„MEASURING OF LOW-CARBON ENERGY INNOVATIONS - THE CASE OF DEVELOPING COUNTRIES“

Dissertation by

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STATUTORY DECLARATION

I declare that I have authored this thesis independently, that I have not used other than the declared sources / resources and that I have explicitly marked all material which has been quoted either literally or by content from the used sources.

……14th April 2012……… ………… …………..

date (signature)

Acknowledgement

This research work has been the product of several hundreds of hours that I spent over the weekends and holidays during the period 2006-2012. Trying to find time for carrying out research on top of an exciting full-time job was indeed been demanding but exciting at the same time. I would like to thank Assoc. Prof. Udo Bachhiesl, Prof. Christian Ramsauer and Prof. Heinz Stigler, at IEE, TU Graz for their constant encouragement and support which made this research work possible. This research work was only possible with the constant encouragement and support of Dr. Marianne Osterkorn, to whom I am very grateful.

This research work was also to fulfil a wish of my parents Kamalaveni and Parthan who encouraged me at every opportunity during these years. It is indeed unfortunate that my mother did not live long enough to see me complete the thesis work. My loving wife Asha was my main strength during these difficult years when I was guilty of not spending enough time with the family as I would have wished. Without her support and prayers, I may not have found the motivation and the courage to persist and complete the thesis. Finally I hope that this research will inspire my sons Ashwin and Aditya to pursue greater achievements in their future endeavours, as they grow up and become men. A number of my professional and personal friends have encouraged me throughout these six years and I would also like to thank all of them for their continued encouragement.

I firmly believe that we need to pursue a more resourse efficient pathway of development in the future and all nations have a common responsibility. Energy technologies I believe will be a key class of technologies for a low-carbon future and unpreceedented levels of technology innovation and deployment will be needed in these technologies.

I would like to dedicate this doctoral thesis work and this report to the memory of my mother who died during the course of my research on 25th March 2011.

Binu Parthan

This doctoral thesis report is dedicated to the memory of Kamalaveni, my mother.

Deutsch Titel: Messung von kohlenstoffarmen Energieinnovationen - Das Beispiel der Entwicklungsländer

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Kurzfassung / Abstract

Kurzfassung

Die Dissertation beschaeftigt sich mit dem Einsatz von CO_2-armen Energietechnologien, wie Erneuerbare Energien, Energieeffizienz, saubere Kohle, Kohlenstoffspeicherung, Kernenergie und Smart Grids, in Entwicklungsländern. Es wurden zu Beginn Methoden zur Messung von Innovationen zur kohlenstoffemissionsarmen Energiegewinnung und deren Anwendungen in Entwicklungslaendern analysiert. Weitreichende Untersuchungen wurden zu CO_2-armen Technologien zur Energiegewinnung hinsichtlich technischer Aspekte, Huerden für deren Einsatz, Anwendungs-Potenziale und Maerkte in Entwicklungslaendern durchgefuehrt. Weiters wurden auch die institutionellen Rahmenbedingungen und wichtige globale Programme zur Forcierung CO_2-armer Energien untersucht. Die Entwicklung von technologischen Innovationen und bestehende Methoden zur Messung von Innovationen zur Bereitstellung kohlenstoffemissionsarmer Energie wurden herausgearbeitet. Auf Basis dieser weitreichenden Untersuchungen wurde ein quantitatives Messinstrument zur Evaluierung von Initiativen fuer die CO_2-arme Energiebereitstellung erstellt. Dieses quantitative Messinstrument - Developing Country Low-carbon Energy Initiative (DeCLEI) Index - wurde am Beispiel von 30 konkreten Innovationen zur Gewinnung CO_2-armer Energie angewandt, welche in insgesamt 21 Entwicklungslaendern umgesetzt wurden. Die Resultate zeigten beim Vergleich mit tatsaechlichen Ergebnissen bedeutendes Potenzial fuer zukuenftige Anwendungen dieser Methode.

Abstract

The reserach work has focussed on the prospects in developing countries of low-carbon energy technologies namely renewable energy, energy efficiency, clean coal, carbon capture and storage, nuclear energy and smart grids. The reserach has explored ways to measure low-carbon energy innovation and deployment in developing countries. An extensive research was carried out into low carbon energy technologies and their scientific and technical aspects, barriers to deployment, application potential and markets in developing countries. Also reviewed were the institutional framework for promoting low-carbon energy and key global low-carbon energy programmes. Processes of technology innovation was studied and existing approaches to measure low-carbon energy innovation was reviewed and analysed. Based on this extensive body of research a quantitative measurement framework to evaluate low-carbon energy initiatives was developed. The quantitative framework – Developing Country Low-carbon Energy Initiative (DeCLEI) index has been applied to 30 low-carbon energy innovations covering 21 developing countries and results when compared with actual achievements show significant future application potential.

Executive Summary

It is evident that in the next decades, energy development is likely to be increasingly concentrated in developing countries. If developing countries follow a high carbon development path as was followed by developed countries in the past, it is likely to lead to dangerous levels of climate change. Therefore there is an imperative for developed countries to work together with developing countries to shift future energy development pathways towards low-carbon energy technologies. Low-carbon energy technologies such as renewable energy, energy efficiency, smart-grids, clean coal, nuclear energy, carbon capture and storage are expected to play an important role in transition to a low-carbon energy system. While the potential for low-carbon energy technologies exist in developing countries, developing countries are likely to deploy their limited resources towards basic infrastructure and basic social services for its population. It is likely that for low-carbon energy transition in developing countries there will be transfer of financial resources and technologies from developed countries to developing countries under the UN Climate Change Convention. The scale of resources required for low-carbon energy transition in developing countries is significant and it is likely that demand for resources and technology transfer will be more than the commitments by developed countries. Therefore an objective and transparent scientific framework is needed to evaluate low-carbon energy innovation and deployment in developing countries to ensure that the resources are prioritised towards the best possible initiatives.

The scientific and technical aspects and economics of renewable energy, energy efficiency, clean coal, carbon dioxide capture and storage, nuclear energy and smart grid technologies were reviewed as well as institutions active in low-carbon energy innovation at the global level. A number of major low-carbon energy innovation and diffusion programmes such as the Brasilian biofuels programme, Clean coal and renewable energy in China, Wind energy in Germany, energy efficiency in the European Union, Japan, India and the United States were also studied to identify the key elements of succesful programmes. Research was also carried out into prospects and diffusion of low-carbon energy technologies in key developing countries such as China, Brasil, India, South Africa and Mexico. A detailed literature survey was carried out to identify and catalouge the barriers to low-carbon energy technologies. Experience from barrier removal of a low-carbon energy promotion institution active in developing countries was also studied to identify the key lessons from the initiatives supported.

The process of technology innovation and its features was reserached on from an energy technology perspective. The measurement of technology innovation, various criteria employed and existing approaches for measuring technology innovation were analysed and observations made. Relevant other approaches measuring sustainability and environmental performance were also anaysed. Based on an understanding of the strengths and limitations of existing approaches to measure low-carbon energy technology innovation, a new quantitative measurement framework– Developing Country Low-carbon Energy Initiative (DeCLEI) was developed. The DeCLEI has three pillars that consider the developing country in which the innovation is deployed, the low-carbon energy technology involved and the energy innovation institution leading the initiative. DeCLEI consists of nine indicators which help quantifying and measuring the three pillars.

DeCLEI was applied to 30 low-carbon energy initiatives in developing countries supported by a global public private partnership focussing on low-carbon energy technologies. These initiatives were spread over 21 developing countries, have been completed and their results independantly assessed. DeCLEI was applied to these 30 low-carbon energy initiatives and the quantitative results obtained by applying DeCLEI were compared with the actual impacts of the initiatives.There was a high level of correlation between the DeCLEI Index scores and the final results of the initiatives. The hypothesis was finalised on the basis of these empirical results. Based on the literature research carried out, the quantitative approach developed and the results of the application of DeCLEI to actual low-carbon energy initiatives, the DeCLEI provides a scientific, objective and transparent quantitative framework to prioritise available limited resources for low-carbon energy development in developing countries. DeCLEI is expected to provide helpful in evaluating proposals for low-carbon energy initiatives for prioritising support under current and future energy and climate change international agreements.

1 Purpose, Conceptual Framework and Methodology

1.1 The rationale for the research

The current and the projected rates of development of the energy economy and the resultant high carbon energy development are likely to take the world through an unsustainable path. According to current energy trends, the world is headed towards a scenario which will result in an atmospheric concentration of greenhouse gases of 1000 ppm and a temperature rise of 6°C[1]. Such a scenario is likely to result in dangerous levels of climate change. It may also be noted that the overwhelming share of energy demand growth upto 2030 is expected to occur in developing countries.

The United Nations Framework Convention on Climate Change (UNFCCC) and the Kyoto Protocol are inter-governmental agreements/legal instruments which can be used to transform the projected high carbon intensive energy development paths of developing countries to low-carbon pathways. Promotion, financing and transfer of low-carbon energy technology innovation in developing countries under the UNFCCC presents an option to allow developing countries to meet their energy needs for development and at the same time stabilise global GHG emissions at an acceptable level. However this transition to a low-carbon energy system in developing countries requires large amounts of resources from both the public and private sector. Added to the costs for low-carbon technology innovation would be the uncertainty about future prices, technological development and the time required for the low-carbon energy technologies to be competitive. These factors are likely to make private sector firms and capital markets to be unlikely to invest significantly in low-carbon technology innovation.

There will be need of significant and unprecedented levels of investments from the public sector to mitigate and adapt to climate change. For public funds to be deployed in an effective manner in the right locations, technologies, institutions and markets, an evaluation and assessment framework is needed to rank available proposals and initiatives for low-carbon energy technology innovation. This assessment framework is required to ensure that the scare resources are invested in the best low-carbon energy technology innovations to increase the chances of a transition to a low-carbon development pathway. The current efforts are focussed on legal issues, architecture of the agreement and also on institutional and administrative arrangements and leveraging financing support.

[1] Source: IEA, 2008a, page 382

Currently there are methodologies available to rank countries for their innovation capabilities and industrial capabilities but not much research has been carried out on assessment frameworks for innovation plans for low carbon energy technologies. Research into elements of an assessment for innovation in low-carbon energy technologies and a proposal for a multi-criteria assessment framework will be critical in channelling funds towards the most potent innovations.

1.2 Objectives

The overall objective of this research study is to develop a quantitative framework for the prioritisation of limited financial resources to developing countries for innovation and deployment of low-carbon energy technologies.

