in the increasingly globalised economy. With the current and predicted cost competitiveness of many renewable energy technologies, however, it is not necessary to wait for strengthened global agreements before taking action at the national level.

> *Climate change is a serious and long-term challenge that has the potential to affect every part of the globe. We know that the increased need and use of energy from fossil fuels, and other human activities, contributes in large part to increases in greenhouse gases associated with the warming of our Earth's surface. While uncertainties remain in our understanding of climate science, we know enough to act now to put ourselves on a path to slow and, as the science justifies, stop and then reverse the growth of greenhouse gases.*
>
> *- G8 Gleneagles Communiqué, July 2005*

1. Background and Context

Scope: Renewable Energy and Climate Change

Over the past two or three decades, the issue of anthropogenic climate change has emerged from a debate in closed scientific circles to a global topic of the highest political importance.

Figure 1.1 (Vital Climate Graphics – update 2005, GRID Arendal) illustrates the increasing concentration of CO_2 in the global atmosphere - primarily due to emissions from energy production and use - along with possible future concentrations depending on emission patterns.

The atmospheric concentration of greenhouse gases (GHG) has grown significantly since pre-industrial times, increasing by about 31% for carbon dioxide, 150% for methane, and 16% for nitrous oxide (IPCC, 2001). The present carbon dioxide concentration of approximately 375 parts per million (ppm) is the highest for 420,000 years, and probably the highest for the past 20 million years.

There is still scientific and political debate about the possible consequences of stabilizing GHG emissions at different concentrations. Although the issue of “dangerous interference” (as noted in the UNFCCC) is also debatable, the emerging consensus illustrated by O’Neill & Oppenheimer (2002) points to a concentration range of 450 to 550 ppm to avoid socially unmanageable climate impacts.

The focus of the current political debate is on a maximum two-degree change, but estimates by the EU Institute of Prospective Studies (Soria, 2005) indicate that even at 450 ppm, the likelihood of exceeding a two-degree change is more than 50%. It is important to stress, however, that the *pace of change* is as important a parameter as the *magnitude of change* since many ecosystems can adapt to moderate changes provided they take place over an appropriate period of time.

It is clear that future developments of the global energy system will not be driven solely by climate change concerns. Economic and financial opportunities and constraints will be important, along with issues of energy security, increased access to modern forms of energy in developing countries, cost of imported fuels, and a number of more specific national priorities.

The current paper on renewable energy and climate change is therefore focused directly on the key characteristics of the climate change challenge, the intergovernmental action to address the challenge, and how current and future renewable energy projects can contribute to global carbon mitigation and adaptation efforts at the local level.

Changing Climates is not prescriptive, but presents the current and possible different future contributions that renewable energy can make. This is based on analysis of different authoritative global scenarios and their underlying assumptions, and is aimed at providing guidance on what would be required in terms of policy decisions and technological developments if renewable energy is going to significantly mitigate climate change.

Although the focus of *Changing Climates* is particularly on climate change and the opportunities for renewable energy, other issues are closely interlinked. Reducing GHG emissions by introducing more renewable energy, for example, will also have positive impacts on the security of energy supply, while potentially compounding the need for investment capital.

Changing Climates begins with the current global energy demand and the contribution of renewable energy to meeting that demand. Next, different key internationally recognised energy development scenarios are presented from the Intergovernmental Panel on Climate Change (IPCC) and the International Energy Agency (IEA), together with selected policy scenarios of very different specific options to mitigate climate change and stabilize CO_2 levels in the range of 450-550 ppm. These scenarios are presented with both high and limited penetrations of renewable energy, along with discussions of underlying assumptions leading to these different results, including comparisons of projected technology costs.

Existing policies worldwide to promote renewable energy are then analysed for their relative efficiency and results. Guidance is presented on the possible policy tools governments can use to move from the stipulated “business-as-usual” – or BAU – renewable energy expansion to a level where renewable energy makes a major contribution to climate change mitigation over the coming decades.

To present realistic recommendations, barriers and opportunities for such a renewable energy expansion are discussed separately. It is not possible to “translate” the results of the global scenarios directly into requirements for policies at the national level. The aim of the section is therefore to show that action is already taking place, which can be scaled-up. Further, experiences with a wide variety of different policy tools are available, which support the realistic call for stronger policies.

The financial implications and requirements related to different short and medium term “energy futures” are then discussed with analysis of current actions and the specific challenges related to rapidly expanding the renewable energy sector. The specific role that carbon finance can play in this regard is addressed in detail. Linking the long-term forecasts directly to finance requirements or even summing up the costs over 100 years would not provide significant (or meaningful) policy insights. Focus is therefore on the trends for the longer term costs of different technologies.

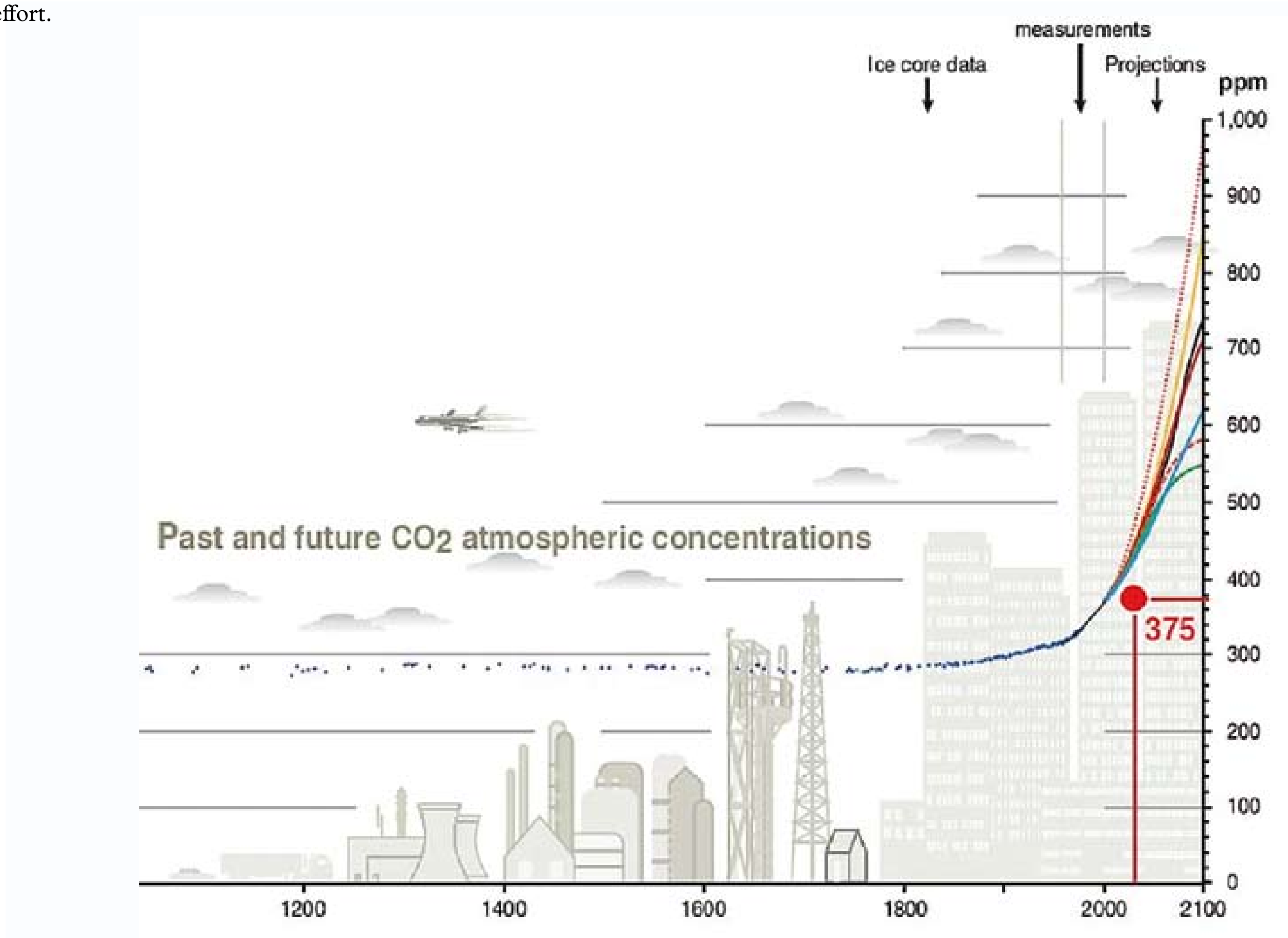
Because all predictions indicate that the Earth will face some level of climate change – even with urgent and decisive action on the mitigation side – *Changing Climates* briefly discuses the possible role that different renewable energy technologies can play to adapt or reduce the vulnerability to climate

change. More analysis is needed to better identify specific renewable energy contributions, although the chapter does provide some initial indications.

It is important to emphasize that the scope here is to examine the contribution of renewable energy to mitigating climate change. The implicit assumption is that this will need to be considered in close connection with activities related to energy conservation and improved efficiency in both energy production and use. This understanding is also embedded in the scenario analysis presented in Chapter 3.

Making this link explicit would merit an entirely separate investigation since energy efficiency and conservation present challenges of a different nature in terms of technologies, policies and implementation. It is therefore considered beyond the scope of this effort.

Fig. 1.1 Past and possible future concentrations of CO2 in the atmosphere.



2. International Action on Climate Change and Energy

Intergovernmental Response to Climate Change

In 1988, UNEP and the World Meteorological Organisation jointly established the Intergovernmental Panel on Climate Change (IPCC) with a mandate to assess the best scientific efforts on climate change, its potential impacts, and possible response strategies.

Since then, the IPCC has produced three comprehensive assessments of the underlying climate science, the possible impacts of projected changes and related adaptation options, and possible mitigation actions. In addition, the IPCC has produced a number of special and technical reports that have significantly helped to inform the global community about likely climate changes, impacts and response options. The IPCC is currently preparing its Fourth Assessment that is due for release in 2007.

Since the underlying scientific efforts have increased tremendously in the 17 years since the IPCC started, the assessments now provide increasingly clearer answers about the likely changes and associated impacts of climate change, and emphasize the need for urgent action on mitigation efforts to ensure that the speed of change is not greater than the global community's capacity to cope.

As a political response to increased climate change concerns, the United Nations Framework Convention on Climate Change (UNFCCC) was negotiated on the basis of initial IPCC findings. The UNFCCC was established and signed by almost all countries in 1992 at the Rio Summit.

One of the major political tools of the Convention is the Kyoto Protocol, which was negotiated and signed in 1997. The Protocol establishes specific GHG reduction targets for all ratifying industrialised countries and a timetable to achieve these targets, plus a process to negotiate later commitments.

The average reduction to be achieved by industrialised countries over the period 2008-2012 is approximately 5% compared to their reported emissions in 1990. Although this is small reduction from 1990 levels, it translates into a 25 – 30% reduction compared to the previously estimated emissions growth in the period from 1990 to 2012.

Due to the strict rules for ratification by major greenhouse gas emitters, the Protocol only entered into force on February 16, 2005. Although major GHG emitters such as the US and Australia have not ratified the Protocol, it has been ratified by 150 states and regional economic integration organisations (as of April 2005).

As is illustrated in Chapter 3, the agreed Kyoto targets – while considered ambitious by some – are still far from sufficient to stabilise atmospheric GHG concentrations in the 450-550 ppm range. Efficiently making further emission reductions is therefore a very important part of the global political agenda, as illustrated recently at the meeting of the G8 heads of state in July 2005, where climate change had a major focus.

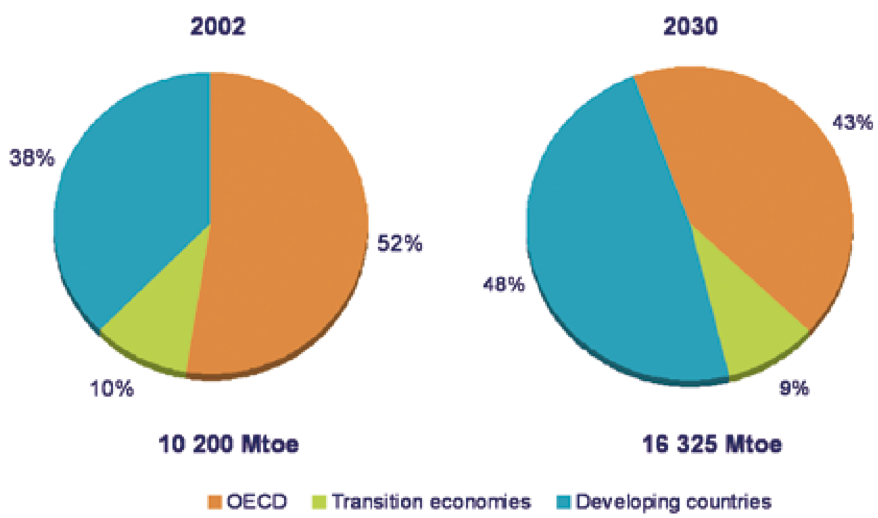
The Role of Energy in Climate Change

Energy activities are by far the largest emitter of greenhouse gases. Their relative dominance can be illustrated by the following figures from the latest compilation of GHG emission data by the UNFCCC Secretariat which are based on national emission inventories from developed countries (called 'Annex I' parties under the Convention).

Total emissions reported for 2002 were approximately 15 gigatonnes (GT) of CO_2 equivalent. Of this amount, 12. 4 GT - or 83% - was in the form of CO_2 with the rest mainly composed of CH_4, N_2O and a mix of other gases. Emissions associated with fuel combustion were estimated at 11. 7 GT, which means that energy contributed 78% of total GHG emissions from Annex I countries.

For developing countries (called 'non-Annex I countries' under the Convention) estimates of GHG emissions indicate a similar dominance by the energy sector, which are less than developed countries but increasing.
Many studies have analysed current and future GHG emissions and the expected shift in contributions between the major country groupings. Fig. 2. 1 from the IEA World Energy Outlook 2004 (IEA, 2004) provides a good illustration of the projected shift towards the increased importance of developing countries, although the detailed figures are naturally very dependent on underlying scenario assumptions.

Fig. 2.1 Regional Shares in World Primary Energy Demand (IEA, WEO 2004)



In summary, it is evident that emissions from energy production and use are the main source of GHG emissions, with industrialised countries responsible for the major share of historic and current emissions. At the same time the IEA report recognised that an increasing share of future energy development and related emissions will be coming from developing countries. This is clearly a challenge for future climate change negotiations where countries will have to meet the agreed UNFCCC principle of common but differentiated responsibilities.

Intergovernmental Action on Energy and Renewable Energy

The general status and development of renewable energy is presented in the *REN 21 Global Status Report*. It will only briefly be discussed here and with a focus on intergovernmental actions.

In parallel with the agreement on the UNFCCC, the Rio Summit's Agenda 21 plan of action included major program areas, such as promoting transitions to different energy sources, increasing energy efficiency, promoting renewable energy sources, and promoting sustainable transport systems. Energy issues where clearly recognised, but limited specific action was proposed with any level of commitment.