Some of the specific objectives of the research are:

1. Investigation of the technical and scientific basis of low-carbon energy technologies and their future innovations. Study the key institutions and the institutional framework for low-carbon energy diffusion in developing countries;
2. Documentation of the experience from key low-carbon energy diffusion programmes across the world and specifically the developing countries, examination of barriers to low-carbon energy technology innovation and identification of key lessons in barrier removal;
3. Investigate the current state-of-play with technology innovation research from the perspective of low-carbon energy technologies;
4. Investigate and analyse the various approaches to measuring technology innovation, identify the key factors and indicators relevant to low-carbon energy technology innovation and developing countries.
5. Development of a new quantitative framework for measuring low-carbon energy technology innovations in developing countries.
6. Testing and validation of the quantitative framework through application to low-carbon energy innovation and deployment projects in developing countries.

1.3 Hypothesis

The extensive literature survey, detailed analysis of actual low carbon energy projects in developing countries, discussions and interviews with several experts and negotiators on issues ranging from technology, low-carbon energy technologies and climate change issues have resulted in development of the following hypothesis:

Low-carbon energy innovations in developing countries can be assessed on the basis of innovation systems and the low-carbon energy technology potential in the developing country where the innovation is proposed, the low-carbon nature of *energy technology involved and the capacity of Energy Innovation Institution involved.*

The research will aim to develop a quantitative measurement framework based on the above hypothesis. The quantitative framework will be developed by integrating different criteria that can characterise low-carbon energy technology innovation in developing countries. It will also test the quantitative framework on 30 actual low carbon energy innovation projects in developing countries and validate the hypothesis.

1.4 Research Questions

The impacts of global warming and climate change are being felt in both the developed and developing countries. The increasing scientific evidence suggests that the current and projected levels of energy sector growth in developing countries present a threat as well as an opportunity to stabilise the global concentration of GHGs. However due to their state of development, levels of industrialisation and competing demands on resources, developing countries are unlikely to make the necessary incremental investments towards a low-carbon energy development pathway. The general research question that is being investigated by the study is:

What would be a measurement framework for low-carbon energy technology innovation in developing countries to channel limited resources towards the most promising initiatives?

The answer to the general question was researched through attempts to answer the following underlying questions:

1. What is the relevance of low-carbon energy technologies to developing countries and why are low-carbon energy technologies important for climate change considerations?
2. What are the characteristics of low-carbon energy technologies? Which have been the key institutions, innovation and diffusion programmes and the key barriers to deployment of low carbon energy technologies and what have we learned?
3. What is the state of current research on technology innovation in general and specifically in low carbon technology innovation?
4. What are the current approaches to measuring technology innovation in developing countries? Which key factors influence technology innovation and specifically low-carbon energy technology innovation?
5. Is it possible to develop an index to measure low-carbon energy innovation initiatives in developing countries?

1.5 Methodology

This thesis report is a compendium of detailed literature research, discussions and analysis on several themes that concern low-carbon energy technologies and their diffusion, institutional framework, major barriers as well as technology innovation research and the factors affecting technology innovation. This is an application oriented research with emphasis on technology innovation and energy technology though it does draw from multi-disciplinary themes such as management, economics, science and sociology.

The research study was carried out through extensive literature survey and analysis of actual experience from low-carbon energy technology programmes and projects in developing countries. The research study also analysed the experience so far globally in measuring technology innovation and the frameworks and indicators considered. Interviews and discussions were also carried out with experts on low-carbon energy technologies, climate change, technology innovation and international development and energy technologies. A quantitative assessment model was developed and assessments were also carried out for 30 actual low-carbon energy initiatives.

The quantitative evaluation and assessments of the 30 low-carbon energy initiatives in developing countries were compared and contrasted with the actual outcomes and impacts of the projects. Inferences and conclusions were made on the basis of this empirical evidence and the hypothesis in section 1.4 was updated to finalise the thesis. Conclusions were drawn and recommendations also made based on outcomes of the research and the final thesis.

1.6 Structure of the thesis

Chapter 1 of the thesis provides the research context and sets out the objectives and defines the hypothesis. Chapter 1 also articulates the research questions and delineates the methodology to be pursued in answering the research questions and validating the hypothesis.

Chapter 2 provides the backdrop to the research by putting it in the context of the global perspectives on economy, climate change and energy issues. It also introduces low-carbon energy technologies and outlines the low-carbon energy challenges in developing countries.

Chapter 3 examines the technical and scientific characteristics of the six low-carbon energy technologies which are covered in this research – Renewable Energy, Energy Efficiency, Clean Coal, Carbon Dioxide Capture and Storage; Nuclear Energy and Smart Grid technologies. The research provided insight to measuring the specific low-carbon energy technologies and their prospects.

Chapter 4 presents research into institutions involved in low-carbon energy technologies and reviews the major successful low-carbon energy programmes globally with a view to identify elements which contribute to making successful low-carbon energy innovation initiatives and energy innovation institutions.

Chapter 5 examines the potential and prospects for various low-carbon energy technologies and their diffusion in some of the key developing countries.

Chapter 6 identifies barriers to low-carbon energy technology diffusion and the lessons from the barrier removal experience of a specific low-carbon energy market development agency. This research has contributed to the definition of the metrics and the framework to measure low-carbon energy institutions.

Chapter 7 researches into the technology innovation process, its classes and national innovation systems. It also reviews the existing approaches to measuring technology innovation and identifies elements to be retained and aspects that require improvement.

In **chapter 8,** a new approach to measuring low-carbon energy innovation – a quantitative framework of indices based on three pillars is developed to measure low carbon energy innovation initiatives in developing countries.

In **chapter 9**, the new quantitative measurement framework is applied to 30 low-carbon energy initiatives covering 21 developing countries.

Based on results of the application, **chapter 10** makes observations and inferences, updates the hypothesis, finalises the thesis, draws conclusions and makes recommendations.

Table 1 below illustrates how the research questions defined in section 1.3 relate to each of the chapters.

Table 1: Research Questions and Chapters

Sl No	Research Question	Chapter
1	What is the relevance of low-carbon energy technologies to developing countries and why are low-carbon energy technologies important for climate change considerations?	Chapter 2
2	What are the characteristics of low-carbon energy technologies? Which have been the key institutions, innovation and diffusion programmes and the key barriers to deployment of low carbon energy technologies and what have we learned?	Chapter 3, Chapter 4, Chapter 5 and Chapter 6
3	What is the state of current research on technology innovation in general and specifically in low carbon technology innovation?	Chapter 7

Sl No	Research Question	Chapter
4	What are the current approaches to measuring technology innovation in developing countries? Which key factors influence technology innovation and specifically low-carbon energy technology innovation?	Chapter 7
5	Is it possible to develop an index to measure low-carbon energy innovation initiatives in developing countries?	Chapter 8, Chapter 9 and Chapter 10

2 Background

2.1 Global Economy

The global economy is currently facing a significant challenge with major deceleration expected in the global economic growth. The global GDP grew at a high rate of 5% during the last four years and is now been projected to decrease to 3.2% in 2009[2]. This growth however will continue to be the high in Asia and the Middle-East. The recent years have seen an increase in commodity prices primarily due to the tightness of the demand supply balances. Commodity prices today are at their highest in real terms than at any time during the last 20 years. The direct result of high commodity prices have been inflation which reached 3.6% for developed countries and 9.4% emerging and developing economies in 2008[3]. The slowdown in global economic growth is expected to moderate inflation and inflation is expected to slow down in developed and developing countries in the future.

2.2 Fossil Fuels

The strong economic growth in the recent years has increased the demand for oil which has driven significant rise in oil prices. The supply response to rising oil prices has been sluggish and has been constrained by a lack of investments in new supply infrastructure during the late 1980s and early 1990s when oil prices remained low. This low supply-demand elasticity has resulted in record oil prices reaching levels of over 140$/barrel during July 2008. However oil prices have softened since due to a demand response due to high prices and a slowing of global growth. Considering the slower GDP growth and the impact of the high price, oil demand will continue to rise at a slower rate from 85 million barrels per day in 2007 to 106 million barrels per day in 2030[4].

World natural gas consumption continues to grow and is increasingly being used for power generation than for heating and cooking as was the case traditionally. Due to high costs of gas transportation through pipelines or through Liquefied Natural Gas (LNG), the natural gas production and consumption is primarily limited to specific regions. Gas prices have also risen recently, reflecting the trend in oil prices. It is expected that the gas demand will continue to rise as a result of increased demand in

[2] The industrialized countries are expected to slow down to 1% GDP growth from 2.6% and emerging and developing economies are expected to slow down to 6.5% from 8%

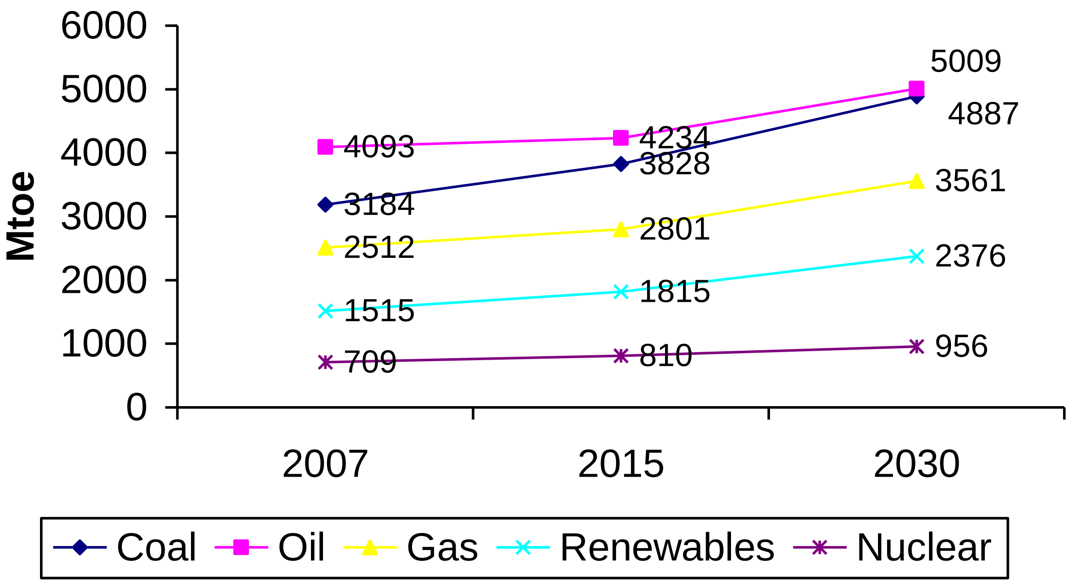
[3] Source: IMF, 2009, page 17

[4] Source: IEA, 2008b, page 92

the power sector and increased demand in developing countries. The gas demand is expected to increase from 2,916 million cubic metres in 2006 to 4,434 billion cubic metres in 2030[5].

Coal was the fastest growing fuel in the world for the fifth consecutive year in 2007 with the current annual increase being 4.9%[6]. Traditionally coal use was predominant in the industry but over the past decade coal use is increasing rapidly in the power sector, especially in China and India. The share of coal in the power sector in 2006 was 80%. With a vast resource base spread in five countries[7] and a global reserves-to-production ratio of 133 years, coal will continue to play an increasingly important role in the future energy economy[8]. The global coal consumption is expected to increase from 4.3 billion tonnes in 2006 to 7 billion tonnes in 2030[9].

Fig 1: World Primary Energy Demand Projections 2007-2030[10]



As shown in figure 1, in IEA's reference scenario[11], even in the year 2030, fossil fuels will continue to dominate world primary energy supply with a share of 80%[12]. Renew-

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[5] Source: IEA, 2008b, page 110

[6] Source: IEA, 2008b, page 124

[7] United States, Russian Federation, China, Australia and India.

[8] Source: IEA, 2008b, page 124

[9] Source: IEA, 2008b, page 124

[10] Source. IEA, 2009b, page 75

[11] The IEA reference scenario takes into account all governmental policies and measures that were adopted by mid-2008, which may have a direct or indirect impact on the energy sector.

[12] Share of oil, coal and gas will be 80% in 2030 according to IEA's reference scenario, slightly decreasing from 81% in 2006.

able energy supply increases significantly but will only make up 14% of the global primary energy supply in 2030[13].

2.3 Climate Change and Energy

The projected increase in global primary energy consumption at 1.6% and the continued high share of over 80%[14] of fossil fuels will result in serious environmental consequences as a result of increased concentration of Greenhouse Gas (GHG) emissions. In 2005 the atmospheric concentration of CO_2 was 379 ppm primarily a result of fossil fuel use, which has exceeded by far the natural range over the last 650,000 years[15]. According to the primary energy demand projections shown in Fig 1, the global energy related CO_2 emissions will increase from 28 Gigatonnes of CO_2 equivalent in 2006 to 41 Gigatonnes of CO_2 equivalent[16]. These continued CO_2 emissions would cause further warming and induce many changes in the global climate system[17] which are likely to be larger than what was observed in the past. These increases in CO_2 emissions are likely to lead to an atmospheric concentration of CO_2 of 1000 ppm and a global mean temperature rise of 6°C[18]. Such high temperatures could melt ice cap and permafrost resulting in sea level rises and inundation of islands and coastal regions, the dangerous effects of climate change according to the IPCC Fourth Assessment report will lead to significant damage to the ecosystem and species, large scale shortages of food and water and large-scale migration of population. The prospect of dangerous climate change as a result of projected development of the energy demand and supply system places an imperative to use cleaner energy sources, technologies and manage our energy demand.

The projected increase in energy demand and thereby the GHG emissions are projected to occur in the developing countries particularly China, India and the middle-east. Energy efficiency and smart grid technologies in the energy demand and energy supply side as well as renewable energy technologies, clean coal, carbon dioxide capture and storage and nuclear technologies for energy supply side will need to be increasingly deployed in developing countries to avoid dangerous climate change.

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[13] Source: IEA, 2009, page 74

[14] Source: IEA, 2008, page 77

[15] Source: IEA, 2008, page 408

[16] Source: IEA, 2008, page 381

[17] Temperature increases across the globe, rising sea levels, decreases in snow and ice extent, variations in precipitation patterns, increased incidence of extreme weather events etc. (IPCC, 2007)

[18] Source: IEA, 2008, page 410

2.4 Low-carbon Energy Technologies

Low-carbon energy technologies provide an opportunity to shift our energy development paths to a low-carbon pathway. Low-carbon energy technologies, processes and measures result in energy services being provided with lower carbon emissions. There are broadly two classes of approaches through which this can be achieved:

- **Emission reductions in energy service**: through these technologies, processes and measures the emissions as a result of each unit of energy used to provide a service is reduced. Examples include renewable energy technologies, clean coal technologies, carbon dioxide capture and storage and nuclear energy;
- **Reduction in energy use/intensity**: through these technologies, processes and measures, the amount of energy that is required to provide a unit of service is reduced. Examples include energy efficiency technologies and measures and smart grid technologies.

For the purpose of this thesis report the following energy technologies have been considered as low-carbon energy technologies that have relevance to the current efforts to lessen the climate change impact of growth in energy demand and supply:

Emission reductions in energy

- **Renewable energy technologies** that involve conversion of renewable sources of energy such as solar, wind, hydro and biomass in to electricity and heat;
- **Nuclear energy technologies** which generate heat and power through nuclear reactions. This report reviews the generation III and IV nuclear technologies such as the advanced boiling and pressurised water reactors, fast neutron reactors and the closed fuel cycle reactors. These technologies are expected to have enhanced safety, produce minimal waste and could be resistant to proliferation[19];
- **Clean Coal technologies** which improve the efficiency of coal combustion systems such a supercritical and ultra-supercritical combustion technology and the coal gasification technology – Integrated Gasification Combined Cycle (IGCC);

[19] The Fukushima nuclear accident on March 11 2011, has significantly affected the plans for nuclear energy developments globally.

- **Carbon Capture and Storage (CCS) technologies** that capture carbon dioxide from large fossil fuel energy facilities, compress and transport for storage in geological formations;

Reduction in energy use/intensity

- **Energy efficiency** technologies that are applied on the supply and demand side of the energy system to reduce the amount of energy required to provide the same amount of energy service or to reduce energy consumption;
- **Smart Grid technologies** that include advanced digital technologies such as micro-processor based measurement and control, communications and computing, advanced metering systems for use in planning and operations of the electric power system**;**

However the focus of the report will be on renewable energy and energy efficiency technologies and relevance to other low-carbon energy technologies such as nuclear energy, clean coal technologies, CCS and Smart Grids are also considered while making judgements and conclusions.

2.5 Role of Developing Countries

2.5.1 Developed and Developing Countries

While there are no single criteria to determine a developed country or a developing country, there is a general consensus that economic criteria should be used to differentiate between developing and developed countries. The three most popular criteria to group countries into developed and developing countries are the UN’s list of countries with high levels of human development based on the Human Development Index, the International Monetary Fund (IMF)’s list of advanced economies or the members of the Organisation for Economic Cooperation and Development (OECD). The UN’s HDI List[20] consists of 33 countries with high levels of human development, the latest IMF’s list[21] consists of 34 advanced economies and there are a total of 30 member countries[22] of the OECD. The OECD membership reflects high per capita incomes and high levels of GDP per capita and for the purpose of this report, members of OECD are considered to be developed countries and non-OECD

[20] Source: www.undp.org, as on December 18, 2008,

[21] Source: www.imf.org/external/index.htm, as on March 2009

[22] Source: www.oecd.org, as on August 2009

member countries are considered to be developing countries. There are a number of countries in Eastern Europe and from the former eastern bloc and former Soviet Union who are not OECD members. These countries are generally referred to as transition countries that are not included as developing countries in this report. The list of developed and developing countries[23] as defined by the report is shown in Table 2 below.

Table 2: Developed and Developing Countries[24]

Developed Countries	Developing Countries			
Australia	Afghanistan	Algeria	Angola	Antigua and Barbuda
Austria	Argentina	Bahamas	Bahrain	Bangladesh
Belgium	Belize	Benin	Bhutan	Bolivia
Canada	Botswana	Brasil	Brunei Darus-salam	Burkina Faso
Czech Republic	Burundi	Cambodia	Cameroon	Cape Verde
Denmark	Central African Republic	Chad	Chile	China
Finland	Colombia	Comoros	Democratic Republic of the Congo	Costa Rica
France	Côte d’Ivore	Djibouti	Dominica	Dominican Republic
Germany	East Timor	Ecuador	Egypt	El Salvador
Greece	Equatorial Guinea	Eritrea	Ethiopia	Fiji
Hungary	Gabon	Gambia	Ghana	Grenada
Iceland	Guatemala	Guinea	Guinea-Bissau	Guyana
Ireland	Haiti	Honduras	Indonesia	India
Italy	Iran	Iraq	Jamaica	Jordan
Japan	Kenya	Kiribati	Kuwait	Laos
Luxembourg	Lebanon	Lesotho	Liberia	Libya
Mexico	Madagascar	Malawi	Malaysia	Maldives
Netherlands	Mali	Mauritania	Mauritius	Mexico

[23] Excluding the transition countries
[24] cf. OECD 2009, IMF, 2009

Developed Countries	**Developing Countries**			
New Zealand	Mongolia	Morocco	Mozambique	Myanmar
Norway	Namibia	Nauru	Nepal	Nicaragua
Portugal	Niger	Nigeria	Oman	Pakistan
Slovakia	Panama	Papua New Guinea	Paraguay	Peru
Poland	Philippines	Qatar	Rwanda	Samoa
South Korea	São Tomé and Príncipe	Saudi Arabia	Senegal	Serbia
Spain	Seychelles	Sierra Leone	Solomon Islands	South Africa
Sweden	Somalia	Sri Lanka	Saint Kitts and Nevis	Saint Lucia
Switzerland	Saint Vincent and Grena-dines	Sudan	Suriname	Swaziland
Turkey	Syria	Tanzania	Thailand	Togo
United Kingdom	Tonga	Trinidad and Tobago	Tunisia	Tuvalu
United States	Uganda	United Arab Emirates	Uruguay	Vanuatu
	Venezuela	Vietnam	Yemen	Zambia
	Zimbabwe			

The developing countries are currently at an early stage in their development and industrialisation process. These countries generally have low levels of per capita incomes and have significant shares of their population that live below the poverty line[25]. Developing country governments are generally expected to make investments in social and poverty alleviation programmes and basic infrastructure development. A group of countries called BRICS for Brazil, Russia, India, China and South Africa of which all countries except Russia are developing countries, has come together to

[25] Living on less than one dollar a day

influence regional and global affaires. These countries represent large economies which are developing rapidly and consisting of large energy infrastructure.