The UN Commission on Sustainable Development (CSD) was established to provide the formal mechanism to follow the implementation of Agenda 21. The CSD 9 in 2001 was dedicated to energy, atmosphere and transport issues - the first time a high level body under the UN discussed the full global energy agenda. In itself, this was a significant event and the result of increasing global recognition of the importance of energy issues in all aspects of sustainable development.

The CSD 9 event also provided a platform for including energy as a priority area for the 2002 World Summit on Sustainable Development (WSSD). During the WSSD itself, energy became one of the major topics on the global agenda for the first time.

A number of countries, including the host South Africa, pushed strongly for agreement on some form of energy targets where countries could commit to moving towards more sustainable and renewable energy systems.

No global agreement on energy targets was reached, but a number of *Type II* initiatives (supported by a number of governments but not requiring global agreement) were launched, including 40 in the energy area. Some of the major initiatives with a broad global mandate include the *EU Energy Initiative (EUEI)*, the *Global Village Energy Partnership (GVEP)*, the *Global Network on Energy for Sustainable Development (GNESD)* and the *Renewable Energy and Energy Efficiency Partnership (REEEP)*. In addition, many of the countries backing the target discussions formed the *Johannesburg Renewable Energy Coalition (JREC)* committed to cooperatively promoting renewable energy. The JREC currently has 87 member countries, including 32 with some form of national renewable energy targets.

Many governments at the WSSD announced initiatives to promote renewable energy, with the major follow-up opportunity provided by the German Government that committed to hosting a global renewable energy conference. The Bonn Conference on Renewable Energies was subsequently held in June 2004, ending with:

- A Political Declaration
- An International Action Programme
- Policy Recommendations for Renewable Energies

In addition to many commitments made by different stakeholders as part of the international action programme, the main follow-up of the Bonn Conference will be coordinated by the Renewable Energy Network for the 21st Century (REN21), which provides a forum for international cooperation on renewable energy.

In parallel with the Bonn Conference, the intergovernmental process at the WSSD established a revitalised process for the CSD and decided that sessions in 2006 and 2007 will address both energy for sustainable development and climate change.

It is evident that the topic of "energy" has gradually moved over the last decades to the forefront of the international political agenda, and which is most clearly illustrated at the WSSD. The important position of energy has been significantly enhanced by increased geopolitical concerns about the security of energy supplies and the related increase of oil prices to one of its highest historical levels.

The *REN21 Global Status Report* presents in great detail recent renewable energy developments and the current renewable energy contribution to the overall energy sector. The focus here is therefore on the analysis of projected future demand and how this can be met in very different ways with a portfolio of technologies. The underlying reasons for different projections are analysed with a focus on cost projections for different technologies and conditions for a high renewable energy penetration in the global energy sector.

3. Current and Possible Future Contributions From Renewable

Renewable Energy and the Current Global Energy Demand

According to the BP Statistical Review (BP 2005), world primary energy consumption in 2004 was approximately 10,200 Million Tonnes of Oil Equivalents (MTOE) or approximately 428 Exajoules (EJ).

Fig. 3.1 shows the historical development in primary energy demand and illustrates the dominance and increasing importance of fossil fuels in the last decade. BP's figures only include commercial fuels and do not include uses of non-commercial biomass in developing countries or any other non-traded energy source.

To provide a more detailed picture, Fig. 3. 2 has been included, illustrating the share of non-commercial biomassas well as a more detailed breakdown of the overall renewable energy contribution. The figure is from the report by the German Advisory Council on Global Change (WGBU) called *World in Transition – Towards Sustainable Energy Systems* (WBGU, 2003), which presents world primary energy consumption by energy source in 1998[1] , plus indications of the range of fossil fuel reserves.

While Fig 3. 2 presents a more complete picture, it confirms the current relatively small renewable energy contribution. Even if there has been a rapid expansion of renewable energy development since 1998, it has, to date, not substantially exceeded the growth in energy demand. Since then, the renewable energy share has therefore only increased marginally at the global level.

Fig. 3.1 World Primary Energy Consumption by fuel (BP, 2005)

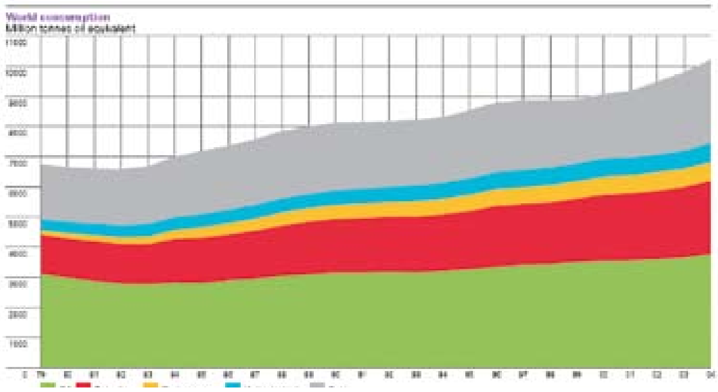


Fig 3.2 Primary Energy Demand by Source (WBGU, 2003)

Energy source	Primary energy [EJ]	Share [%]	Static range of reserves [Years]	Static range of resources [Years]	Dynamic range of resources [Years]
Oil	142	35.3	45	~200	95
Natural gas	85	21.1	69	~400	230
Coal	93	23.1	452	~1,500	1,000
Sum of fossil energy sources	*320*	*79.6*			
Hydropower	9	2.2		renewable	
Traditional biomass	38	9.5		renewable	
New renewables	9	2.2		renewable	
Sum of renewables	*56*	*13.9*			
Nuclear power	26	6.5	50	>>300	
Total sum	*402*	*100.0*			

Future Energy Demand and the Role of Renewable Energy

Future energy projections are driven by assumptions on key variables such as the global population, economic growth, technology development and diffusion, global and regional economic integration, fuel prices, agriculture, land-use patterns etc. Each scenario has its own set of assumptions and therefore presents different possible futures. To illustrate the span of scenarios and potential consequences for both the development of energy demand and the contribution from different energy sources, *Changing Climates* includes two of the most authoritative sets of scenarios prepared respectively by the IPCC and the IEA.

Fig. 3.3 shows the main IPCC scenarios produced as part of the *Special Report on Emission Scenarios – SRES* (IPCC, 2000). The four SRES scenario families (A1, A2, B1 and B2) project alternate global energy development and emissions up to the year 2100. The renewable energy projections include biomass and other renewable energy sources in the primary energy mix by fuel as well as land-use for biomass energy crops.

The four sets of scenarios were created assuming different directions for future development and building "storylines" representing progressively different development paths. This is illustrated by the A1 set focused around high economic growth and technological development, while B1 represents a more ecological development direction.

The renewable energy share (including large hydro) in global primary energy is projected to be between 8% (A2) to 17% (B2) under alternate scenarios in 2030. The share increases to above 61% under the A1 scenario in 2100, with biomass supplying 17% and resulting in almost 4% of global land use devoted to biomass for energy purposes.

It is important to emphasize that SRES scenarios are not policy intervention scenarios but simply an attempt to illustrate the range of possible futures, and it is clear the major differences

Energy

occur in the longer term. In 2030, the expected demand increase is relatively similar in all scenarios, and while the share of renewable energy differs somewhat, the share in 2030 remains relatively small in all cases.

In the *World Energy Outlook 2004*, the IEA presents both a *Reference Scenario* (business-as-usual) and an *Alternative Policy Scenario* illustrating what could be achieved if countries around the world adopted the more progressive environmental policies they were already considering or might be expected to adopt. In that case, energy demand in 2030 could be about 10% lower than in the Reference Scenario, almost halving the growth of CO_2 emissions from 2002 to 2030.

Renewable energy technologies would play an increasing role in the alternative low emission energy development path, contributing around 20% of the projected emission reductions according to IEA estimates. However, end use energy efficiency improvements will have to carry the bulk of reductions - around 60% - with changes in the mix of fossil fuels and nuclear energy responsible for the remaining reductions.

The projected increase of almost 60% in total demand by 2030 to 16,200 MTOE is very similar to the 2030 estimates in all four IPCC scenarios (650 to 700 EJ), illustrating that basic changes in consumption and production patterns have a long lead time.

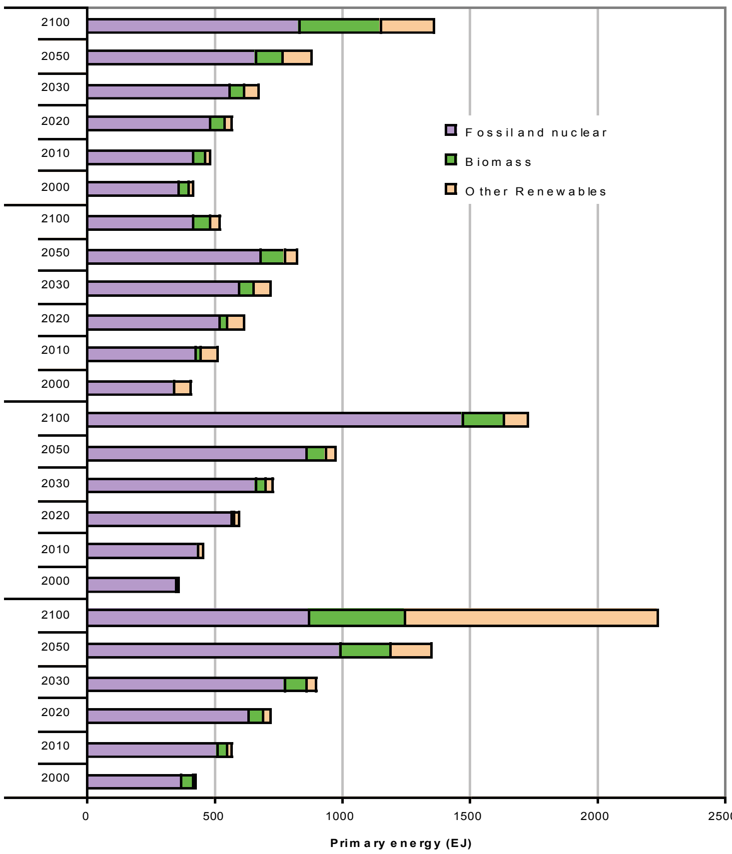
A large number of studies have been developed with different assumptions of policy interventions. Two have been selected here: a *renewable energy promotional analysis* represented by the WBGU that includes a strongly policy-driven "exemplary path" to stabilise the GHG concentration at 450ppm, and as comparison, *a study by one of the leading global modellers*, Prof. Edmonds, Chief Scientist at the US-based Joint Global Change Research Institute of the Pacific Northwest National Laboratory. This specific study focuses on carbon sequestration options and included here to illustrate that a 450 or 550 ppm carbon dioxide atmospheric concentration can be achieved in very different ways depending on technology development, cost improvements, and policies over the next decades.

Comparing the IEA scenarios to the WBGU analysis, it is evident that energy demand projections are quite similar. Therefore, it is the *detailed* assumptions behind the scenarios that lead to different technological solutions. Primary consumption in 2030 is even slightly higher in the WBGU scenario than estimated by the IEA, but the supply from advanced biomass and wind energy sources is significantly higher. After 2030, the WBGU projections gradually shift towards an energy system based on solar energy, with fossil fuel use peaking in 2030/2040 at around 600 EJ and then declining the rest of the century.

The analysis is constrained to reach an atmospheric GHG concentration of 450 ppm, so technology shifts are introduced partly by changes in cost levels and partly from policies constraining emissions. The WBGU scenario notes, "*Due to the long time lags, the next 10–20 years are the decisive window of opportunity for transforming energy systems. If this transformation is initiated later, disproportionately high costs must be expected.* "

Figure 3.3: World primary energy projections (EJ) under alternate scenarios

Source: SRES, 2000



Different Options for a Carbon Constrained World

The WBGU analysis represents a strong, renewable energy based solution to meet carbon constraints of a 450 to 550 ppm atmospheric carbon dioxide concentration. A similar type of analysis by J. Edmonds et al (Edmonds, 2002) is presented in Fig. 3. 5 and focused on achieving GHG stabilisation at around 550 ppm.

The Edmonds study has quite a different focus from the WGBU analysis - placing much more emphasis on carbon capture and storage, and the role of hydrogen as an energy carrier for transport. So while the figure presents a similar peak and decline of fossil fuels, the study identifies quite a different portfolio of technologies for reaching the stabilisation target. Although the role of biomass and energy efficiency improvements is similar, the role of solar power is entirely different, and various types of sequestration technologies play a large role.

To better understand the differences presented in different types of scenarios, the underlying assumptions have been studied in detail, particularly in relation to costs for renewable energy technologies.

Compared to fossil fuels, renewable energy technologies are characterized by relatively higher capital costs but lower running costs. However, capital costs have substantially declined over the past two decades, with wind energy costs declining by a factor of four and solar PV by a factor of two. Fig. 3.6 presents a summary of the expected cost reductions over the coming decades for key renewable energy technologies. PV is projected to continue its current rapid cost reductions for the next decades while cost reductions for wind will gradually level off and reflect increased competitiveness with fossil based technologies.

The realisation of these projected cost reductions is naturally closely linked to market development, government policies, and support for research and development. If made, these cost reductions will allow solar, wind and biomass sources to compete with fossil fuels in the second half of the 21st century. As illustrated in table 3. 1, wind and biomass sources are already competitive under certain conditions.

Table 3.1 illustrates the span of projected cost assumptions, which is the main reason the above scenarios present such different technical solutions to carbon constraints.

Another contributing factor is the assumptions about fossil fuel prices where, for example, the IEA WEO assumes crude oil prices will remain below US$29 per barrel until 2030. This is still close to a consensus with other EU and US forecasts.

However, the Reference Scenario of the WEO 2005 (just published and therefore not fully referenced here), shows that according to the most recent analysis, prices are expected to fall from their current levels to around US$35 in 2010 and then climb to US$39 in 2030. The WEO 2005 also contains a "Deferred Investment Scenario" where averaged prices are 20% higher over the period.

Some general conclusions can be drawn from the presented analysis:

- Global energy demand will continue to grow and is expected to increase approximately 50%-60% by 2030 unless major conservation and efficiency programmes are undertaken.
- Current energy supply is dominated by fossil based technologies. With current price expectations and reserve projections, this domination will not dramatically change in the next decades unless renewable energy technologies become more cost competitive.