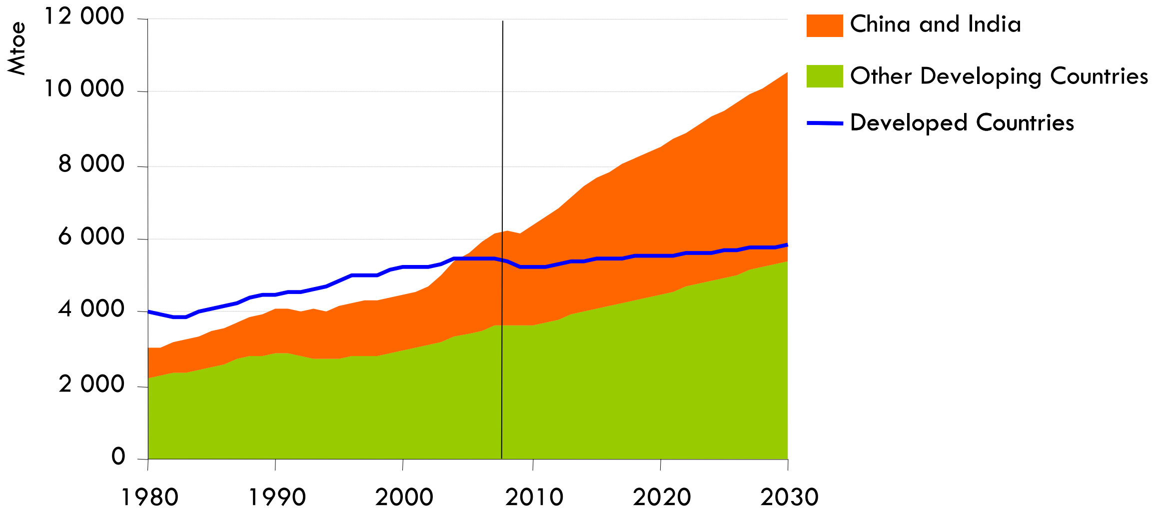
2.5.2 Energy Sector in Developing Countries

Energy demand in developing countries exceeded that of the developed countries for the first time in 2005. In 2007, the share of developing countries was 52% of the world energy demand[26]. According to the IEA's world energy outlook, 90% of the increase in world primary energy demand between 2007 and 2030 is projected to occur in developing countries[27]. Consequently in 2030 the share of the developing countries is projected to increase to 63% and the share of the developed countries to fall to 37%[28], which is shown in fig 2.

The increase in energy demand in developing countries is a result of increased economic growth in combination with population growth. The growth is also a result of industrialisation and rapid urbanisation in developing countries. While the absolute energy demand in developing countries will be significant in the coming decades, the per-capita energy consumption will still lag behind developed countries. According to the IEA, in 2030 the average per capita energy consumption in developing countries will be 1.5 toe compared to 4.4 toe in the developed countries[29]. Some developing regions of the world will lag significantly behind others and for example the per-capita energy consumption in 2030 in Sub-Saharan African developing countries will only be 0.38 toe compared to 4.4 toe in the developed countries[30].

[26] Source: IEA, 2009, page 76
[27] Source: IEA, 2009, page 76
[28] Source: IEA, 2009, page 76
[29] Source: IEA, 2009, page 78
[30] Source: IEA, 2009, page 78

Fig 2: Shares of Energy Consumption Growth in Developed and Developing Countries 2007-2030[31]



Considering that the overwhelming majority of energy consumption growth will happen in developing countries, the opportunity for a low-carbon energy transition will also be significant in developing countries. However the industrialisation levels, technology innovation capabilities and the economic resources are relatively limited in all developing countries. In most developing countries scarce government resources are often directed towards poverty alleviation programmes providing basic social services such as healthcare and education or for building the basic infrastructure. As there is an incremental cost associated with most of the low-carbon energy technology options, developing countries need financial resources or technology transfers or both from developed countries to be able to finance a transition to a low carbon economy.

2.6 Low-Carbon Energy Technology and Climate Agreements

To address the threat of climate change, the UNFCCC provides a common but differentiated framework. The UNFCCC was agreed in 1992 in the Earth Summit in Rio de Janeiro, Brasil. The goal of the UNFCCC is to stabilise Greenhouse gas (GHG) concentration in the earth’s atmosphere which would prevent dangerous interference with the climate system. A total of 192 countries[32] have ratified the UNFCCC and the UNFCCC came into force in March 1994. In 1997 the UNFCCC parties met in Japan to negotiate and agree on the Kyoto protocol which contains

[31] Source: IEA,2009, page 76

[32] Source: www.unfccc.int ,as of August 2009

clear and quantitative emission reduction targets and a timetable for action. The Kyoto protocol aims for a 6-8% reduction in GHG compared to 1990 levels. The Kyoto protocol entered into force in February 2005 and has been ratified by 184 countries[33]. The first commitment period of the Kyoto protocol will end in 2012.

Under the UNFCCC[34], the developed countries are required to take steps to facilitate and finance the transfer of environmentally sound technologies to developing countries. This commitment was also articulated in an article of the Kyoto Protocol. However progress on technology transfer to developing countries from developed countries has been limited. Technology Needs Assessments (TNAs) have been carried out in many developing countries, organisation of meetings and workshops, development of a technology transfer information clearing house – TT:Clear[35] and a number of reports have been developed.

However within the UNFCCC, investments in innovation and diffusion in climate friendly technologies, especially low-carbon energy technologies have been significantly limited. In the recent years technology innovation, deployment and diffusion has become one of the key determining issues in the negotiations regarding a long term cooperative action on climate change and a framework beyond the first commitment period of the Kyoto Protocol. The Bali Action Plan (BAP), agreed by the parties to the UNFCCC, places technology as one of the four building blocks of a future agreement.

The current discussions on the elements of the future technology transfer framework under the UNFCCC envisage that there will be expanded technology innovation programmes and stronger innovation centres in developing countries, stronger technological and institutional capacities and an annual investment of up to US$ 1 trillion per year in technologies for climate change mitigation and adaptation. A new technology transfer framework and funding commitment is expected to be in place by 2012 and an implementation programme is expected to be launched by 2013. While the negotiations about the various elements of the technology innovation, diffusion and framework and the level of commitments are far from clear, investments in low-carbon energy technology innovation in developing countries is expected to be a significant component.

The investments in programmes and initiatives involving low-carbon energy technology innovation in developing countries between now and 2030 are expected to be at an unprecedented scale. Going by the historical commitments to technology innovation and diffusion by developed countries it is expected that the demand for investments in low-carbon energy innovation will be more than the actual commitments

[33] Source: www.unfccc.int, as of September 2009

[34] Article 4.5 of the UNFCCC

[35] http://unfccc.int/ttclear/jsp/index.jsp

made. It therefore seems imperative that there will be competition for resources among low-carbon energy technology innovation projects in developing countries. It is expected that quantitative evaluation frameworks for low-carbon energy technology innovation will be needed to ensure that the available resources are targeted towards the most promising initiatives.

3 Low-Carbon Energy Technologies

3.1 Renewable Energy

3.1.1 Scientific Basis

3.1.1.1 Renewable Energy Sources

The renewable energy sources - wind energy, small hydro, solar energy, biomass and geothermal energy are widely distributed globally and environmentally attractive. The different renewable energy sources are explained below:

- **Wind Energy**: Winds result from the differential heating of earth and atmosphere by sun and the air circulates from cold to warm areas producing winds. Wind resources are concentrated in certain regions and can vary significantly with time and location. Wind contains kinetic energy and this energy of motion gives the ability to generate power. The terrain and surface conditions affect wind patterns and wind velocity and hence power, vary directly with height above the ground[36].
- **Small Hydro**: Small scale hydro power usually consists of smaller-scale hydro electric projects that do not involve dams or storage. Small hydro projects are typically less than 10 MW of capacity and can be broadly categorised into two types as 1) projects on canal falls and dam toes in the plains which are usually low head sites utilising large discharge and 2) medium or high head based in hilly regions where small discharge from streams and run-of the rivers are available[37].
- **Solar Energy**: There is a large quantity of energy generated from the sun, whose surface is at a temperature of about 6,000^{o}C. This energy is liberated as a stream of photons of various energies leaving the surface. These photons reach the earth’s surface about 8.5 minutes later and posses the same quantity of energy when they left the sun’s surface[38]. Before entering the earth’s atmosphere, the energy in sunlight is about 1,358 W/m^2. At sea level, this energy is reduced by atmospheric attenuation to about 930 W/m^2 [39].
- **Biomass:** covers all forms of matter derived from the biological activities and present either on surface of the soil or at different depths of the water bodies. Plant materials use the sun’s energy to convert atmospheric carbon dioxide to

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[36] The more the height, the effect of terrain conditions and geographical features on wind speed and turbulence will be limited.

[37] Source: Parthan, 1997, page 34

[38] Source: Parthan, 1997, page 20

[39] Source: Parthan, 1997, page 20

sugars during photosynthesis. On combustion of the biomass, energy is released as the sugars are converted back to carbon dioxide. Thus, energy is harnessed and released in a short timeframe, making biomass energy a renewable energy source.

- **Geothermal Energy:** Geothermal energy is the natural heat generated from within the earth. Underneath the earth’s crust in the core, there are elements like radioactive thorium, potassium and uranium dispersed evenly which produce heat as part of its’ decay process. About 10% of world’s landmass contains accessible geothermal resources that could provide significant amounts of heat and electricity[40].

These renewable energy sources are harnessed through a range of technologies that are specific to each source. The technologies can either produce electricity or heat depending on the application. Both electricity and heat technologies are explained below:

3.1.1.2 Renewable Electricity Technologies

Electricity can be generated from all renewable energy sources – wind, hydro, solar, biomass and geothermal. The technologies for conversion of these renewable energy sources are explained below:

- **Wind Electricity**: Wind electricity is generated using wind turbines which are mounted on a tower to maximise energy capture. A wind turbine consists of subsystems, such as 1) blade and rotor system which is the energy conversion device, 2) drive train, usually including a gear-box and generator and 3) various supporting systems including controls and electrical cables. Wind energy applications generally consist of a number of wind turbines in a single location called wind farms.
- **Hydro Electricity:** Hydro electricity is generated by hydro-mechanical turbines with the aid of civil and mechanical structures[41] to direct water at the hydro turbine. The turbine which is placed in the power house converts hydro energy into mechanical energy. The turbines can be broadly classified into impulse and reaction categories according to principles of water flow and structural features. The turbine is coupled with an electric generator which converts the mechanical energy on the shaft to electrical energy.
- **Solar Photovoltaics:** The sunlight is converted to electrical energy using a process named photovoltaic process. The photovoltaic solar energy conversion is made using solar cells which is basically a large diode. In the solar cell the passage of current, in the form of free charge carriers such as electrons, is

[40] Source: Parthan, 1997, page 58

[41] Diversion structure, fore bay and penstock

impeded in one direction and facilitated in the other. This result is achieved by creating a fixed electric field with the aid of two semiconductors of different materials. The electric field will propel carriers of a given charge through it and repel carriers of the opposite charge. When solar photons strike a solar cell a large portion of them are absorbed. The absorbed photons produce two free carriers: the free electron in the conduction band and a free hole in the valence band and these are driven in opposite directions by the force of the built-in electric field. Usually conductors are attached to both the top and bottom of the cell and connected in a circuit. The free charges will flow through it as direct current continuously, as long as the cell is exposed to light. This results in electricity generation whenever the solar cell is exposed to sunlight. The Solar photovoltaic cells can be made from a number of materials the most common being silicon, the other materials include alloys like Copper Indium Disselinide, Cadmium Telluride and Gallium Arsenide and Titanium Dioxide. A sealed panel containing a number of interconnected cells is called a photovoltaic module.

- **Biomass Power:** Most biomass power plants use direct-fired systems. The biomass feedstocks are combusted in a boiler to produce steam. This steam drives a turbine coupled with an electric generator to generate electricity. Normally woody biomass and agricultural and forest residues are used for biomass power applications. Biomass resources can be stored and therefore biomass power is available when needed.
- **Geothermal Electricity:** The geothermal electricity plants use geothermal reservoirs of water at high temperatures. This very hot water flows up through wells in the ground under its own pressure. As it flows upward, the pressure decreases and some of the hot water boils into steam. The steam is then separated from the water and drives a turbine coupled with an electric generator to produce electricity. Any leftover water and condensed steam are injected back into the reservoir.

3.1.1.3 Renewable Heat Technologies

In case of certain renewable energy sources namely solar, biomass and geothermal it is possible to thermodynamically match the sources with compatible energy uses. The technologies for thermal applications of renewables are explained below:

- **Solar Thermal:** Hot water, space heating, cooling and industrial process heat needs can be met by solar thermal energy captured using solar collectors. The solar collectors consist of front glazing, metallic absorber and piping to carry the heat transfer medium. The solar thermal systems usually consist of a storage tank for storing the heat transfer medium – typically water.

- **Heat from Biomass:** For thermal applications, the steam from the boiler fed by biomass feedstocks is directly used for manufacturing processes or to heat buildings. Sometime biomass systems (sugar mills, paper mills etc.) are configured to produce both heat and electricity. Such combined heat and power systems can increase overall energy efficiency.
- **Geothermal Heat:** For direct use of geothermal energy, the hot water is brought up through the well, and a mechanical system piping, a heat exchanger, and controls, delivers the heat directly for its intended use. Geothermal heat can be used for many applications such as heating buildings, raising plants in greenhouses, drying crops, heating water at fish farms, and several industrial processes, such as pasteurizing milk. A disposal system then either injects the cooled water underground or disposes of it on the surface.

3.1.2 Economics

Renewable energy technologies generally result in higher investment costs compared to conventional fossil fuel energy sources. Based on the World Energy Assessment, there are a range of initial investment costs for renewable electricity and heat generation technologies. Table 3 below shows the 2001 investment and energy costs and the projected future energy costs of renewable electricity. It can be seen that initial investment costs and electricity costs are comparable for biomass, hydro, geothermal and wind electricity technologies but that of solar electricity technologies are relatively high. In the future major cost reductions are expected in solar electricity technologies which could make them competitive compared to other renewable energy technologies[42].

Table 3: Costs of Renewable Electricity Technologies[43]

Renewable Electricity Technology	Investment costs in 2001 ($/kW)	Electricity Cost in 2001	Potential Future electricity cost
Biomass	500-6000 $	3-12 ¢/kWh	4-10 ¢/kWh
Wind	850-1700 $	4-8 ¢/kWh	3-6 ¢/kWh
Solar PV	5000-18000$	25-160 ¢/kWh	5-25 ¢/kWh
Solar Thermal Electric	2500-6000$	12-34 ¢/kWh	4-20 ¢/kWh
Small Hydro	700-8000$	2-12 ¢/kWh	2-10 ¢/kWh
Geothermal	800-3000$	2-10 ¢/kWh	2-8 ¢/kWh

[42] UN-DESA/NREL, 2005, page 25

[43] Source: UNDP, 2004 and WEC, 2004

Table 4 shows the 2001 investment and energy costs as well as the projected energy costs of renewable heat. It can be seen that geothermal and biomass thermal systems are already cost competitive and solar thermal energy applications are also comparable. While the geothermal and biomass heat technologies are at a mature stage and not much cost reductions are expected in the future, cost reductions are expected for solar thermal heat. Significant cost reductions were seen in solar PV and wind energy technologies in 2010, as a result of large scale manufacturing investments.

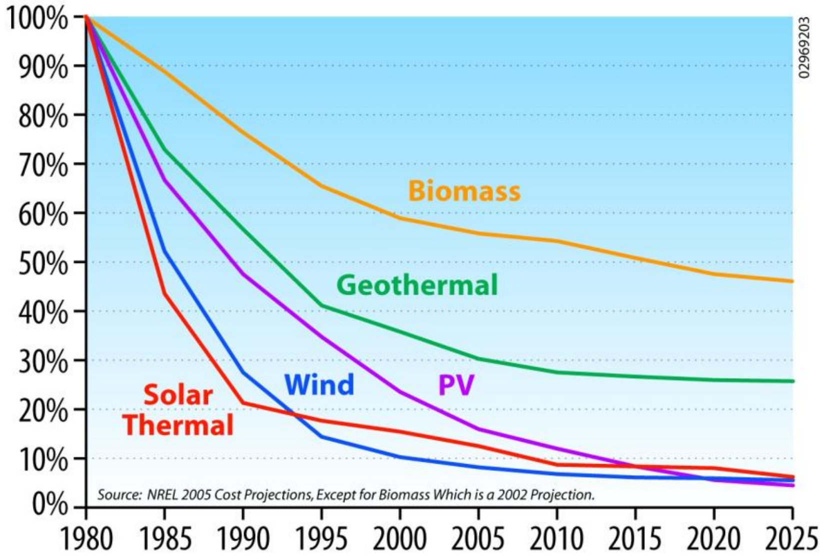
Table 4: Costs of Renewable Heat Technologies[44]

Renewable Heat Technology	Investment costs in 2001	Heat Cost in 2001	Potential Future heat cost
Biomass	170-1000 $	1- 6 ¢/kWh	1-5 ¢/kWh
Solar Thermal	300-1700$	2-25 ¢/kWh	2-10 ¢/kWh
Geothermal	200-2000$	0.5-5 ¢/kWh	0.5-5 ¢/kWh

The investment costs have declined rapidly over the past years and are projected to decrease. The continued cost reductions are expected as a result of increased scale economies, technology improvements and market development. Fig 3 shows the historical and projected costs of renewable electricity generation costs as a percentage of 1980 levels.

[44] Source: UNDP, 2004 and World Energy Council, 2004.

Fig 3: Historical and Projected Renewable Electricity Costs 1980-2025[45]



A report developed by the UN's department of Economic and Social Affaires (UN-DESA) on the historical and future cost trends for renewable energy technologies such as Wind, solar Photovoltaic and solar thermal electric show that the cost trends will continue till 2025 but at a slower rate as technologies mature[46].

3.2 Energy Efficiency

3.2.1 Scientific Basis

From scientific and engineering perspective energy efficiency is a dimensionless number, with a value between 0 and 1 or, when multiplied by 100, is given as a percentage. The energy efficiency of a process, denoted by „eta“, is defined as

Efficiency η = Output / Input

Where „output“ is the amount of mechanical work or energy released by the process, and „input“ is the quantity of work or energy used as input to run the process. Energy efficiency as defined by this thesis report goes beyond this scientific definition.

However energy efficiency as commonly referred to is actually „efficient energy use“ which is using less amount of energy to provide the same level of energy service. An example would be insulating a house or an apartment to use less heating and/or cooling energy to achieve the same indoor temperature. Another example would be installing fluorescent lights instead of incandescent lights to attain the same level of

45 Source: UN-DESA/NREL, 2005, page 13

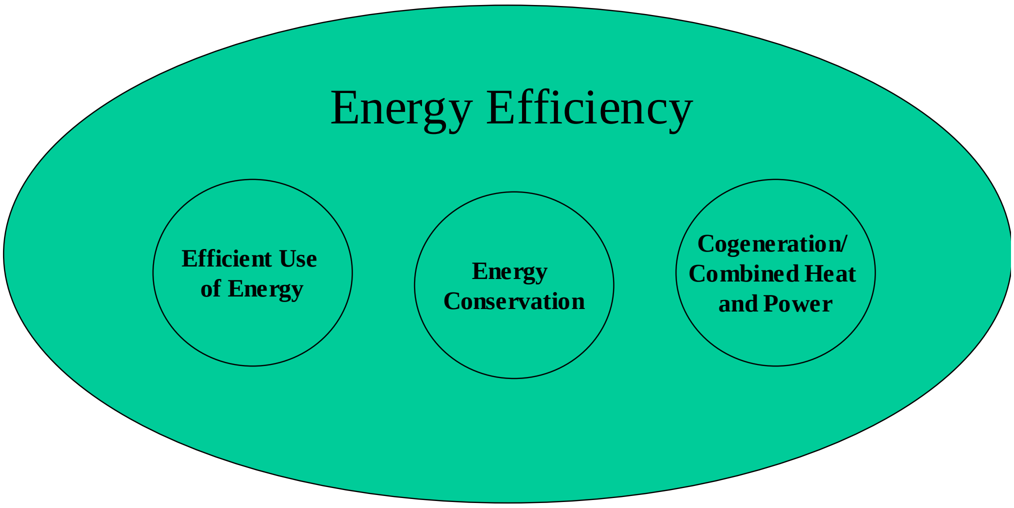
46 Source : UN-DESA/NREL, 2005, page 15

illumination. Efficient energy use is achieved primarily by means of a more efficient technology or process rather than by changes in individual behavior.

While examining issues relating to energy efficiency it is important to understand the concept of „energy conservation” or rational use of energy. Energy conservation is broader than energy efficiency in that it involves using less energy to achieve a lesser energy service, for example through behavioral change, as well as encompassing energy efficiency. Examples of conservation without efficiency improvements would be turning down the heating of a room in winter, using public transportation systems instead of driving a car, or working in a less brightly lit room. As with other definitions, the boundary between efficient energy use and energy conservation can be unclear.