Fig. 3.4 Transforming the global energy mix: The exemplary path until 2050/2100. Source: (WBGU, 2003)

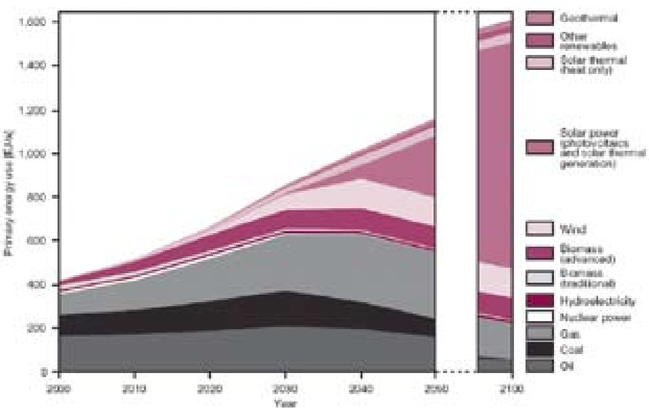


Figure 3.5: World primary energy projections (EJ) under alternate scenarios (Edmonds et al. , 2002)

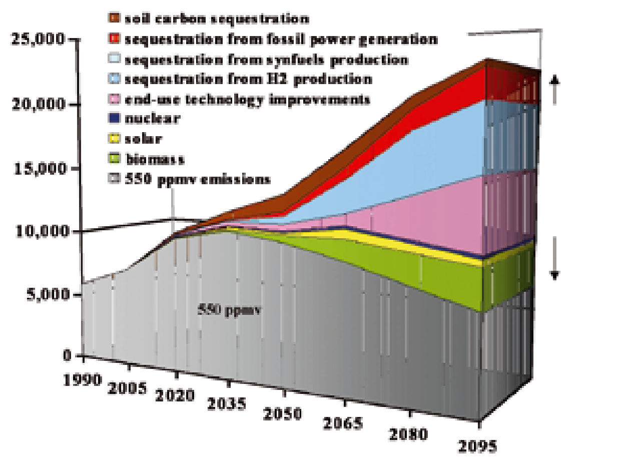


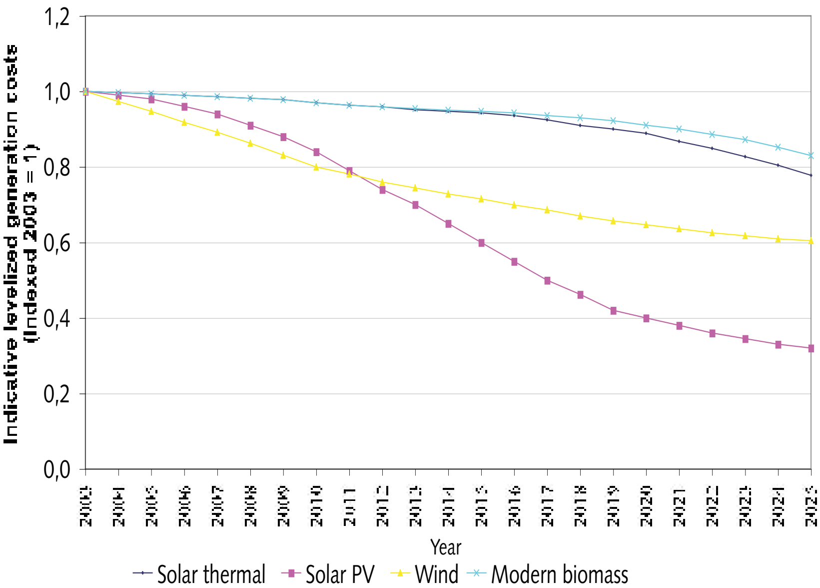
Table 3.1: Indicative power generation costs (US 2000$ cents per kWh)
Derived and compiled from IEA 2004; IPCC TAR (WG-3, chapter 3) 2001; ICCEPT 2002; Wind Force 12; EPRI Renewable Energy Technical Assessment Guide (http://www. epri. com/portfolio/product. aspx?id=1315&area=30&type=10); http://www. hawaii. gov/dbedt/ert/rps01/gec01. html

Technology	2005		2010		2020		2030		2050		2100	
	Low	High	Low	High	Low	High	Low	High	Low	High	Low	High
Large hydro	2	8	2	7	2	7	2	8	3	12	4	15
Wind	3	10	3	7	3	6	2	5	2	6	3	7
Small hydro	4	15	4	15	3	12	3	10	3	10	3	12
Modern biomass	5	15	5	14	5	12	3	10	3	10	3	12
Solar PV	18	80	10	60	6	35	4	10	3	10	3	8
Solar thermal	12	18	10	16	7	12	4	10	3	10	3	8
Other (geothermal, tidal etc.)	5	20	3	18	4	14	3	12	3	10	3	10
Nuclear	1. 2	5	1	5	1	4	1	4	1	4	1	4
Coal	2	7	2	7	2	6	2	6	2	6	2	6
CCGT	3	10	3	10	3	12	4	14	6	18	6	18
Gas turbine	4	10	4	10	4	12	5	14	6	18	6	18

- The atmospheric GHG concentration of 450-550 ppm can only be reached with major long-term emission reductions from either a larger renewable energy penetration, or significant efforts to increase carbon storage and sequestration.
- Renewable energy technologies have achieved major cost reductions over the last decades and costs are expected to decline further in the coming decades. This will make most renewable energy technologies cost competitive by the middle of the century.
- Renewable energy is the fastest growing part of the energy sector, although it is starting from a very low base.

While it is evident global energy demand will gradually be met with an increasing share of renewable energy, the challenge is that this will only happen at a pace that leads to major changes in the energy mix in the second half of the century. The analysis of the carbon constraints imposed by associated climate change on the other hand, show that major

Figure 3.6 Indicative future levelized costs of power generating technologies (Indexed 2003 = 1)
Sources: Derived and compiled from (EWEA, 2003 and Renewable Hydrogen Forum 2003(http://www.ases.org/hydrogen_forum03/Forum_report_c_9_24_03.pdf) and http://europa.eu.int/comm/energy_transport/atlas/htmlu/rover31.html; http://www.ucsusa.org/clean_energy/renewable_energy/page.cfm?pageID=100;



reductions in GHG emissions will be required from around 2030 to ensure that the long-term stabilisation of GHG concentration levels is manageable.

The solution to this challenge clearly lies in the political arena and will, as indicated in the WBGU *Exemplary Path* analysis, require dedicated action by governments on policies for economic incentives, technology transfer, private sector investment, and research and development. The study by Edmonds et al. shows that climate constraints can be addressed in very different ways, and that increased utilisation of renewable energy is not the only solution. Under some assumptions, it is not even the main contributing factor.

The following section presents examples of projected actions at the national level. It is not possible to "translate" the results of the global scenarios directly into requirements for policies at the national level. The aim of the section is therefore to provide a practical insight on what is actually happening compared to the global analysis.

In total, however, the selection of national and regional examples covers the major part of the global energy scene, providing a snapshot of current analysis. In subsequent chapters, some possible options are presented for addressing the policy, institutional and financial challenges associated with a more rapid renewable energy expansion.

Regional and National Renewable Energy Projections

The following examples demonstrate some of the projections currently under analysis.

India

The possible implications of a 550 ppm stabilization for India have been analysed by Shukla et al. (2005), including a mitigation of 53% of projected emissions in 2095 and 31% in cumulative emissions for 105 years[2]. There are two major insights from this analysis.

First, a variety of sources contribute to mitigation, and since mitigation is required in large amounts and spread over the time horizon, it cannot be achieved with any single 'silver bullet' action. Practically, India needs every contribution from a wide range of options, including new and emerging technologies such as hydrogen and CO_2 capture and storage. Significant contributions from biomass sources, a carbon-neutral source, and energy efficiency are required to enable such choices.

The second insight is that most mitigation will be achieved by replacing coal in all possible industries and technologies. This has a very significant implication on energy security and on the need for large coal reserves under such a strong stabilization regime.

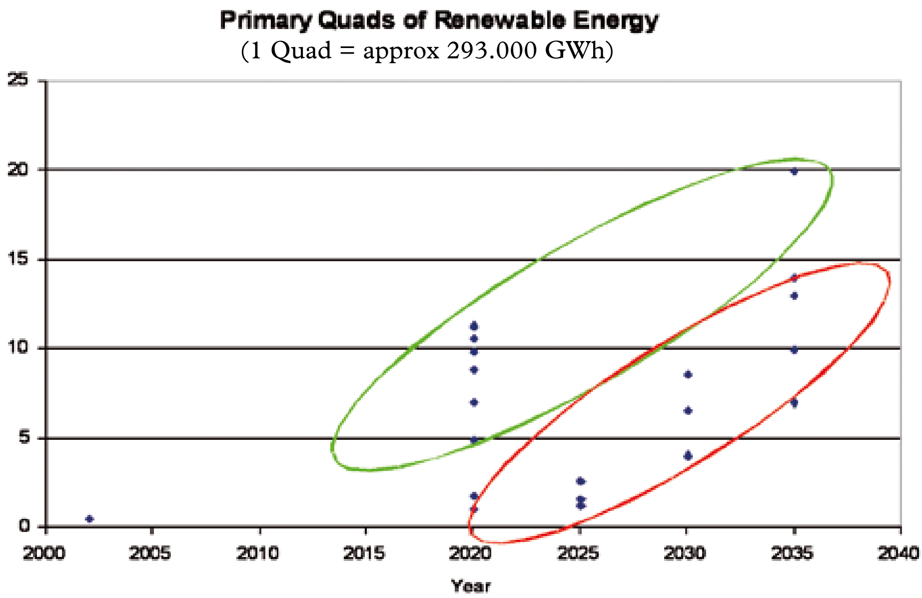
United States

The official US Energy Information Administration (EIA) projections are that grid-connected generators using renewable fuels in the US will remain minor contributors to U. S. electricity supply (AEO, 2005) – despite strong growth in renewable electricity generation as a result of technology improvements and expected higher fossil fuel costs. In their analysis, electricity generated from renewable energy sources increases from 359 billion kWh in 2003 (9. 3% of total generation) to only 489 billion kWh (8. 5%) in 2025.

Results like those already mentioned vary considerably, depending on critical scenario assumptions[3]. Results from a number of recent research studies[4]have therefore been analysed and are summarized in Figure 3. 7. Generally, these studies show a higher penetration of renewable energy, representing 15-20 quads of energy, or 10-20% of total primary energy by 2035, based on scenarios employing some combination of renewable portfolio standards (RPS) at the national level, strong support of energy efficiency, carbon constraint policies and increased R&D investments (to reduce costs).

Lower ranges of renewable energy penetration, as indicated by the EIA above, result from "business as usual" assumptions or moderate policy changes, including increased R&D and

Figure 3.7: Renewable Energy Penetration in the US



policies by state rather than federal agencies. None of the lower scenarios include a carbon tax.

European Union
The share of electricity generated from renewable energy sources for the European Union is targeted to increase from the current 14% to 21% by 2010 (EU, 2002). Policies and actions aimed at increasing the use of renewable energy have also been successful in some EU Member States, contributing to growth in electricity generated from renewable energy of 2. 8% per year. However, since electricity consumption grew by almost the same rate, the share of renewable energy in electricity generation remained almost constant during the 1990s.

Current BAU projections for the EU Commission Directorate-General Energy and Transport indicate that the share of renewable energy in power generation will only increase to around 18% by 2030[5]. Consequently, more vigorous policies strongly supporting renewable energy are required to meet the 2010 target, combined with measures to increase energy efficiency and energy conservation.

China
The Government of China's *Medium and Long-term Energy Development Strategy and Plan to 2020* has specific targets for renewable energy power generation. The increase from the current 35 GW capacity to the 60 GW target for 2010 will represent about 10% of China's total installed power generation capacity. The 2020 target of 121 GW will be about 12% of total projected enewable energy thermal sources, liquid biofuels, and other options. China's use of renewable energy is expected to increase to 20,000 PJ/year by 2020 – 17% of the country's projected total energy consumption.

To achieve these ambitious targets, the Government of China has established a *Renewable Energy Law* to be effective from 2006, as well as established a number of institutions to implement the targets.

These national examples illustrate the different levels of action in some of the largest countries. All national analyses indicate that significantly larger renewable energy use would be possible but depends to a very large extent on policies regulating national markets or incentives that make renewable energy more competitive in current market structures. As clearly illustrated by the Indian example of national assessments, major reductions of GHG emissions will come from a broad menu of technological options, with the specific selection depending very much on individual national circumstances.

4. Institutions and Policies

As discussed in Chapter 3, renewable energy can potentially play an important role in stabilizing greenhouse gas emissions and mitigating climate change. To secure broad public and policy support to promote renewable energy development, it is essential to include not only the climatic aspects, but also other broader economic, environmental, and social benefits in any analysis. It is therefore not possible to link the global scenario analysis directly to requirements for specific policies at a national level.

This chapter presents both some of the challenges of a major transition towards increased utilisation of renewable energy, and some of the many existing examples of actions taking place which can be scaled up, replicated in other countries, or form a basis for collective international agreements.

To effectively sustain support to renewable energy in the long-term, policy makers need to integrate renewable energy policy with non-energy sector and cross-sector issues. Agriculture/forestry, transport, economic development, poverty alleviation, education, urban and land-use planning and infrastructure development are among the policy areas that have the highest potential for renewable energy to enter mainstream energy options.

Chapter 3 concluded that the high renewable energy penetration scenarios could only be achieved with active intervention from governments in energy markets. Such market interventions involve removing existing market barriers and correcting market distortions limiting development and investments in renewable energy.

Barriers and Market Distortions

Investments in renewable energy are limited by energy market barriers that either increase the costs of renewable energy compared to other energy options, or unfairly discriminate against renewable energy choices. Generic barriers to renewable energy can be categorized into i) costs and pricing, ii) legal and regulatory, and iii) market performance (Beck and Martinot, 2004).

Costs and pricing barriers intensify the cost difference between renewable energy and conventional fuels. Legal and regulatory barriers refer to the absence/presence of rules that facilitate/discriminate market entry of renewable energy options while market performance barriers include factors that hinder financing of renewable energy projects.

Barriers in developing countries are similar to those of industrialised countries, although there are specific national characteristics that can play an important role.

Energy Market Distortions
In addition to market barriers, market distortions also impede the development of renewable energy. The pricing structures of energy markets in both developed and developing countries mostly do not reflect the full costs of producing energy to society, and make renewable energy less competitive with conventional energy choices. Conventional energy supplies are highly subsidized in many countries, both directly and indirectly. As well, the full costs of producing energy from conventional fuels are not normally factored into energy pricing, including external costs (also called ‘externalities’) such as human health impacts, environmental damage, and the global impacts of climate change.

The World Bank estimated that annual fossil subsidies in the OECD and 20 largest countries outside the OECD amount to US$58 billion. The 2000 World Energy Assessment (UNDP, 2000) calculated that global subsidies to fossil fuels and nuclear energy in mid-1990s reached around US$250-300 billion annually. The large difference between these assessments indicate the difficulties obtaining exact numbers, as many subsidy arrangements are indirect or cross sectors. Furthermore, R&D funding is generally heavily biased towards conventional fuels, nuclear fusion and nuclear fission.

National Strategies and Targets

After analyzing the experiences from countries that have effectively promoted private investments in renewable energy, it’s evident that national strategies, policies and targets are key elements. Most existing successful national renewable energy strategies have wider goals, such as security of energy supplies, environmental protection, climate change mitigation, renewable energy industry development, and sustainable development (enhancing energy access, alleviating poverty, addressing gender and equity issues, etc).

With diverse institutions and organizations, these strategies are expressed in various policy documents, such as renewable energy policy or broader policies covering energy, electricity, environment, climate change and economics. These policy documents come in various forms, such as policy statements and frameworks, laws and regulations, plans and programmes, etc. For some countries, regional or state strategies are emerging in addition to (or in the absence of) national strategies,

Setting national renewable energy targets can be a key component of a renewable energy policy, and several industrialized countries have already done so. The European Union, for example, has prescribed an indicative target of 12% renewable energy in the total EU energy mix and 22% in the total electricity consumption by 2010. National targets for individual EU Member States were also set to meet the overall target. Other developed countries with defined national or regional targets include Australia, Canada, Japan, New Zealand, Norway, Switzerland, and some US States.

National targets are also increasingly an important component of renewable energy strategies in developing countries. Developing countries with renewable energy targets include China, India, Korea, Indonesia, Malaysia, the Philippines, Singapore Thailand, Brazil, Israel, Egypt, Mali and South Africa.

These targets are usually set as a percentage of the primary energy and/or electricity generation mix. Some developing countries have defined targets as a percentage of the total electricity generation. However, the most effective targets are based on the share of energy generation or consumption, since this optimizes the utilization of generation capacity. The targets set by many developing countries are modest compared with those in some industrialized countries.

Renewable energy targets in most countries are indicative and non-binding, but they have stimulated government actions and regulatory frameworks. Making renewable energy targets legally binding or mandatory could, however, be an important tool to achieve higher renewable energy penetration.

Policy Instruments

National strategies include different policy instruments to achieve the pre-defined goals and targets. These instruments aim to remove market barriers, level the playing field for renewable energy, internalize environmental externalities, and create a favourable market environment for private investments.

Renewable energy policies and instruments are being categorized in various ways. Beck and Martinot (2004) categorized them according to their effects on renewable energy market incentives while the IEA (2004) categorized policies adopted by developed countries based on the direction of their support. Both approaches are shown in Table 4. 2. The choice of a specific policy instrument is influenced by various factors, such as resource endowments, economic structures, and market development objectives.

In very broad terms, policies adopted by developed countries can be grouped into seven main categories i) research, development and demonstration incentives; ii) investment incentives; iii) tax measures; iv) incentive tariffs; v) voluntary programs; vi) mandatory programs or obligations; and vii) tradable certificates. Moreover, each country has employed a combination of these policies. Figure 4. 1 (see Annex 1) presents the evolution of these policies since the 1970s and reflects among other things, an increased market orientation of policies moving from regulation towards economic policy tools.

Presently, *feed-in tariffs, obligations and tradable green certificates* are emerging as the main policy instruments in many developed countries. Investment incentives and various tax measures do, however, remain important mechanisms to stimulate renewable energy investment.

Feed-in tariffs encompass schemes that set preferential rates or pay premiums to electricity generated from renewable energy sources. Feed-in policies in some countries comprise a range of renewable energy technologies while in others countries, they cover only one or two technologies. Tariffs are often differentiated according to technology types, sites/location of power generation, year of operation, and season of the year.

In the UK, Ireland, France and Norway, feed-in tariffs are set through competitive bidding. Feed-in tariffs are popular with European countries, including Austria, Czech Republic, Denmark, Estonia, France, Germany, Greece, Hungary, Latvia, Lithuania, Portugal, Slovak Republic, Slovenia, Spain, and Sweden. European feed-in tariffs have stimulated investments in wind power, biomass, small-scale hydro, PV and solar thermal power generation.

In the US, premiums were paid for electricity from renewable energy sources through the Federal Production Tax Credit (PTC). The PTC was initially designed for wind power and ‘closed-loop’ biomass systems and later extended to include geothermal, solar, bio-energy, municipal solid waste energy, and small renewable energy projects for irrigation.

Table 4.1 : Renewable energy policy categories (summarized from Beck and Martinot, 2004 and International Energy Agency, 2004.

Policies based on market incentives	Policiesbased on support direction
Price-setting and quantity policies Mandates prices to be paid for renewables, or requires a fixed amount or share of generation to be renewable. • Instruments: US PURPA, electricity feed-in laws; competitively-bid renewable resource obligations; renewable energy portfolio standards; renewable energy certificates	*Policies addressing supply and capacity* Stimulating producers with facility and/or capital costs as policy variables. • Instruments: Investment tax credits; property tax exemptions, capital grants; government purchases; third party finance
Cost reduction policies Reduces investment costs. • Instruments: subsidies and rebates; tax relief; investment tax credits; accelerated depreciation; production tax credits; property tax incentives; personal income tax incentives	*Policies addressing supply and generation* Stimulating producers with product and/or associated price as policy variables. • Instruments: bidding systems; production tax credits; guaranteed prices/feed-in tariffs; obligations; tradable certificates
Public investment and market facilitation policies Provides public funds • Instruments: public benefit funds; infrastructure policies; government procurement; grants; loans	*Policies addressing generation and demand* Stimulating consumers with product and/or associated price as policy variables. • Instruments: net metering; green pricing; voluntary programmes; government purchases; excise tax exemption
	Policies addressing demand and capacity Stimulating end-users with equipment and/or capital costs as policy variables. • Instruments: consumer grants/rebates; tax credits; sales tax rebates; third party finance

Obligations – also termed quotas or renewable energy portfolio standards (RPS) – include schemes where energy suppliers must provide a set quantity or a percentage of their supply from renewable energy sources. These schemes do not make distinctions between different renewable energy sources and the market determines which are selected. Obligations are common in Australia, Europe, Japan and North America. At present, eighteen US States and ten Canadian Provinces have enacted renewable energy portfolio standards (RPS). In Europe, various forms of obligations or quota systems are implemented in Belgium, Italy, Poland, Sweden and the UK.

The use of *tradable green certificates* is very recent.
Under this type of scheme, a certificate is created to represent the environmental attribute of renewable energy (such as its carbon free nature) and is traded separately from the electricity itself. Certificates can be used to record compliance with renewable energy obligation schemes or sold in the voluntary green power markets. Netherlands was the first country to introduce tradable certificates in conjunction with its renewable energy target, but shifted back to a feed-in system in 2004. Australia also uses tradable certificates as a compliance tool for its *Mandatory Renewable Energy Target*. Approximately ten developed countries have introduced the use of tradable certificates.

Some developed countries have also introduced environmental and carbon taxes to reduce energy market distortions and to partly reflect external costs associated with the production and use of conventional fossil fuels. Germany, Denmark, Italy, the Netherlands, New Zealand, Norway, Sweden, Switzerland and the UK have applied environmental or carbon taxes and charges. Other than in Germany, energy generated from renewable energy sources is exempted from these charges. These levies are revenue neutral, and revenues are partly (in some countries fully) used to provide investment incentives to renewable energy projects and/or partly returned to the industry through various means.

Policy instruments to stimulate the development of renewable energy markets in many developing countries can be in two forms: *investment incentives*, such as capital investment subsidies, consumer grants, soft loans or guarantees; or *tax measures*, such as reduction and/or exemption on investment, property, sales or excise taxes, or import duties.

Recently, a number of developing countries have adopted more advanced policy instruments as a logical step following market-oriented reforms of the energy sector. Various forms of feed-in policies have been introduced in Brazil, China, India (States of Andhra Pradesh, Madya Pradesh and Maharasthra), Indonesia, Korea, Nicaragua, Sri Lanka and Thailand. Renewable energy portfolio standards were recently adopted in India (Karnataka, Maharasthra and Madya Pradesh) and Thailand. Further, Brazil's PROFINA programme seeks to increase electricity from renewable energy sources in the second phase of the programme through tradable renewable energy certificates.

Based on analysis of a number of national strategies and their achievements, it can be concluded that policy approaches resulting in the most significant and sustained growth of renewable energy markets in both developed and developing countries are all characterised by:

- A combination of different policies, rather than using a single policy,
- Long-term and predictable policy support,
- The use and adaptation of markets.

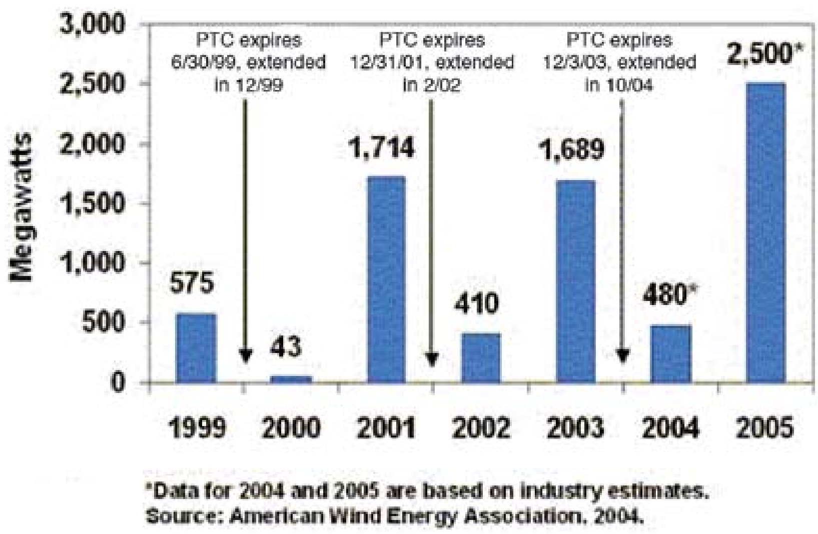
The growth of the PV market in Japan, for example, has been attributed to a mix of policies such as RD&D investments, demonstration projects, financial incentives and net metering (where the rate paid for renewable energy electricity entering the grid from a renewable energy source is the same as the rate charged for electricity taken from the grid). In Spain, the growth of the wind energy market is supported by feed-in tariffs, low-interest loans, capital grants, and local support for manufacturing.

Wind power capacity in India has grown rapidly in the past five years due to the combined effect of an appropriate buy-back rate (preferential tariff), fiscal incentives such as accelerated depreciation, and facilitative regulatory approaches. In Thailand, the growth of a biomass-fuelled electricity market has been driven by production subsidies, fiscal incentives, and non-fiscal policies.

Long and predictable policy support – often referred to in the finance community as 'loud, long and legal' support – has also contributed to successful market development. Feed-in tariffs in many countries have a time frame of around 8-10 years.

The US is a well-known example of the opposite situation where private investments were undermined by the stop-and-go nature of production tax credits. The earlier mentioned PTC was instrumental in providing an enabling environment for wind energy, but as illustrated in Figure 4. 2[6], the unstable policy environment impacted heavily on new capacity. New installations dropped dramatically in anticipation of the expiration of the PTC in 1999, 2001, and 2003, and resumed the long-term trend when the credits were reinstated. Each of the "crashes" led to major upheavals in the industry, and contributed to a significant loss of both global market share and technical leadership by the US wind equipment sector.

Figure 4.1: US Power Capacity Additions, 1999-2005



Electricity Market Reforms

The electricity sector constitutes a large part of the market potential for renewable energy and most countries have polices to promote investment in renewable energy power generation. Over the last two decades, countries worldwide have engaged in some form of electricity market reform and introduced changes to industry ownership and structure. Public sector owned and operated utilities have in many countries been transformed into commercial entities or privatised, while previously vertically integrated monopolistic industries are unbundled and transformed into competitive electricity markets.

Electricity industry restructuring and privatisation positively and negatively affect renewable energy development. Some barriers to renewable energy are exacerbated by different structural changes and privatisation policies, while others are significantly reduced.

Single buyer market and IPP frameworks
In many countries, the opening of power generation to independent power producers (IPPs) is one the first stages of power industry restructuring. The IPP regulatory frameworks serve as an important basis for the development of renewable energy. In some countries, specific IPP frameworks are created for the development of renewable energy. The 1980s PURPA regulation in the US, for example, mandated the purchase of electricity from small renewable energy generators and co-generators. Renewable energy IPP programmes have also been adopted in developing countries such as Indonesia, Malaysia, Sri Lanka and Thailand.

Wholesale competition and new policy frameworks
The introduction of competition and the establishment of spot or short-term markets for wholesale electricity can also retard renewable energy development. These markets may push wholesale electricity prices down and place renewable energy at a *competitive disadvantage* with other technologies, particularly those such as gas that have lower initial costs and are therefore easier to finance in uncertain markets. In many countries that have introduced wholesale electricity markets, IPP frameworks have been abandoned. To address this issue, many developed countries have adopted new regulatory frameworks consistent with competitive electricity market structures. In fact, current renewable energy policies in some European countries and states in the US are being implemented against the backdrop of market restructuring and liberalisation.

Unbundling and transmission access and pricing policies
The unbundling of generation, wholesale and retail parts of an energy business with access to electricity transmission grids and transmission pricing policies has an important effect on renewable energy development. For example, access to the transmission grid as the result of unbundling has been found to accelerate wind power development in India. Companies generate wind power in remote areas and use the national grid to wheel their electricity over long distances to their own facilities or third party buyers at a wheeling rate controlled by the government.

Transmission pricing policy in Brazil is also attributed to growth of the country's small hydropower industry, where renewable energy producers are given a discount of 50% off wheeling (or transmission) fees. Transmission rates can also have an important impact on renewable energy development – penalizing intermittent renewable energy generators if they are based on capacity (kW) rather than energy (kWh).

Retail competition and green power markets
The introduction of retail competition in some developed countries has resulted in the development of *green power* markets where electricity suppliers offer to sell electricity from renewable energy sources to consumers, often at a premium price. The US and the Netherlands are the main countries where green power markets have grown as a result of power industry restructuring.

The growth of green power markets in the US is also partly attributed to incentives provided by state governments. At present, more than 30 US States offer green power programmes that are available through about 500 different utility companies. The options for green power purchases continue to evolve as the process develops for electricity industry restructuring and competition in retail electricity markets. In the Netherlands, the growth of green power markets is also driven by an exemption from the tax levied on fossil fuel-based electricity, making green power almost competitive with conventional power supplies.

There are also options to purchase "green tags" where the "green" (or carbon-neutral) attribute of renewable generation is sold separately from the electricity, allowing consumers to support renewable energy generating capacity that may be far from their point of consumption.

Privatisation and appropriate policy frameworks
Privatisation may provide a new source of capital from debt and equity markets that can be used to finance capital-intensive renewable energy projects. Privatised utilities on the other hand, may prefer to invest in conventional energy technologies due to such factors as short project time horizons, the lack of access to low interest rate loans, and higher requirements for returns on their investments.

However, the privatisation process in many countries is undertaken in conjunction with power industry restructuring. In some cases, privatisation is carried out simultaneously with unbundling or the introduction of wholesale competition. Appropriate regulatory frameworks could therefore be adopted to promote renewable energy during the privatisation of utilities in a given electricity market structure, such as IPP frameworks under a single buyer market, or various types of obligations, feed-in tariffs and tradable green certificates in competitive electricity markets.