While discussing energy efficiency a discussion about cogeneration or Combined Heat and Power (CHP) is important. Cogeneration/CHP is the use of thermal power station to simultaneously generate both electricity and useful heat. Usually conventional power plants emit the heat created as a byproduct of electricity generation into the environment and CHP captures the byproduct heat for domestic or industrial heating purposes. Therefore CHP is a thermodynamically efficient use of fuel. This thesis report considers energy efficiency to encompass efficient use of energy, energy conservation as well as cogeneration which is shown in fig 4.

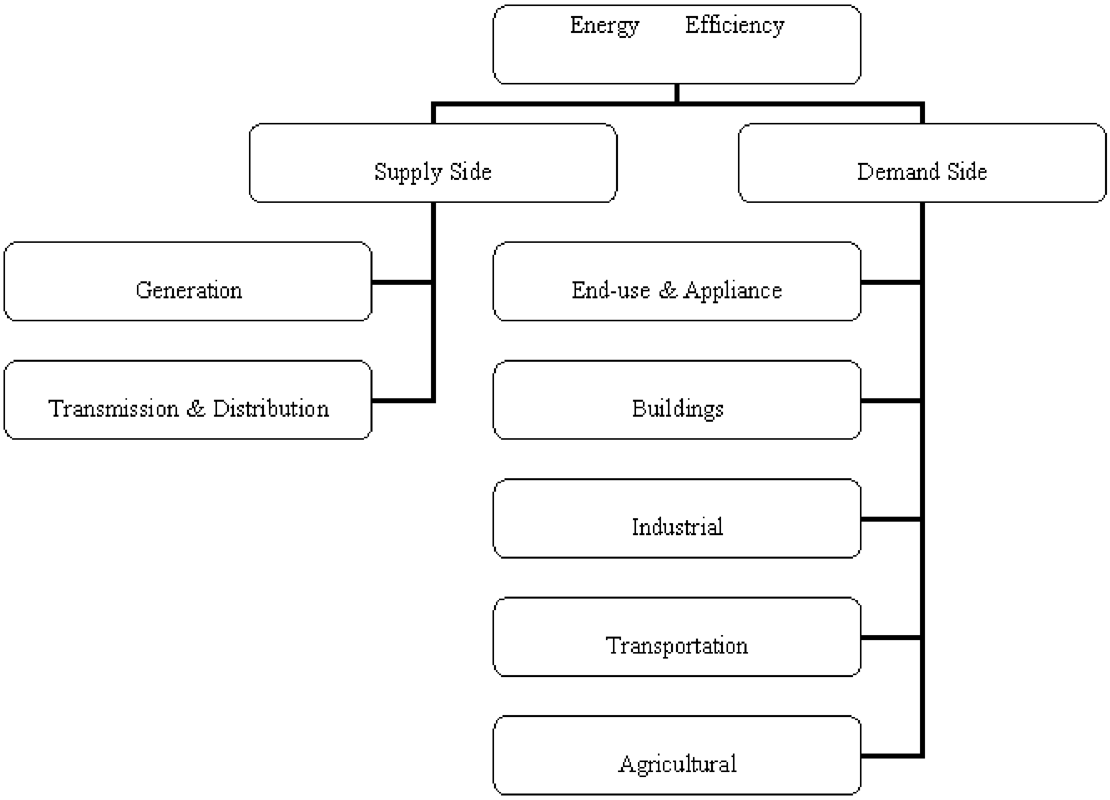
Fig 4: Key Components of Energy Efficiency



Energy efficient applications, technologies and measures can be classified according to the form of energy and also the stage in the value chain when the efficiency measures have been applied. According to the energy forms and related technologies it can be classified as thermal energy efficiency or electrical energy efficiency. Scientifically mechanical energy efficiency is also defined but has limited scope in real-life applications. Energy efficiency can also be classified according to the energy value chain as supply side energy efficiency or demand side energy efficiency.

Supply side energy efficiency measures consist of applications that improve the efficiency of energy generating systems or improving the distribution efficiency of electrical or district heating transmission and distribution systems. Demand side energy efficiency consists of the use of efficient end-use equipment such as appliances or energy efficiency measures in buildings, transportation, agriculture or industrial facilities that consume thermal or electrical efficiency or both. The classification of supply side and demand side energy efficiency is elaborated in fig 5.

Fig 5: Classification of Energy Efficiency[47]



The technologies, approaches, policies, financing and institutional mechanisms for realising energy efficiency projects and programmes in each of the sector require a good understanding of the characteristics of that application segment. Therefore classification of energy efficiency applications and measures along with a specialised approach for each sector is required to realise the energy efficiency potential.

3.2.2 Measurement of Energy Efficiency

Changes in energy use are driven by a combination of energy efficiency changes, changes in weather, behavioural changes, and other economic effects that may be

[47] Source: developed by the author

only partially separable and may differ among energy services. Therefore, the task of measuring and assessing energy efficiency and its change over time presents a major challenge. Some of the key issues relating to measurement of energy efficiency include:

- Deciding on which effects should be considered in measuring energy efficiency and which effects should be ignored;
- Establishing a framework for energy efficiency measures including a categorisation of energy services;
- Combining the statistical measures into an assessment of energy efficiency and its trends;

3.2.2.1 Approaches

There are several approaches to energy efficiency measurements and a key issue is to establish a reference point or a baseline against which the energy efficiency improvements and the resultant savings can be measured.

- **Market Basket Approach**: estimates energy consumption trends for a controlled set of energy services with individual categories of energy services controlled relative to their share in the index[48].
- **Factoral Decomposition Approach**: separates out using Laspeyres indices[49], changes in energy use due to specific effects Energy use is separated into effects of activities, structure and intensity. Each of these three effects is measured by holding the other two effects constant[50]. This approach can be used to measure change relative to a base year in energy use that would have occurred due to one of these effects if there had been no changes in other two effects. This has been used by the IEA in its energy efficiency and energy use indicators and is used widely.
- **Comprehensive Approach:** The comprehensive approach considers all energy use and bases the process of measurement with all the available measures of demand indicators and energy use. Changes in energy demand and use over a period of time will be influenced by changes in weather, behaviour, structure, and energy efficiency. Finally all effects that are unrelated to energy efficiency changes, are then removed. This is also called as the top-down approach[51].

[48] Source: Department of Energy, Energy Information Administration,1995, page 4

[49] Developed by Etienne Laspeyres is an index that measures current quantities to those of a selected base period.

[50] Source: Natural Resources Canada,1997, page 11

[51] Source: Department of Energy,1995, page 5

- **Divisia Index Approach**: uses data on time trends to measure energy savings over a longer time horizon. This is accomplished by the decomposition of time trends into factors such as intensity and structural factors. United States Department of Energy (DoE) used this approach for its energy efficiency analysis[52]
- **Best Practice Approach**: this approach determines the difference between the average or current practice and what is considered as the best practice. This approach can be used to compare a specific enterprise or even a specific process within the enterprise. Depending on the type of analysis a number of best practices can be used as the reference case[53].

The various approaches described above have their own strengths as well as weaknesses.

3.2.2.2 Measurement Guidelines and Protocols

3.2.2.2.1 International Performance Measurement and Verification Protocol (IPMVP)

The International Performance Measurement and Verification Protocol (IPMVP) is a reference document describing a framework and four Measurement & Verification (M&V) options for transparently and consistently reporting energy efficiency savings. IPMVP is currently promoted globally by Efficiency Valuation Organisation (EVO). The IPMVP stems from previous work supported by the DoE which resulted in the North American Energy Measurement and Verification Protocol in 1996[54].

3.2.2.2.2 Danish Energy Management Standard

Denmark in 2001, introduced the energy standard DS 2403 which is designed to apply to all companies irrespective of size, and caters for industrial and commercial businesses, the service industry, and the public sector. The standard thus enables all types of business to take a systematic approach to energy management. Verification is implemented in accordance with the current rules of the Danish Energy Agency, which involves, among other things, a review of the company’s energy manual and subsequent audit at the company’s premises in order to check the implementation[55]. This type of audit is always performed with the participation of a competent energy specialist. From January 2002, the standard DS 2403 has served as the basis for agreements with the Danish Energy Agency concerning tax concessions[56].

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[52] Source: Department of Energy,1995

[53] Source: Utrecht University,1998, page 6

[54] Source: Efficiency Valuation Organisation, 2007, pages 1-11

[55] Source: McKane, et al, 2005, page 6

[56] Source: McKane et al, 2005, page 6

3.2.2.2.3 California Energy Efficiency Evaluation Protocols

These protocols consist of technical and methodological requirements for energy evaluators who evaluate energy efficiency programmes in California. One of the protocols is the measurement and verification protocol, which is designed to prescribe how field measurements and data collection will be conducted on energy efficiency impact evaluations and provides ex-ante measures of actual savings[57]. These protocols were developed for evaluation of the programmes of the California Public Utilities Commission’s Energy Division (CPUC-ED) and the California Energy Commission (CEC).

3.2.2.2.4 ASHRAE Guidelines 14-2002

The American Society of Heating, Refrigerating and Air-conditioning Engineers (ASHRAE) have produced guidelines 14 for measurement of energy and demand savings. These provide guidance on reliably measuring energy and demand savings of commercial equipment. Energy service companies (ESCOs), ESCO customers, utilities and other energy users can use these measurements before the sale or lease of energy-efficient equipment to determine post-transaction savings. These measurements can also be used to document energy savings for various credit programs, such as emission reduction credits associated with energy efficiency activities[58]

3.2.2.2.5 Swedish Programme for Improving Energy Efficiency (PFE)

The PFE came onto effect in 2005 with the Swedish Energy Agency as the implementing agency for the programme. The Swedish Energy Agency is the supervisory authority for the programme and the programme provides a tax exemption on electricity consumption of energy intensive industries if they take energy efficiency measures. One of the features of the programme is to introduce an energy management system which makes it easier for the company to check energy use and plan energy consumption[59].

3.2.2.2.6 Irish Energy Management System

The Irish energy management system IS393 initiated by Sustainable Energy Ireland (SEI) is a systematic approach to improving energy efficiency continuously. The approach of the energy management system is to embed energy management into business processes and operations[60].

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[57] Source : TecMarket Works , 2004, pages 1-3

[58] Source: http://www.ashrae.org/

[59] Source: McKane et al,2005, page 8

[60] Source: SEI 2006, page 4-6.

3.2.2.2.7 ISO Energy Management Standard

In 2008, ISO announced that they will be developing an ISO Energy Management Standard with a view to harmonise and standardise energy management standards globally. This work will involve UNIDO and also developing countries such as Brasil and China. REEEP will also be supporting the UNIDO efforts[61].