Distributed renewable energy generation
Embedding smaller generators within a grid network, referred to as 'distributed generation', can provide a number of benefits, including reduced greenhouse gas emissions (for generation based on renewable energy and low carbon fuels); increased energy security and diversity of supply; and reduced costs (as electricity is generated by more efficient systems and closer to the point of consumption). Additional benefits can include deferred transmission upgrades, reduced distribution losses, and increased network support.
The current regulatory frameworks, however, often fail to recognize, allocate and evaluate most of these benefits.

The IPP frameworks and net metering regulations have helped the growth of renewable energy distributed generation in both develop and developing countries. In net metering regulation, customers/generators are allowed to sell power to the grid and are charged the same rate for the power that is either taken or sold. The customer/generator only pays (or is paid) for the net consumption, with the difference in retail and buy back rates being factored in.

Net metering regulation is becoming widespread in developing countries where Thailand has recently adopted a net metering law. In the US, approximately 38 states have net metering laws while in Europe, net metering is available in Germany, Switzerland, the Netherlands, and the UK.

Policies to Promote Biofuels

In addition to energy security and environmental objectives, biofuel policies in many countries have been designed to support the development of the agricultural sector. To promote biofuels in the transport sector, several countries have passed tax incentives and mandates to blend biofuels with conventional fuels.

Most recently, biofuel targets have been established in some countries as part of (or additional to) national renewable energy targets. The EC Directive on biofuels set an average target of 5. 75% of energy from biofuels by 2010 for the 15 original EU Member States. Thailand's national renewable energy target aims to achieve 3% of total diesel consumption from biodiesel by 2011.

Countries with ethanol blending mandates include
Brazil, Canada, China, India, Thailand and the United States. Except in Brazil and Thailand, these mandates are issued at the state/provincial levels. In Brazil, ethanol blends range from 20-25% while in the other five countries the blends are between 5-10%. At present, only Brazil has a biodiesel-blending mandate of 2% by 2008, which may increase to 5% or more by 2013.

In addition to blending mandates, some EU countries exempt biofuels from fuel taxes while in the US, tax credits have been provided to ethanol-blended gasoline and biodiesel. In Thailand, incentives include exemption from taxes on ex-plant ethanol and on ethanol mixed with petrol; deduction of contribution rates to the Oil Fund and the Energy Conservation Fund for gasohol; and a subsidy to make gasohol cheaper than Octane 95 gasoline.

Renewable Energy and Public-Private Partnerships

Public private partnerships (PPP) are becoming an important mechanism in the energy sector to provide and deliver energy services. They cover a spectrum of arrangements that progressively engage the resources (expertise and/or financial capital) of the private sector. At one end, services are publicly contracted while at the other end, services are publicly administered but within a framework that allows for private finance, design, construction, operation, and to some extent ownership of an asset. In between, there are various forms of arrangements such as service contracts, joint ventures, concessions, and build-own-transfer (BOT) schemes.

Various existing arrangements of public private partnerships in developed and developing countries are being designed to promote the development of renewable energy. In the Philippines, for example, the government provided a risk guarantee to a privately owned 25 MW wind power project. In Argentina, the government competitively awarded concessions to private companies to provide energy services through solar home systems in isolated areas under the PERMER project. These companies are also required to contribute partly to equipment costs and recover their investments through monthly payments by their customers.

There are many more examples of public private partnerships in both developed and developing countries involving renewable energy services. In some countries, the partnership involves the development of large-scale renewable energy projects, while other countries develop small community-based power plants or distributed individual systems. Many of these partnerships are in rural or remote communities where renewable energy projects improve access to electricity, and where local communities are actively engaged in the development of projects.

In summary, this chapter has shown that there is significant experience with different policy approaches to promote renewable energy in many regions of the world. To understand successes and failures, a more detailed analysis is required, but the Annex 1 overview illustrates that there has been a gradual shift from regulatory instruments towards more market-based approaches. This reflects not only the general liberalisation of electricity markets, but also the increased commercialisation of renewable energy. Although individual national policies will need to be developed to reflect specific national or regional circumstances, it is clear that a large number of successful experiences are available for replication and adaptation.

5. The Role of Renewable Energy Finance

Investment Requirements to Meet Energy Demand

The growing demand for energy illustrated in all scenarios presented in Chapter 3 will require massive investments. According to the IEA's WEO and their *World Energy Investment Outlook* (WEIO, 2003), US$16 trillion of investment will be needed in the energy sector over the next 30 years to maintain, replace, and expand infrastructure if the projected 60% increase in energy demand is going to be met.

Approximately 60% – or US$10 trillion – of this amount will be needed for investments in the electricity sector. This is three times the amount invested in the past 30 years and reflects the expected doubling of global electricity demand that is also the major part of the forecasted 60% increase in overall energy demand.

As discussed in the previous chapter, the required investment naturally depends on how the demand is met. As an example, the alternative scenario presented in the WEO shows a 14% lower investment requirement – due mainly to significant efforts to improve energy efficiency.

The WEIO warns that raising the capital to finance the required investment will be a significant challenge, particularly in developing countries and transitional economies where almost half of the global energy investment will be needed. Investment in these regions is impeded by poorly developed financial markets, products, and institutions. These countries also have high political, credit, currency, and economic risks, as well as the lack of local capacity to adapt technology and the lack of infrastructure to deliver modern energy services.

The estimated investment requirements in the energy sector must be seen against the background of recent setbacks for the sector, such as the electricity shortage in the US State of California, the Enron collapse, and the summer 2003 blackouts in the US and Europe. In the new, deregulated environments, investors in power generation projects discovered that they are more exposed to risk than they were in a regulated market. The collapse of power prices and asset values, power project failures, and corporate fraud, shook the confidence of investors and lenders, and resulted in the loss of hundreds of billions of dollars of investment[7]. It will take time and new business models to restore that confidence.

To obtain the needed investment, the energy sector will also have to compete with other sectors, and within the energy sector, renewable energy projects will have to compete with other conventional segments of the industry. Generally, however, renewable energy is becoming more competitive and investment is growing, as illustrated in Chapter 3.

In the wind industry, for example, financial deals are now transacted on a regular basis worth hundreds of million of dollars; and for the first time, bond markets have been tapped to finance projects. Biofuel investments have recently also been developing quickly. Conventional large energy and technology companies such as GE and Allianz are increasing investments in clean energy. The renewable energy share of the venture capital market for new technology development is also growing, although more slowly than other environmental technology areas[8].

However, as described in Chapter 3, the share of renewable energy in the global energy mix will remain largely unchanged up to 2030 under business-as-usual assumptions. Even as the economics of renewable energy projects continues to improve, traditional financiers and investors remain reluctant to invest in these "new" industries because they view them as "high risk – low return options" with many market hurdles to overcome. Without a conscientious effort to improve the availability and types of finance, investment in clean and "low carbon" sustainable energy options will not be enough to really make a difference.

Consequently, this brief overview of investment requirements and possible finance options leads once again to stressing the conclusions from Chapter 3: an expanded contribution from renewable energy in the coming decades will require policies at the national level to draw investor interest to renewable energy. These policies must improve the financial performance of renewable energy projects and provide conditions for steady, long-term growth in renewable energy markets.

Developing Finance for Renewable Energy

The following section examines possible options for government actions to stimulate the finance needed to increase renewable energy penetration in the energy sector[9].

Figure 5. 1 maps the renewable energy project development process as a *finance continuum*, which begins with project preparatory activities, then construction, and finally the operations and maintenance stage[10]. There are two major areas where financing gaps occur in this continuum: the first, involves a lack of project development capital in the preparatory stages, and the second involves a range of issues such as the lack of risk management instruments that impede the financial structuring of the full project. Of course, the specific challenges that contribute to finance gaps vary somewhat according to local financial, regulatory, and technology conditions.

Project preparation for grid-connected renewable energy projects is generally carried out either by large energy companies (IPPs or utilities) or specialised project-development companies (as is the usual case in Germany). Energy companies finance the project preparation phase from operational budgets while specialised companies finance project development work through private finance, capital markets, or with risk capital from venture capitalists, private equity funds, or strategic investors (e. g. equipment manufacturers).

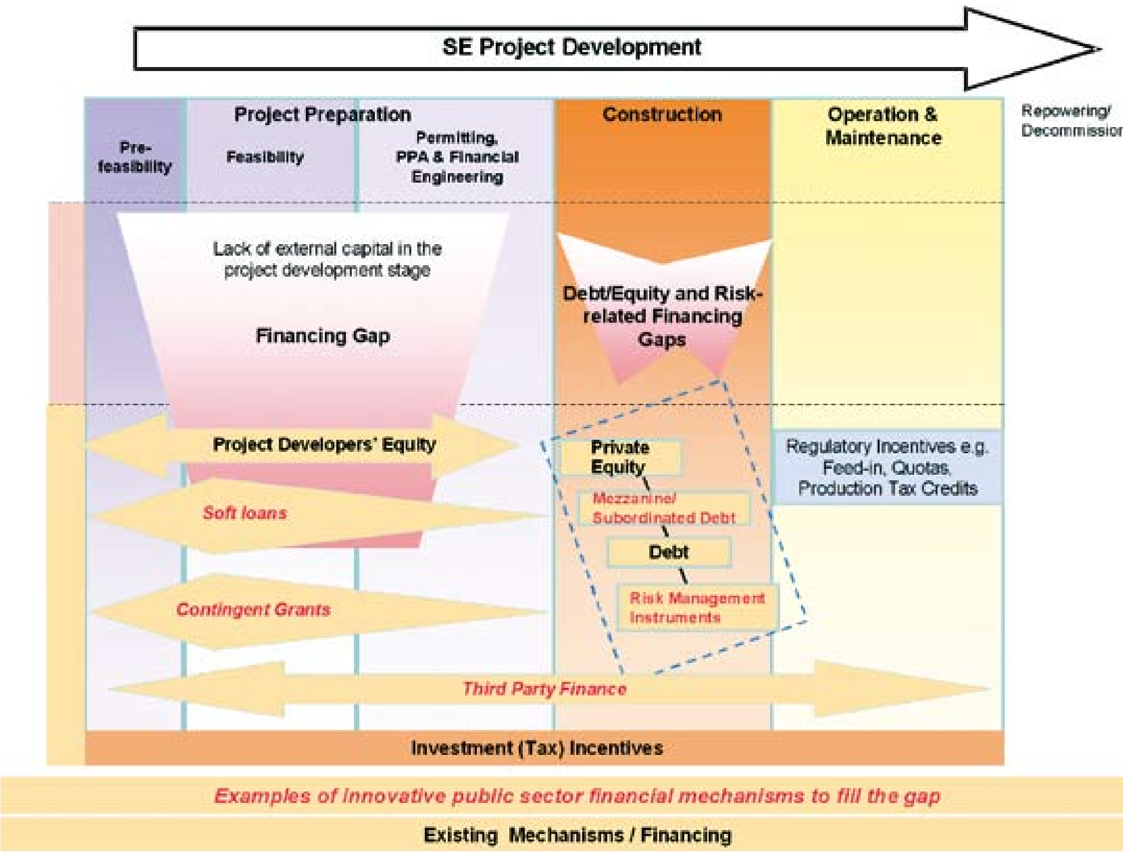
The entire project preparation process can take years and significant resources to complete, particularly in young

and evolving policy environments. This carries risk and therefore makes the 'cost of capital' of this early phase of development very high. Public support facilities can sometimes play an important role in sharing risks and costs at this early stage.

After the development stage, the project developer can access external financing from equity sponsors, and eventually banks, to construct their projects. Generally, larger renewable energy projects are financially structured in the same way as conventional fossil-fuelled energy projects, combining various forms of equity, debt and risk management instruments. For grid-connected renewable energy projects, this can be a difficult process, and the gaps can often only be filled with niche financial products, some of which already exist and some of which need to be created.

Equity is normally sourced from corporate treasuries, strategic investors, private equity funds, or the capital markets (i. e. , public equities). Although some equity investment is now available in the renewable energy sector, it is often not enough to cover the required equity share that banks usually expect in a project, particularly in uncertain markets with high equity requirements. Innovative finance structures – both public and private – can close the widening gap between the equity and debt available for project finance. For example, public interventions can help close the debt/

Fig. 5.1 Project Development Finance Continuum



equity gap by attracting third-party investors to take "mezzanine" positions in between equity investors and senior lenders.

The bulk of the financing provided to a project is usually in the form of *senior debt*, which can be structured as corporate finance or project finance.

There is currently substantial innovation in public support instruments for debt financing in the developing world, driven in part by the lack of supportive regulatory instruments, which creates the need to boost the financial performance of clean energy projects to directly compete with conventional energy systems. To improve access to long-term financing, a variety of instruments are being used, including currency swaps to reduce foreign exchange risk, two-step bridging mechanisms to allow long term financing, lease-financing arrangements to reduce off-take risk, and various other approaches[11].

An integral element of a projects financial structuring is *risk management*. This entails assessing the risks and mitigating them where possible while shifting others through contracts and warranties to insurers and other parties better able to underwrite or manage risks. There are many barriers to the development of risk management instruments, which have left insurance gaps in the finance continuum (see Figure 5. 2)[12]. Many risks are non-traditional and hence uninsurable. Like bankers, insurance underwriters also have limited understanding of renewable energy and associated risks, and thus have difficulty finding strategies for dealing with them. This is also an area where public/private partnerships could play an important role.

The finance continuum analysis can also be applied to off-grid renewable energy systems such as solar home systems, biogas digesters or wind pumps. At present there are also many gaps in this continuum, such as the lack of start-up risk capital for clean energy small and medium enterprises (SMEs) and the lack of end-user financing options for their customers. Ultimately, these gaps make it difficult to launch a new off-grid renewable energy business or even to expand an existing, proven business.

Although innovative financial instruments can go some way to scale up investment in renewable energy, capturing some of the external benefits of these technologies in the revenue structure will potentially have a far larger impact, as shown in the following section.

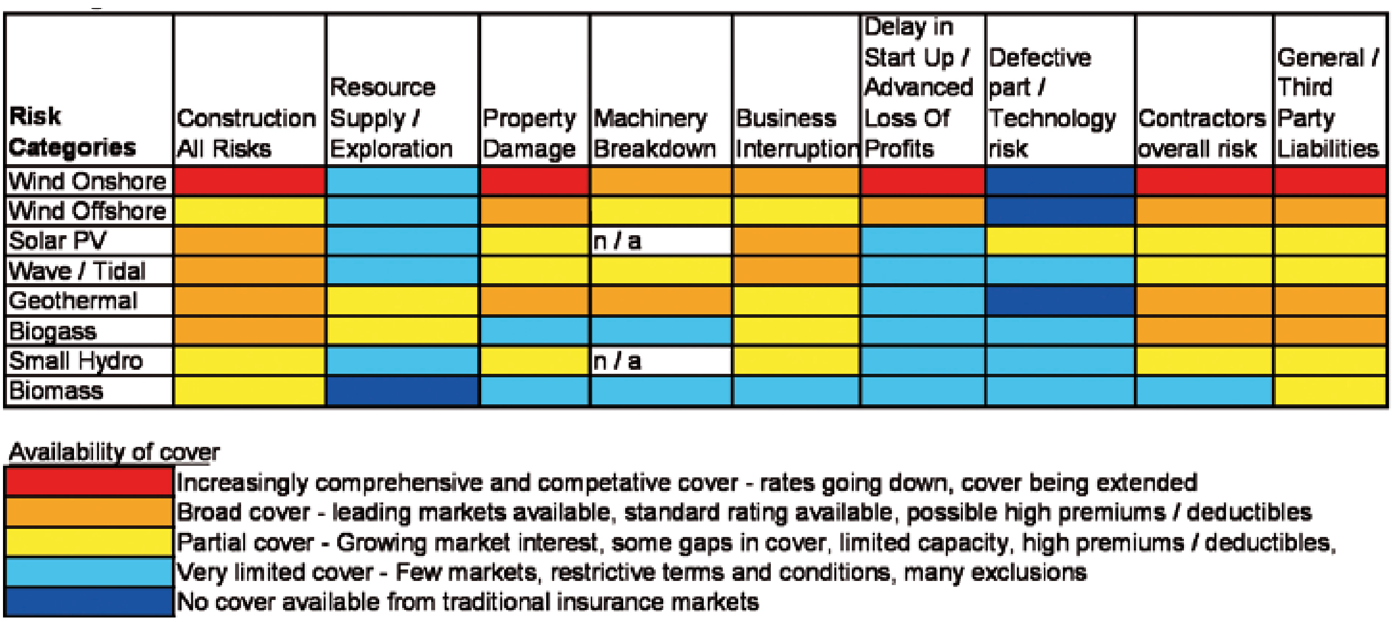
Carbon Finance and Renewable Energy

Using funds from the sale of carbon credits generated by either international regulations (such as the CDM) or voluntary initiatives can be an important source of revenue for renewable energy projects and substantially affect their ability to attract finance. The following is a summary of current efforts.

Global Environment Facility
To stimulate and support action on climate change and other key global environmental issues such as biodiversity, international waters, and protection of the ozone layer, governments established the Global Environment Facility (GEF) in 1991 to support developing countries. Since beginning, the GEF has provided around US$1.5 billion for activities related to climate change and leveraged several times more resources through its implementing agencies of the World Bank, the UN Development Programme (UNDP) and UNEP.

The GEF has stated from its inception

Figure 5.2: Generic RET Risk Transfer Heat Map Existing Insurance Products



that widespread application of renewable energy offers some of the best prospects for achieving deep reductions in greenhouse gas emissions at the global level over the next century while satisfying some of the increased demand for commercial energy. Almost half of GEF funding has been directed to renewable energy projects and activities.

The GEF can obviously not provide any significant direct contribution to the investment needs discussed previously. But the GEF can contribute substantially to removing barriers that prevent increased use of renewable energy by facilitating pilot and demonstration programmes in areas where technologies are not yet competitive in conventional terms.

Kyoto Mechanisms and Carbon Markets
The Kyoto Protocol establishes reduction targets for participating industrialized countries (as discussed in Chapter 2) and provides "flexibility mechanisms" to help countries meet their targets in a globally cost-effective manner. The Protocol defines three mechanisms – the Clean Development Mechanism (CDM), Joint Implementation (JI) and Emissions Trading (ET). The mechanisms have an elaborate set of rules and regulations but in simple terms, CDM and JI are project-based mechanisms where concrete projects in respective developing countries and countries with economies in transition can generate carbon credits. Industrialized countries can purchase these credits towards meeting their own targets.

The CDM can grant credits from 2001 while the JI project can only give credits from 2008 (start of the first Kyoto commitment period).

Table 5.1: Technology Distribution of CDM Projects till March 2005.
(Fenhann, UNEP RISOE, 2005).

Project Technology	Number of Projects	% Share	CERs/year (000)	Percentage Share
Landfill Gas (flare)	8	8%	1566	10%
Landfill Gas (power)	14	15%	5250	33%
HFC	2	2%	4,780	30%
Biomass Power	28	29%	1,812	11%
Hydro	28	29%	1,018	6%
Biogas Power	4	4%	436	3%
Wind	3	3%	247	2%
Geothermal	2	2%	602	4%
Other Waste	1	1%	5	0%
EE Industry	2	2%	77	0%
Fuel Switching	1	1%	14	0%
Energy Distribution	1	1%	15	0%
EE Household	1	1%	17	0%
Solar	0	0%	0	0%
Agriculture	1	1%	5	0%
Total	96	100%	15,845	100%
Renewables	79	82%	9365	59%
Other	17	18%	6480	41%

Emissions trading facilitates trade in carbon emissions among countries with Kyoto commitments. In parallel with the formal Protocol mechanisms, a number of countries have initiated domestic carbon emissions trading schemes. In early 2005, for example, a regional emissions trading scheme (ETS) was started by the EU. This combination of mechanisms has led to the gradual emergence of a global carbon market, which has the potential to leverage additional financial resources for clean energy, particularly renewable energy projects.

The current carbon market is still quite fragmented, and one of the challenges is to link the different types of mechanisms, including:

- *Project-based (baseline and credit system)*
  Emission reductions are created and traded through a given project or activity (JI and CDM).
- *Allowance market (cap and trade system)*
  Emission allowances are defined by regulations at the international, national, regional or firm level – Kyoto-ET, EU-ETS, Domestic: UK, Japan, Canada, Korea. Firms: BP, Shell. A system has been developed to link project based mechanisms, and the EU ETS has been established allowing for use of credits generated by CDM projects to be used in the EU ETS.
- *Voluntary market*
  Individuals and companies account and trade their greenhouse gas emissions on a voluntary basis (for example, travel compensation schemes).

Since the major activities have been on CDM projects due to the earlier starting period, the analysis here will focus on the initial action, current trends, and potential of the CDM.

From the host country perspective, the primary objective of the CDM is to contribute to sustainable development while reducing GHG emissions compared with what would have been the normal BAU activity. The list of possible CDM project types include:

- End-use energy efficiency,

- Supply-side energy efficiency,
- Renewable energy,
- Fuel switching,
- Industrial processes,
- Waste management, and
- Carbon sinks (only forestation and reforestation)

Consequently, the CDM and the emerging carbon market in general can potentially contribute to the financial viability of renewable energy projects, although not necessarily making them fully viable. The World Bank notes that the impact on a project's financial Internal Rate of Return (IRR) with revenue from selling emission reductions will vary depending on the technology and type of GHG being reduced (according to its global warming potential).

At a price of US$4 per tonne of CO_2, for example, "the impact on project financial IRRs for a range of CDM projects undertaken by the World Bank is 0. 5-2.5% for hydro, wind and geothermal, 3-7% for forest and crop residue, and 5-15% for municipal waste (landfill gas projects)" (Bishop 2004). Naturally, as the price of carbon increases, which is the current trend, the impacts become more significant.

During 2004, global CDM activities demonstrated the preference of project proponents towards projects that reduce industrial gases and gases with high global warming potential (GWP) such as HFC23, N2O and methane. For example, "of the 240 million credits being claimed up to 2012 by 111 projects documented (until Nov. 2004), 40 million credits come from two HFC23 projects and another 70 million from one N2O project; about 46% of all credits from these 3 projects alone" (CDM Watch, 2004).

Similarly, the World Wide Fund (WWF) stated in their July 2004 report, *A Clean Energy Future? The Role of the CDM in Promoting Renewable Energy in Developing Countries*, that a total of 48 potential renewable energy CDM projects developed up to the date of the report will generate Certified Emission Reductions (CERs) representing 11% total generated CERs. These are equivalent to CERs generated from a single HFC23 project in India. (WWF, 2004).

However, a recent analysis[13]shows that the trend may be gradually shifting. In addition, the total number of global HFC23 projects is very limited, and it is debatable whether they contribute to local sustainable development efforts.

The results of the analysis (Table 5. 2) indicate that the original bias towards non-renewable energy CDM projects may be shifting towards more renewable energy projects. However, further analysis and longer-term action is required before the overall validity of this trend can be assessed. The basic point, however, is that revenues from CDM projects can make a contribution to increasing the penetration of renewable energy in developing countries and one of the financial tools to consider in possible broader policy actions to promote renewable energy.

Table 5.2: World Bank Renewable Energy & Energy Efficiency CDM Projects

Project Technology	ERPAs (US$ million)	Project Cost (US$ million)	Emission Reductions Contracted (million tCO_2e)
RE Total	87. 7	656	21. 1
"New" RE	58. 6	309	14. 7
Hydro>10 MW	29. 1	347	6. 4
EE	17. 1	192	4. 6
RE + EE	104. 8	848	25. 7

Source: Veronique Bishop, World Bank, 2005.

The Table 5. 1 shows that renewable energy sources such as solar, wind, landfill gas (power), biogas, and hydro are now responsible for the largest share of CERs to be generated annually from the current global portfolio of CDM projects. Also, international development agencies such as the World Bank and its Carbon Funds have been making efforts to ensure that all the emissions reduction projects they support offer a balanced technology focus where renewable energy options are given adequate attention due to their long-term sustainable development benefits to the host country.

Carbon Funds

CDM projects and related credits can be organised at both the government level, and at the private enterprise level (subject to government approval). Large international companies may therefore choose to organise their own projects, but initially several so-called carbon funds have been established to procure project-based emissions reductions for Annex-I countries. The World Bank's Carbon Finance Business comprises the largest number of carbon funds. Table 5. 3 presents the status of the size of funding for the current carbon funds at the Bank by April 2005. Contributors to these funds are primarily large corporations in Annex-I countries and/or Annex-I governments, all of which seek World Bank assistance to procure emissions reductions that would be generated by implementing projects with clear sustainable development benefits to host countries.

In addition to the World Bank's carbon funds, many national carbon funds have also been established to procure carbon credits for Annex I countries, including the Japan Carbon Fund, the German KfW Carbon Fund, and the Austrian Carbon Fund. These and other funds adopt various carbon procurement approaches, including project tendering as well as one-on-one project negotiations.

It is still too early to judge the possible future contribution from the CDM to finance for renewable energy projects. But some estimates based on the need for emissions reductions by EU countries, Japan and Canada indicate that the market value of credits for 2008–12 will be in the order of US$2 billion–US$10 billion, depending on credit prices. Since this amount will leverage a core investment of usually 5 to 10 times the carbon value, CDM finance has the potential to make an interesting – although not significant - contribution to energy sector development when compared to the WEIO figures of around US$500 billion of investment per year. This modest role may change if there is agreement for stricter emissions reductions beyond 2012 and a more global participation in a future regime.

Table 5.3: Carbon Funds managed by the World Bank.

Fund	Budget (million US$)
Prototype Carbon Fund	180
Community Development Carbon Fund	129
BioCarbon Fund	33
Netherlands CDM Facility	180
Italian Carbon Fund	80
Netherlands JI Facility	35
Spanish and Danish Carbon Funds (under establishment)	230
Source: Presentation by Veronique Bishop, Andrea Marui et al, from World Bank's 2005 Energy Week.	

Allowance markets – the EU Emissions Trading Scheme
In addition to generating opportunities for project-based credits from JI and CDM, *allowance markets* are designed to ensure emissions reductions in the national or regional context. The EU Emissions Trading Scheme (EU ETS) imposes a cap on emissions of CO_2 from installations or facilities within the EU, and covers initially around 12,000 facilities. Sectors or activities covered by the EU ETS include electricity generators, heat/steam production, oil refineries, steel, cement/lime, pulp and paper, and the ceramics sector. The EU ETS stipulates that installations with a minimum fuel input of 20 megawatts (thermal) or more are included in the EU ETS and are hence granted an Emission Allowance through the National Allocation Plans (NAPs). Allowances are allocated by national governments and granted free of charge. The key objective of the EU ETS is to contribute to a low-cost compliance with the EU Kyoto Protocol target of an 8% reduction in GHG emissions (relative to the 1990 emissions) by 2008-2012. (Lesscarbon, 2005).

The target installations have various options, including reducing on-site emissions, purchasing allowances from the market, and/or purchasing project-based emissions reductions (specifically those generated from CDM and/or JI projects) (SGS, 2005).

Several studies have analyzed the impact of EU ETS on the renewable energy sector prior to and following its enforcement. For the UK, for example, the EU ETS is expected to result in an increase in power prices due to increased generation costs. A recent report by Lesscarbon states that "recent annual baseload power prices have reached over UK£34 per MWh, whereas 12 months ago, they were only just in excess of UK£22 per MWh".

Such an increase in the power generation cost may not be adequate to render all renewable energy projects

Box 6.2 : Voluntary Corporate Efforts

Case Study: Dupont

DuPont is a science company, delivering science -based solutions in food and nutrition, health care, apparel, home and construction, electronics, and transportation. In 2001, it had revenues of $24.7 billion and employed 79,000 people.

The company has established the following corporate targ ets to reduce GHG emissions:

✓ Reduce GHG emissions by 65 percent from 1990 levels by 2010. (Actual reduction by 2002 is 67 percent.)

- Hold total energy use flat at 1990 levels through 2010. (Actual use in 2002 was 9 percent below 1990 levels while production has increased by almost 30 percent.)
- Source 10 percent of global energy use from renewable resources by 2010.

To help meet these targets in a cost -effective manner, Dupont participates in emissions trading schemes, including the Chicago Climate Exchange described above and the UK Emissions Trading Scheme.

DuPont also leads the Integrated Corn -Based Bioproducts Refinery (ICBR) project. As part of the ICBR, DuPont is working with the U.S. National Renewable Energy Laboratory and other companies to develop the world's first integrated pilot -scale "biorefinery" that will make use of the entire corn plant —including the stalks, husks, and leaves —to make ele ctricity, fuel -grade ethanol, and chemicals.
In 2005, The *Wilmington* (Delaware) *News Journal* 's 'Best in the Business' annual ranking named DuPont 'Best Place to Work' and 'Best Community Involvement' for the chemicals and materials industry. DuPont was also named 'Company to Watch' for the technology industry. This is the first time DuPont has been recognized in the technology category.

Sources: www.pewclimate.org, www.dupont.com, www.thegreenpowergroup.org, www.environmentaldefense.org more commercially viable, but will certainly benefit renewable energy generators that do not rely on fuel inputs and are not subject to EU ETS Emissions Allowances (Lesscarbon, 2005).

The fact that EU ETS is expected to lead to long-term increases in power generation costs implies that EU ETS will inevitably contribute to an improvement in the economic performance of renewable energy options, especially within the electricity generation sector (Salay, 2004).