3.2.2.2.8 GHG Protocol

The GHG Protocol (GHG Protocol) is an international accounting tool to quantify GHG emissions. The GHG Protocol was developed by the World Resources Institute and the World Business Council for Sustainable Development. It provides the accounting framework for GHG standards and does include energy efficiency savings measurement and quantification methodologies as well.[62]

3.2.3 Energy Efficiency Indicators

Indicators are used to describe and characterise energy efficiency trends in specific sectors. Energy efficiency indicators are used to provide the metrics to compare energy efficiency across economies and to adjust for climatic and structural differences. Energy Efficiency indicators are required due to a number of reasons prominent among which are[63] [64]:

1) Characterise and monitor energy efficiency trends across economies;
2) To evaluate the impact of energy efficiency programmes;
3) To forecast future levels of energy consumption.

There are six broad types of energy efficiency indicators that can be used to characterise energy efficiency and are explained below[65] [66].

3.2.3.1 Energy Intensities

Energy Intensity is the ratio between energy consumption and economic activity. Energy consumption is usually measured in energy units such as toe and economic activity is measured in monetary units such as value added and Gross Domestic Product. When energy efficiency is assessed at a high level the use of energy energy intensities are of particular relevance. This is due to the inability to use physical or

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[61] Source: ISO, 2007, page 9

[62] Source: www.ghgprotocol.org

[63] Source: Asia Pacific Energy Research Centre, 2001, page 23-32.

[64] Source : Odyssee-indicators.org/indicators/indicators.html, accessed February 2008

[65] Source: Asia Pacific Energy Research Centre,2001, page 23-32

[66] Source : Odyssee-indicators.org/indicators/indicators.html, accessed February 2008

technical indicators to characterise energy efficiency at a higher level such as a sector or the economy. For example the energy intensity of the united states is more than four times the energy intensity of Bangladesh due to differences in standards of living and lower economic performance.

3.2.3.2 Specific Consumption

Specific consumption is defined at the end-use or sub-sector level and is obtained by relating physical outputs and the energy consumption. Examples include energy consumption per ton of cement or fertilizer or fuel consumption per mile for vehicles. Values for specific energy consumption may be obtained through surveys or calculated from statistics. Specific consumption can also be related to consumption unitis such as households, cars etc.

3.2.3.3 Indices

Energy efficiency indices provide an overall assessment of energy efficiency trends of a sector. They are calculated as a weighted average of detailed sub-sectoral indicators (by end-use, mode of transport). A decrease would mean an improvement in energy efficiency. Such indices are more relevant for grasping the trends of energy efficiency changes than energy intensities.

3.2.3.4 Diffusion Indicators

Diffusion indicators have been introduced to complement the existing energy efficiency indicators, as they are easier to monitor, offering a possibility of more frequent updating. Diffusion indicators aim at improving the interpretation of trends observed on the energy efficiency indicators.

Two types of diffusion indicators can be defined for energy efficiency:

1) Market penetration of efficient technologies: number of efficient lamps sold, % of label A in new sales of electrical appliances etc.,

2) Diffusion of energy efficient practices: % of passenger transport by public modes, % of transport by non motorised modes; % of transport of goods through rail by combined rail-road transport, % of efficient process in industry etc.

3.2.3.5 Adjusted Indicators

Energy efficiency indicators need to be adjusted across regions, provinces, states and countries to factor in differences in climate, technological state, standard of livening and lifestyle as well as economic structures. Comparisons across countries of energy efficiency performance can lead to inaccurate results without adjustment.

3.2.3.6 Target Indicators

The objective of target indicators is to set possible targets for energy efficiency opportunities and improvements for countries. They consist of reference values and are similar to benchmark values and defined at a macro level. Target indicators can be grouped into two based as:

1) Technical and non-technical potential indicators such as increases in technical efficiency and as well as high penetration of efficient practices.

2) Indicators of technical progress

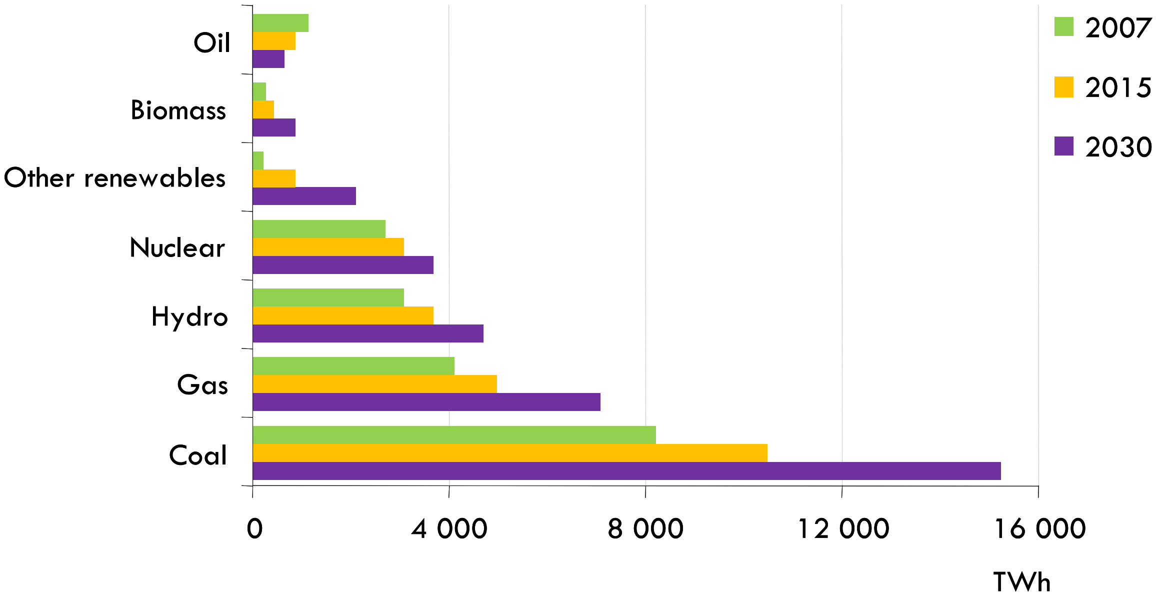
The values used in target indicators are adjusted for regional, size and climatic differences, differences in standards of living and lifestyles as well as differences in industrial structures and variations in industrial and development policy.

3.3 Clean Coal Technologies

Coal accounts for about 27% of world primary energy demand and is the second most important fuel after oil[67]. However coal is the major fuel for electricity generation in the world today accounting for over 48%[68]. The prices of steam coal had steadily increased over the years before peaking in 2008 after hitting a price level of 137 US$/t[69]. The increased demand for coal which stood at 937.8 million tonnes compared to 926 million tonnes in 2007 is also driving considerable investments in infrastructure for coal mining and coal transport. According to IEA, the share of coal in the electricity generation mix is going to increase from 42% to 44% in the period from 2007 to 2030[70] which is illustrated in fig 6.

[67] Source: IEA, 2009, page 89
[68] Source: IEA, 2009, page 90
[69] Source: IEA, 2009, page 89
[70] Source: IEA, 2009, page 97

Fig 6: World Electricity Generation by Fuel (2007-2030)[71]



The projected increase in the use of coal will come from North America and the developing countries and in particular China and India. Since 2004, coal is the leading source of world CO_2 emissions ahead of other fossil fuels – oil and natural gas. Since 2003, CO_2 emissions from coal have grown per annum by an average of 650 $MtCO_2e$ or an average growth of 6.5%. The majority of these CO_2 emissions come from the power sector the share of which was over 70% in 2006[72]. It is therefore clear that coal will continue to play a major role in energy sector in developing countries and a low-carbon energy transition in developing countries will need to address the projected increase in the role of coal in the energy sector. Fig 7 shows the coal based power generation capacity under construction globally.

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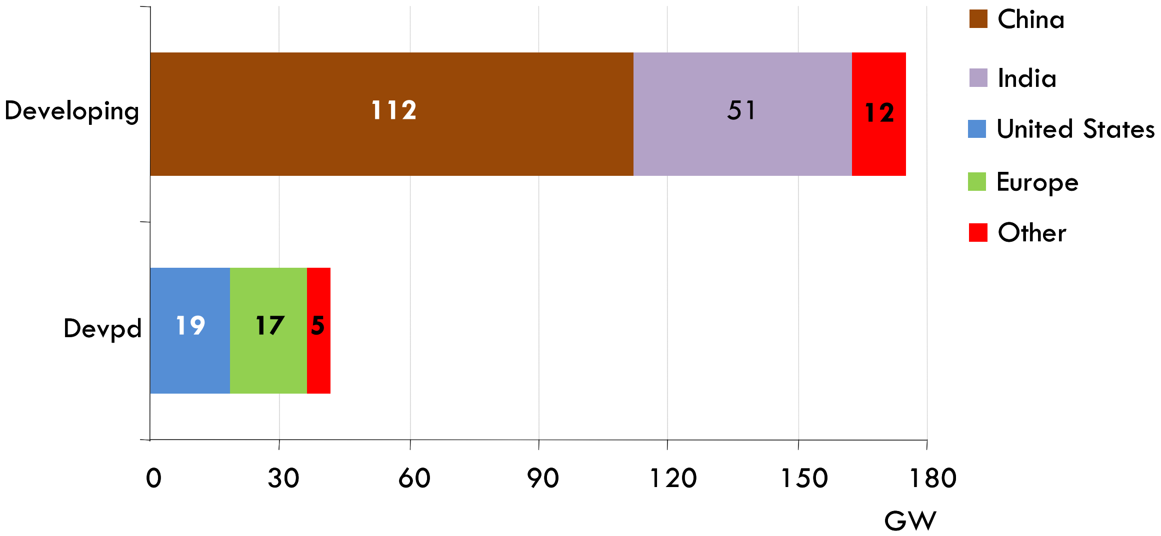
[71] Source: IEA, 2009, page 97

[72] Source: IEA, 2008, page 28

Fig 7: Coal-based power generation capacity under construction in developed and developing countries[73]



3.3.1 Reducing GHG emissions in coal power generation

There are generally three approaches which can help in decreasing the carbon emissions of coal-based power generation. These are:

- **Coal Upgrading**: is achieved through washing/drying and briquetting of coal. Coal generally has high levels of moisture content. The high moisture content and resultant low heating value affect both boiler efficiency and transportation costs. Upgrading enhances power plant efficiency, increases coal energy density and reduces other emissions such as fly ash and sulphur. It is estimated that upgrading could reduce CO_2 emissions by as much as 5%[74]. Coal upgrading is commonly practiced in developed countries but not in developing countries.
- **Efficiency Improvements at Existing Power Plants**: the efficiency of coal power plants averaged about 35% from 1992 to 2005[75]. The best available coal power plants today achieve 47% efficiency[76]. The efficiency of coal-based thermal power plants in developing countries is lower, with the average efficiencies in China and India being 33% and 30% respectively. The measures to improve the efficiency of thermal power plants include upgrading and system-

[73] Source: IEA, 2009, page 99

[74] Source: IEA, 2008a, pages 24, 26

[75] Source: IEA, 2008a, pages 26

[76] Source: Franco and Diaz, 2009, page 351

atic performance monitoring and diagnostic testing of boilers, turbines, condensers and auxiliary equipment. Efficiency improvements of 40% could reduce CO_2 emissions by as much as 22%[77].