To illustrate the relationship between current costs and carbon prices, an analysis of a number of the scenarios included in Chapter 3 indicates that a price per ton of CO_2 in the order of US$20-$30 would make hydro, wind and biomass sources competitive with coal and gas for power production in the short term. (Sources: Derived and compiled from IEA 2004; WEO 2004; SRES 2000; EPRI (RETAG); Wind Force 12; Ravindranath et al. 2004).

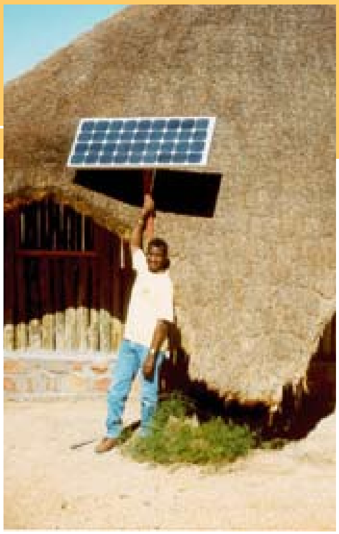
When this is compared with current carbon credit prices for CDM projects ranging between US$5-$10 per tonne of CO_2 and credits traded under the EU ETS currently in the range of €10-€25, it seems obvious that the costs of wind, biomass and hydro under good conditions should now be competitive.

Voluntary Initiatives - US Examples
Voluntary government programs and efforts by individual companies and NGOs play a significant role in the still limited initiatives to reduce US GHG emissions. In the absence of federal mandates or regulations to limit greenhouse gas emissions, many US corporations have taken on voluntary emissions reductions targets (see box 6.2), some of which include explicit plans to increase the use of renewable energy. For private companies, the key motivation to pursue such voluntary targets is generally two-fold: (1) To maintain competitiveness in light of regulations undertaken outside the US, and (2) to position themselves to receive credit for "early adopter" activities and prepare for what they view as inevitable domestic regulations. US non-profit organizations are helping companies explore this new territory by creating programs to facilitate corporate voluntary efforts. Three key examples are the *Partnership for Climate Action (PCA)*, led by the US non-profit Environmental Defence Fund (EDF); the Pew Center's *Business Environmental Leadership Council*; and the World Resource Institute's (WRI) *Green Power Market Development Group*. These programs provide forums for companies to increase their experience with GHG reductions and renewable energy targets, share information, and contribute to policy discussions.

Such private initiatives can be substantial. The Green Power Marketing Group describes itself as "a collaboration of 12 leading corporations and the World Resources Institute dedicated to building corporate markets for green power", with a goal of developing markets for 1,000 MW of new cost competitive green power by 2010 (Green Power Marketing Group, 2005). In its four years of operation, the group has contracted for 112 MW of new green power projects from a mix of technologies including hydrogen fuel cells, wind, landfill gas recovery, and renewable energy certificates.

Companies achieving GHG emissions reductions can participate in the *Voluntary Reporting of Greenhouse Gases Program* established under the US Energy Policy Act of 1992 (EPACT) and administered by the Energy Information Administration (EIA). This program permits corporations to report their emissions of greenhouse gases and actions taken to reduce or avoid emissions, as well as actions to sequester carbon. A number of US States, including California, New Jersey and Wisconsin, have developed registries to establish baselines and corporate voluntary actions to reduce GHG emissions.

6. Renewable Energy for Integrated Adaptation



While the general focus of this paper is on the possible renewable energy contribution to mitigating climate change, it is important to consider the special contribution renewable energy can make in developing countries to both adaptation and mitigation responses (Venema and Cissé, 2004)[14]. In some cases, renewable energy presents a viable opportunity for developing countries to address energy poverty, mitigate climate change, and develop cleaner, non-fossil based energy systems.

As examples, adaptation activities and policies in forestry and land use sectors can help to avoid emissions. This is especially true in relation to sequestering methane and CO_2, which feeds into direct mitigation activities. Watershed policies to reduce flooding can also involve reforestation, which can also sequester carbon (Dang et al, 2003)[15].

The bulk of rural populations, particularly in developing countries, rely on agricultural activities for their livelihoods. Climate change is expected to exacerbate current problems related to increased variability in temperatures and precipitation, and more unpredictable extreme events.

Decentralized renewable energy options such as solar photovoltaics can contribute to addressing current climate-related problems, affording poor communities important breakthroughs – both in terms of climate change adaptation and income generating activities. This is especially relevant in food processing and storage activities that require energy inputs. Similarly, small-scale wind generators can reduce greenhouse gas emissions from diesels generators as well as creating power to pump water for irrigation and other agricultural activities. Both agriculture and water are vulnerable resource sectors, yet they are intimately related to rural livelihoods.

For example, in the drought-prone African region of the Sahel where both access to water and quality of water tend to be major constraints, solar photovoltaics have been used to widen access to water resources. Solar water pumps have been used within the Regional Solar Programme (RSP)[16]- mainly for irrigational uses, rearing livestock and village water supplies. In the case of Senegal, the use of solar energy has enabled water pumping for irrigation and livestock, thus reducing the tendency of rural people to migrate to cities.
The use of cow dung for energy and fertiliser has helped pastoralists and farmers in land resource management, and eased climate related stresses while building resilience to climate change. (Venema and Cissé 2004)[17]. Modern applications of biomass can also constitute a potentially sustainable renewable resource for electricity generation, decreasing urban mitigation as well as creating economic opportunities for rural poor communities (Venema and Cissé, 2004).

Where renewable energy contributes to domestic cooking via biogas or waste-derived charcoal briquettes, it not only eases the pressure on natural resources and limits deforestation, but also reduces substantially fire hazards, indoor air pollution and acute respiratory-related infections that claim thousands of lives across the developing world. Electrification per se – including renewable energy systems – is not directly related to climate adaptation, but benefits from electrification include improved livelihoods, which can help poorer communities adapt to climate change. An attempt to illustrate how different small-scale renewable energy technologies can contribute to both climate change adaptation and mitigation is shown in Fig. 6. 1

It is clear that if renewable energy is to be a serious climate adaptation option, there is a strong need to move from clustered, marginal applications and pilot projects to widespread dissemination, especially within the African continent where climate change has disproportionate impacts.

Fig. 6.1 Mitigation and adaptation benefits from different small-scale decentralised renewable energy technologies.

Types of Renewables	Application	Mitigative Benefits	Adaptive Benefits	Ancillary Benefits
Efficient use of biomass:Shells, peanuts, bagasse	Electricity generation Heat	Reduced use of charcoal and woodfuel and less pressure on natural resources	Reducing the likelihoods of deforestation through continued used of woodfuel and charcoal	Creation of jobs and livelihood opportunities Reduced drudgery therefore better quality of quality of live Reduction of time spent on fuel collection Reduction of incidents related to indoor air pollution and respiratory infections prevalent with biomass
Wind pumps	Crop processing Irrigation Water pumping	Decreased dependence on biomass Avoidance of CO2 emissions	Greater resilience to climate related stresses through reduced vulnerability to water scarcity More adaptation choices i. e. through irrigated agriculture and not relying solely on rainfed agriculture	Increased access to energy and energy consumption Greater prospects for income generation Improved quality of life Reduced risks of vector borne diseases Improved water supply that is beneficial for agricultural productivity and livestock rearing Improved food security Reduced out migratory fluxes Improved performance and attendance level of school children particularly girls
Biogas plants	Production of sludge for fertilisers	Reduced use of biomass	Adapting to soil erosion, aridity and environmental degradation	Environmental sustainability; better prospects of agricultural productivity there more chances to generate income
Solar Home Systems	WaterHeating Cooking	Reduced consumption of woodfuel, kerosene and dry cell batteries Reduced pressure on the environment and natural resources		Improved quality of life Reduced health risks
Solar panels, PVs	Lighting Water pumping Water desalination	Improved local air quality Reduction of CO2 and reduced dependency on kerosene, woodfuel and dry cell batteries	Build resilience and coping strategies of communities especially during drought periods Thus reduced vulnerability to water shortages	Improved access to water Reduced drudgery for women responsible for water collection Reduced risks of infected water therefore improved sanitation and health
Micro hydro	Lighting Access to information technology etc	Reduction of GHG Protection of land cover		Improved health (indoor air pollution and other respiratory illnesses) as kerosene lamps are not no longer used Greater school attendance with electrification at school Access to internet facilities with electrification

7. Conclusions and Reflections

There is no reasonable doubt that climate change is a major issue of global concern. Some, including the Executive Director of UNEP, Klaus Toepfer, have called it the greatest threat facing human society. Yes, the science is still evolving on the specific details, but there is an increasing consensus in both the scientific and political communities that significant greenhouse gas reductions are necessary to limit the magnitude and extent of climate change.

There is also an increasing awareness that meeting the climate change challenge brings with it an enormous opportunity for new industries, new products and new ways of thinking about a global economy built on carbon-free, renewable energy. How will the world grasp this opportunity?

At one level, the facts are not promising. Even though energy from renewable energy sources is growing quickly, with markets such as solar cells, wind and biodiesel experiencing annual double digit growth, the overall share is only expected to increase marginally over the coming decades as the demand for energy also grows rapidly, particularly in many developing countres, according to the IEA World Energy Outlook (IEA 2004 & 2005).

The "business-as-usual" forecasts show that energy use and greenhouse gas emissions will continue to increase – growing 50-60% by the year 2030 from today's level. It is fundamentally important to stress, however, that *prediction does not have to be reality.* In their 2005 World Energy Outlook, the IEA basically considers the business-as-usual forecast as unsustainable.

There is also no doubt that ***renewable energy can play a major role in the global energy supply and help to mitigate climate change.*** The REN21 *Global Status Report* shows that in 2004, about US$30 billion was invested in a renewable energy sector that currently contributes 160 GW, or approximately 4% of global power capacity. Most long-term energy projections show that renewable energy will play a major role in the global energy supply in the second half of the century, with capacity increasing gradually in the first three decades. This process can be accelerated with dedicated policy action at national and international levels.

For renewable energy to play a major role, ***research and development (R&D) is essential.*** Analysis of R&D expenditure shows that the recent increased commercial interest in renewable energy has not resulted in higher R&D investment, which is still predominantly oriented towards nuclear and fossil technologies. This imbalance must be corrected.

It is also imperative to have ***policies that remove barriers and create markets.*** The renewable energy sector is still hampered by a number of market distortions and institutional, financial, and economic barriers. Overcoming these barriers and accelerating the current gradual transition to renewable energy can be accomplished with the right policy mix, and as an important and necessary action to mitigate potential climate change impacts. Recent increases in the price of oil and gas have also stimulated concerns about longer-term prices and supply security.

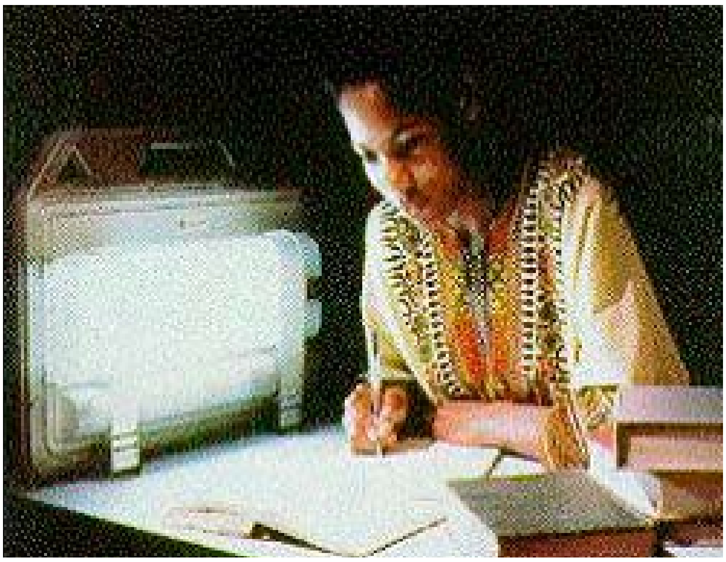
Significant policies to promote the renewable energy sector already exist in many countries. It is clear that concerted action is needed, based on long-term and predictable policies that acknowledge local circumstances and stimulate the power of market forces. With an energy sector increasingly deregulated and market-orientated, economic policy instruments have proven to be effective to stimulate change.

The evolving experiences with carbon finance and emissions trading show promising results to provide strong, longer-term incentives for developing renewable energy markets.

Finally, ***renewable energy in not a panacea***.

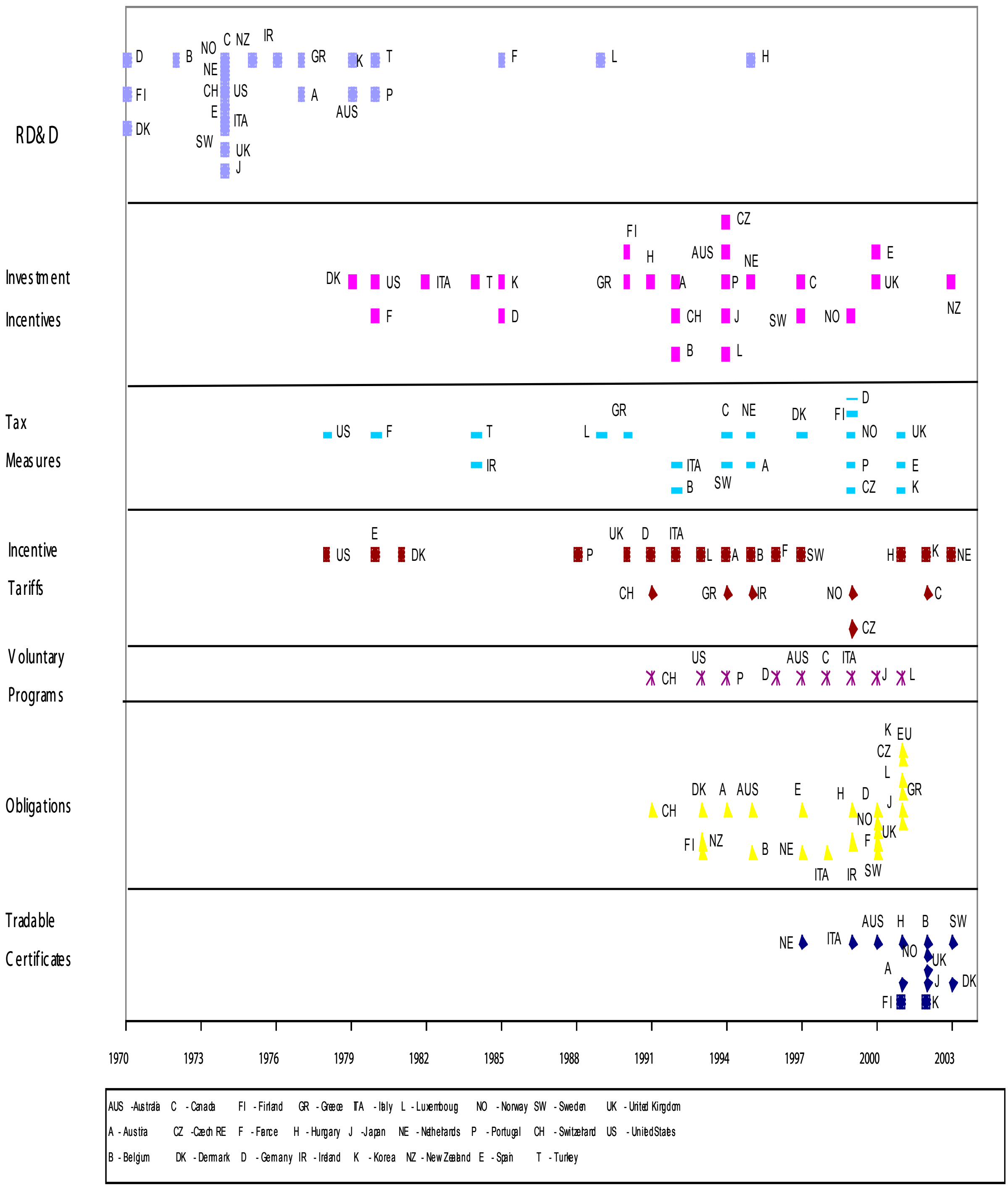
This report has demonstrated that there are many paths to a cleaner energy future. The best ones, offering the greatest benefits for the least economic, environmental and social costs, result from a portfolio of actions that continuously increase efficiency and replace carbon-based energy supplies with those that are renewable and carbon-free or carbon neutral.

This report is only the beginning of the necessary analysis that can continue making the case for investments in renewable energy. There is much work to be done on the financial and political mechanics of making the most desired scenarios a reality.



Annex 1

Figure 4.1:Evolution of Renewable Energy Policies in the IEA(Source: IEA, 2004)



Endnotes

1. Figures are originally produced by UNDP in the World Energy Assessment and are compatible with the BP figures for 1998 with the addition of the traditional biomass and integrating new renewables under hydro.

2. Specific assumptions about the global burden sharing rules have not been assessed and figures are mainly included to illustrate options at the national level.

3. This discussion focuses on renewable electric generation, and does not consider some other potentially important renewable technologies such as biomass-derived fuels.

4. Scenarios were reported in the following reports:Bernow et. al. (2001), Brown et. al. (2000), Clemmer et. al. (2001), Energy Information Administration (2004), International Energy Agency (2001) , Mintzer et. al. (2003), Union of Concerned Scientists, (2001), Platts Research and Consulting (2003), and Electric Power Group (2004).

5. Kapros et al. http://www. sessa. eu. com/public/madrid-present. php

6. The graphic in Figure 3 may be copyrighted. If desired, permission for use can be obtained, or a public domain version can be created.

7. Jacob J. Worenklein, "The Global Crisis in Power and Infrastructure: Lessons Learned and New Directions",, Institutional Investor, Inc. Spring 2003.

8. Cleantech Ventures Network (2003).

9. For further reading see V. Sonntag-O'Brien, E. Usher, Theme paper 5 Mobilising finance for RE, www. renewables2004. de.

10. Taken from Public Finance Instruments to Support the Sustainable Energy Sector, SEFI, 2005 (to be released).

11. An in-depth review of these mechanisms is in "Financing Instruments for Renewable Energy", P. Lindlein, W. Mostert, Final Draft, KfW (2005).

12. *Financial Risk Management Instruments for Renewable Energy Projects*, UNEP, June 2004.

13. May 2005 by J Fenhann from UNEP RISOE Centre (see www. cd4cdm. org).

14. Venema, D and M. Cissé (eds.) , Seeing the Light: Adapting to Climate Change with Decentralized Renewable Energy in Developing Countries, IISD, CCKN Publications, Winnipeg Canada, 2004.

15. Dang H. H. , Michaelowa, A. Tuan D. D. "Synergy of adaptation and mitigation strategies in the context of sustainable development: the case of Vietnam, Climate Policy, 3, Supplement 1, 2003, PS81-S96.

16. "The contribution of renewable energies to the fight against desertification : some lessons learned from projects and programmes promoting the use of renewable energy to improve access to water and the sustainable use of biomass in the Sahel.

17. Venema et al, op. cit., p 77-99

References

Beck, Fred and Martinot, Eric, (2004). Renewable Energy
AEO, (2005). Annual Energy Outlook 2005 with Projections to 2025. Report #: DOE/EIA-0383(2005) of Energy Information Administration, Release date: January 2005. http://www. eia. doe. gov/oiaf/aeo/.

Audus, H. and P. Freund, 2004. Climate change mitigation by biomass gasification combined with CO_2 capture and storage. Proceedings of 7th International Conference on Greenhouse Gas Control Technologies, to be published.

Azar, C. , K. Lindgren, E. Larson, K. Möllersten, and J. Yan, 2003. Carbon capture and storage from fossil fuels and biomass costs and potential role in stabilizing the atmosphere. Energy.

Baron, Richard, Emissions Trading & the Clean Development Mechanism: Resource Transfers, Project Costs and Investment Incentives, IEA, 1999.

Bishop, Veronique, Catalysing Climate-friendly Investment] in Carbon Finance magazine, March 2004.

Bishop, Veronique, Carbon Finance Business, Presentation at World Bank's 2005 Energy Week.

BMZ/BMU (2004). Conference Report, International Conference for Renewable Energies. Bonn, Germany.

CDM Watch, Market Failure: Why the CDM Won't Promote Clean Development, (www. cdmwatch. org), November 2004.

Dang H. H. , Michaelowa, A. Tuan D. D. (2003) "Synergy of adaptation and mitigation strategies in the context of sustainable development: the case of Vietnam, Climate Policy, 3, Supplement 1, 2003, PS81-S96.

Daniel M. Kammen, Kamal Kapadia, and Matthias Fripp, 2004. Putting Renewables to Work: How Many Jobs Can the Clean Energy Industry Generate? RAEL Report, University of California, Berkeley.

Edmonds, J. A. , J. F. Clarke, J. J. Dooley, S. H. Kim, and S. J. Smith, S. J. , 2002. Stabilization of CO_2 in a B2 World: Insights on The Roles of Carbon Capture and Storage, Hydrogen, and Transportation Technologies. Energy Economics, Special Issue, [Weyant, J. , and R. Tol (eds.)].

Ellis, Jane et al. Taking Stock of Progress Under the Clean Development Mechanism, OECD, (downloadable from www. oecd. org), 2004.

EREC (2005). Renewable Energy Scenario to 2040.

ESD (2003). Partnership for Access to Community Electricity (PACE): Policy Guidelines. ESD LTD UK.

EU, 2002. Update on the environmental dimension of the EU Sustainable Development Strategy from Environmental signals 2002. Prepared for Environment Council, 4 March 2002.

EWEA/ Greenpeace, 2003. Wind Force 12: A Blueprint To Achieve 12% Of The World's Electricity From Wind Power By 2020. http://www. ewea. org/documents/WF12-2004_eng. pdf

EWEA/Greenpeace (2004). Wind Force 12 – May 2004 Report.

Fenhann, Jorgen. CDM Market Status, (unpublished), www. cd4cdm. org, UNEP RISOE CENTRE, May 2005.

German Advisory Council on Global Change (WGBU, 2003), World in Transition – Towards Sustainable Energy Systems, 2003.

Goldemberg et al. , 2000: World Energy Assessment: Energy the Challenge of Sustainability, [Chapter 7: Renewable Energy Technologies] (a study sponsored jointly by the United Nations Development Programme, the United Nations Department of Social and Economic Affairs, and the World Energy Council), published by the Bureau for Development Policy, United Nations Development Programme, New York. Bureau for Development Policy, United Nations Development Program, New York.

Goldemberg et al, 2003. Expanding The Access To Electricity In Brazil. Report prepared to GNESD – Energy Access I Working Group, 2003.

Goldemberg J. and Coelho S. T. , 2003. Renewable energy: Traditional biomass vs. modern biomass. Accepted for publication in Energy Policy.

Government of Ireland, Department of the Environment, Heritage and Local Government (2004). Local Authorities and Renewable Energy: A framework for Public Private Partnerships.

Greenpeace, 2002. http://archive. greenpeace. org/climate/climatecountdown/solargeneration/solargenback. pdf

Grubb, Michael. The Economics of Kyoto Protocol. World Economics, Vol. 4, No. 3, July-Sept. 2003.

Gupta, S. P. , 2002. Special Group on Targeting Ten Million Employment Generation Opportunity per Year. Planning Commission, Government of India, New Delhi, 2002.
SRES, 2000.

GWEC/Greenpeace (2005). Wind Force 12 – June 2005 Report.

G8 Renewable Energy Task Force (2002), Final Report, 2002.

IEA (2002). Distributed Generation in Liberalized Electricity Markets. Paris, France.

IEA, 2002. Socio-economic aspects of bioenergy systems. IEA Bioenergy Agreement, Activity 29. www. eihp. hr/task29. htm

IEA (2004) World Energy Outlook, Paris 2004.

IEA (2004a). Renewable Energy: Market and Policy Trends in IEA Countries. Paris, France.

IEA (2005) World Energy Outlook 2005, Paris 2005.

IPCC, 2001. Climate Change Mitigation. Third Assessment Report, Intergovernmental panel on Climate Change, Cambridge University Press, UK., www. ipcc.ch

IPCC, Climate Change 2001: Mitigation Report, Working Group III, 2001.

Jiang, K. , X. Hu, Y. Matsuoka, T. Morita, 1998. Energy technology changes and CO2 emission scenarios in China. Environment Economics and Policy Studies, 1, 141-160.

Kheshgi, H. S. and Prince, R. C. , 2005. Sequestration of fermentation CO_2 from ethanol production. Elsevier Energy, Kidlington, United Kingdom, 30 (2005) 1865-1871.

Milton, S. Kaufman, S. Solar Water Heating as a Climate Protection Strategy: The Role of Carbon Finance. Green Markets International, USA, 2005.

Möllersten, K. , J. Yan, J. and J. R. Moreira, 2003. Potential Markets Niches for Biomass Supply with CO_2 Capture and Storage – Opportunities for Energy Supply with Negative CO_2 Emissions. Biomass and Bioenergy, 25, pp 273-285.
Morita, T. , N. Nakicenovic and J. Robinson, 2000. Overview of Mitigation Scenarios for Global Climate Stabilization based on New IPCC Emission Scenarios (SRES). Environmental Economics and Policy Studies, 3(2).

Mostert, Wolfgang. Financing Grid-Connected Renewable Energy Systems in Developing Countries. Danish Conference on Renewable Energy, Sept. 17-19, 2003.

Mostert, Woflgang. Development of a Commercial Wind Farm Market in Egypt. Danida/World Bank document (unpublished), June 2003.

O'Neill, B. C. and M. Oppenheimer (2002). Dangerous climate impacts and the Kyoto Protocol", Science 296, 1971 , 2002.

Pacala, S. & R. Socolow (2004) "Stabilization wedges: Solving the climate problem for the next 50 years with current technologies" Science, 305, 968, 2004.

Pacudan, Romeo (2004). The Challenge of Renewable Energies Integration in Energy Distribution Systems, in Networked Knowledge for Renewable Energies, Science Forum of the Renewables 2004. pp. 51-54.

Pacudan, Romeo (2004). Renewable Energy in Asia and the Pacific: Challenges and Opportunities. Background Thematic Paper, The Regional Conference for Asia and the Pacific on Renewable Energies 2004. Bangkok, Thailand. Unpublished document.

Policies and Barriers in Cutler J. Cleveland, Encyclopedia of Energy. Academic Press/ Elsevier Science.

Reiche, Kilian, Covarubbias, Alvaro, and Martinot, Eric (2000). Expanding Electricity Access to Remote Areas: Off-Grid Rural Electrification in Developing Countries. World Power 2000, pp. 52-60.

REPP, 2001. Renewable Energy Policy Project (co-authored by Virender Singh of REPP and Jeffrey Fehrs of BBC Research and Consulting).

Salter, Liam. A Clean Energy Future? The Role of the CDM in Promoting Renewable Energy in Developing Countries, WWF (downloadable from www. panda. org), 2004.

Sawin, Janet,TBP 3 - National policy instruments: Learning from variety - time to concentrate on success – Bonn, 2004.
Sawin, Janet (2004). National Policy Instruments: Policy Lessons for the Advancement and Diffusion of Renewable Energy Technologies Around the World. Thematic background Paper, International Conference for Renewable Energies. Bonn, Germany.

Shukla, P. R. , Rana, A. , Garg A. , Kapshe, M. and Nair, R. , 2005. Global Climate Change Stabilization Regimes and Indian Emission Scenarios: Lessons for Modeling of Developing Country Transitions. Accepted for publication in Environment Economics and Policy Studies.

UNDP (2000): World Energy Assessment, New York, 2000.

UN-ESCAP (2005). Lighting Up Lives: Pro-poor Public Private Partnerships.

UNIDO, 2002. Rethinking the Future: Youth Employment Opportunities in Renewable Energy. Discussion Paper. http://www. yesweb. org/docs/rebook. pdf

UNEP, MEDREP Project Financing Mechanisms, (unpublished), 2004.

UNEP, Legal Issues Guidebook to the CDM, CD4CDM Project Publication, UNEP RISOE CENTRE, Denmark, june 2004.

Van Vuuren, D. P. , Li, Y. , de Vries, H. J. M. , Kejun, J. , Graveland C. and Zhou F. , 2002. Energy and emission scenarios for China in the 21st century - Exploration of baseline development and mitigation options. The Netherlands, National Institute of Public Health and the Environment.
Venema, D and M. Cissé (eds. 2004) , Seeing the Light: Adapting to Climate Change with Decentralized Renewable Energy in Developing Countries, IISD, CCKN Publications, Winnipeg Canada,

WEC. www. iiasa. ac. at/cgi-bin/ecs/book_dyn/bookcnt.py

WEO, 2004.

Williams, R. H. , 1998. Fuel decarbonisation for fuel cell applications and sequestration of the separated CO_2, in Eco-Restructuring: Implications for Sustainable Development, R. W. Ayres (ed.), United Nations University Press, Tokyo, pp. 180-222.

Worenklein, J. J. (2003)“The Global Crisis in Power and Infrastructure: Lessons Learned and New Directions”, Institutional Investor, Inc. Spring 2003

World Bank (2004). Public and Private Sector Roles in the Supply of Electricity Services: Operational Guidance for World Bank Group Staff. Washington DC.

Zhongying, W. , Zhu Junsheng, William Wallace, Li Junfeng, Frederic Asseline (2000). Establishing a renewable energy industries association in China. Presented at the 16th European Photovoltaic Solar Energy Conference and Exhibition, May 1-5, 2000 in Glasgow, Scotland.

Zhu, J. , Proc. Sino-USA Renewable Energy Business Workshop, Xian, P. R. C. China (Nov. 3 1999), No. 5.