- **Advanced Technologies**: there are advanced coal conversion technologies such as supercritical and ultra-supercritical coal technologies. Supercritical coal power plants are defined as achieving steam outlet temperatures of 540-566°C and a pressure of 250 bar[78]. Ultra-supercritical coal power plants are defined as those with outlet steam temperatures above 590°C and pressures above 250 bar[79]. It is possible to achieve efficiencies of over 40% for supercritical coal technologies and in the 45-50% range for ultra-supercritical technologies[80]. Another advanced coal technology is the Integrated Gasification Combined Cycle (IGCC) coal technologies offer efficiencies in the range of 50-55% range. The advanced coal conversion technologies could reduce CO_2 emissions by as much as 25%[81].

For the purpose of this thesis report, advanced technologies such as ultra-supercritical coal conversion and IGCC will be examined, which are the low-carbon energy technologies relevant to developing countries. These are explained in more detail below:

3.3.2 Ultra-Supercritical Coal

Ultra-supercritical coal represents an evolution in the pulverised coal combustion technology. The steam conditions are advanced with outlet steam temperatures above 590°C and pressures above 250 bar[82]. Because of this higher temperature and pressures, these plants are able to achieve higher efficiencies than conventional pulverised coal power plants. Apart from the advanced steam conditions, ultra-supercritical coal power plants incorporate several other technologies such as new burner designs, new scheme of combustion in the boiler furnace, new design of steam super-heaters and gas cleaning systems[83].

The introduction of supercritical coal has been a feature of countries such as Japan, China, Germany, Denmark etc. The current research is focussing on the development of new materials such as steels for boiler tubes and high-alloy steels that minimise corrosion. The development of such new materials is expected to achieve

[77] Source: IEA, 2009, page 27
[78] Source: IEA, 2009, page 26
[79] Source: IEA, 2009, page 27
[80] Source: IEA, Clean Coal Technologies, 2009, page 27
[81] Source: IEA, Clean Coal Technologies, 2009, page 26
[82] Source: Franco and Diaz, 2009, page 351
[83] Source: Franco and Diaz, 2009, page 351

steam pressure levels of 350 bar and temperatures of 700°C resulting in efficiencies of 50%[84].

3.3.3 Integrated Gasification Combined Cycle

The integrated gasification Combined Cycle plants use a gasifier to convert coal to gas. Coal is combined with oxygen and steam in the gasifier to produce syngas[85]. The impurities in the gas such as sulphur, ash mercury etc. is cleaned thereafter and the syngas is used in a gas turbine to produce electricity. The waste heat from the gas turbine is recovered to create steam which drives a steam engine producing electricity – hence a combined cycle system. There are generally three types of gasification process available –entrained flow[86], fixed bed[87] and fluidised bed[88]. There are currently four plants operating in the US, Netherlands and Spain. These are the 252 MW Wabash River in Indiana, US, 250 MW of Polk County, Florida, 253 MW at Buggenum, Netherlands and 318 MW in Puertollano in Spain[89]. The efficiencies that have been experienced under operating conditions are in the range of 35-42%, although efficiencies around 50% are achievable[90]. One of the advantaged of Integrated gasification combined cycle systems is that other solid fuels such as biomass can also be used. The Integrated Gasification Combined Cycle power plants are also very clean coal technology in terms of lower levels of SOx[91], NOx[92] and particulate matter and solid waste and waste water.

Reliability and availability have been the challenges facing Integrated gasification Combined cycle. Cost has also been a major factor with the incremental costs being in the range of 40-60% based on the initial experience[93]. Gasification does hold a significant future promise due to the flexibility of feedstock and provides the only feasible bridge from coal to hydrogen. Fig 8 shows the schematic of an Integrated gasification Combined Cycle power plant.

[84] Source: Franco and Diaz, 2009, page 351

[85] Consisting of hydrogen and carbon monoxide.

[86] Used by Shell, Texaco, Conoco-Phillips

[87] Used by BGL, Lurgi, EPIC

[88] Used by Southern Co and KRW

[89] Source: Franco and Diaz, 2009, page 352

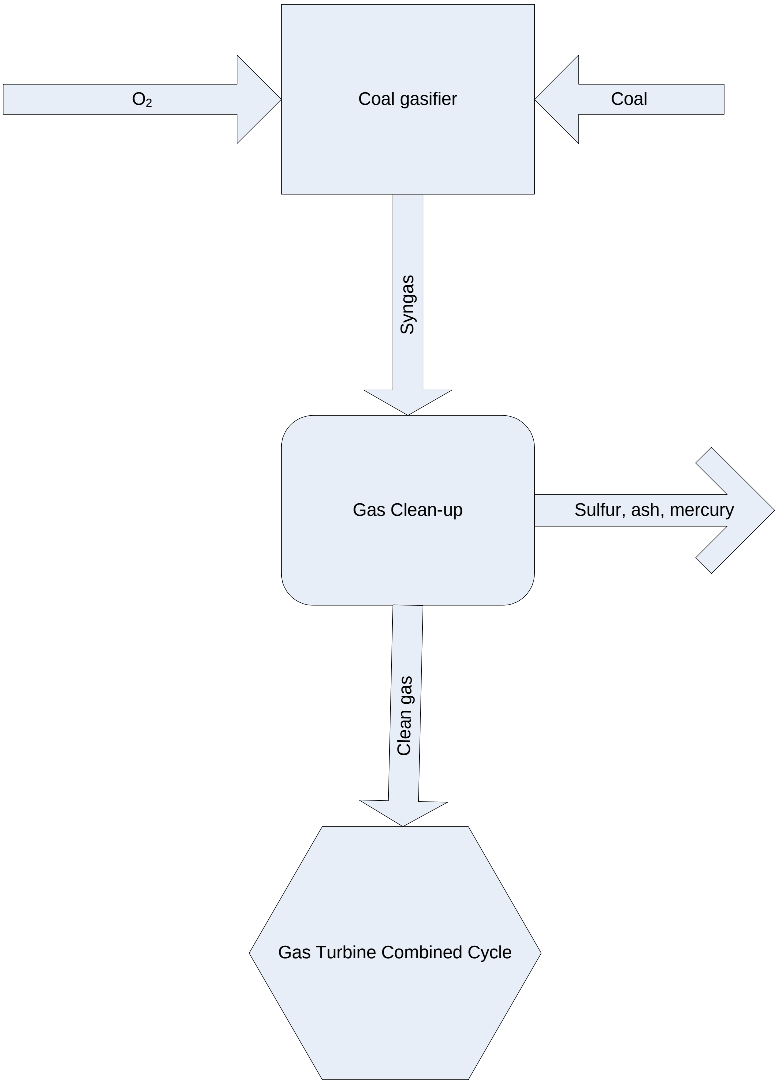
[90] Source: IEA, 2009, page 27

[91] Oxides of Sulfur such as SO_2, SO_3 etc.

[92] Oxides of Nitorgen such as NO, NO_2, N_2O_2 etc.

[93] Source: Franco and Diaz, 2009, page 352

Fig 8: Schematic of Integrated gasification Combined Cycle Power Plant[94]



3.4 Carbon Dioxide Capture and Storage

Carbon Dioxide Capture and Storage (CCS) has been receiving considerable climate policy attention in recent times. The attention CCS has been receiving is a reflection of the realisation in some international institutions and with governments that it is likely that the power generation systems and industrial activities in the future will continue to be large emitters of carbon dioxide. The interest in CCS is also a result of plans to apply the technology to large stationary sources of CO_2 emissions such as power plants and large industrial installations.

[94] Source: Franco and Diaz, 2009, page 352

CCS involves the use of technology to collect and concentrate carbon dioxide, transport the collected carbon dioxide to storage location and store carbon dioxide for a long period of time. Therefore the use of CCS would allow fossil fuel use in power plants and industries in the future with lower emissions of carbon dioxide. Several climate scientists and policy makers regard CCS as an option to help stabilize the atmospheric concentration of GHG gases and prevent dangerous climate change. Several climate scientists, policy makers and environmentalists oppose the use of CCS as a climate technology option due to questions about the permanency of the carbon dioxide storage.

CCS consists of 3 sub-processes – capture, transport and storage. Each of these sub-processes and the technological options available are discussed below.

3.4.1 Carbon Dioxide Capture

The objective of the carbon dioxide capture process is to capture and concentrate carbon dioxide from power plants and large scale-industrial installations with high levels of capture efficiency. Considering the requirements for transport and storage the objective is to ensure high concentration of carbon dioxide at a high pressure. The carbon dioxide can be captured from fossil fuels such as coal, oil, natural gas or biomass. There are three main technological approaches to capturing carbon dioxide from power generation applications of fossil fuels or biomass:

- **Post-combustion** systems seek to separate the carbon dioxide from the post combustion flue gases where the carbon dioxide fractions are 3-15% by volume[95]. Post-combustion carbon dioxide capture systems use a liquid solvent to capture carbon dioxide present in the flue gas. For coal and gas based modern power plants the solvent used is Monoethanolamine (MEA).
- **Pre-combustion**: systems pre-treat the fuel to produce synthesis gas – a mixture of carbon monoxide and hydrogen. Additional hydrogen along with carbon dioxide is produced by the reaction of carbon monoxide and steam in a shift reactor. The carbon dioxide and hydrogen is separated and the hydrogen is combusted to produce power and heat. The carbon dioxide gas stream is then transported and stored. While the pre-combustion carbon dioxide capture technology is more complex and expensive than other options, it produces higher concentrations of carbon dioxide and higher pressures that are more favourable for carbon dioxide separation. Pre-combustion capture technology is more suitable for application in IGCC systems[96].
- **Oxyfuel Combustion**: systems use oxygen for combustion of the fossil fuel and biomass in the place of air. This results in the flue gas to be mostly water

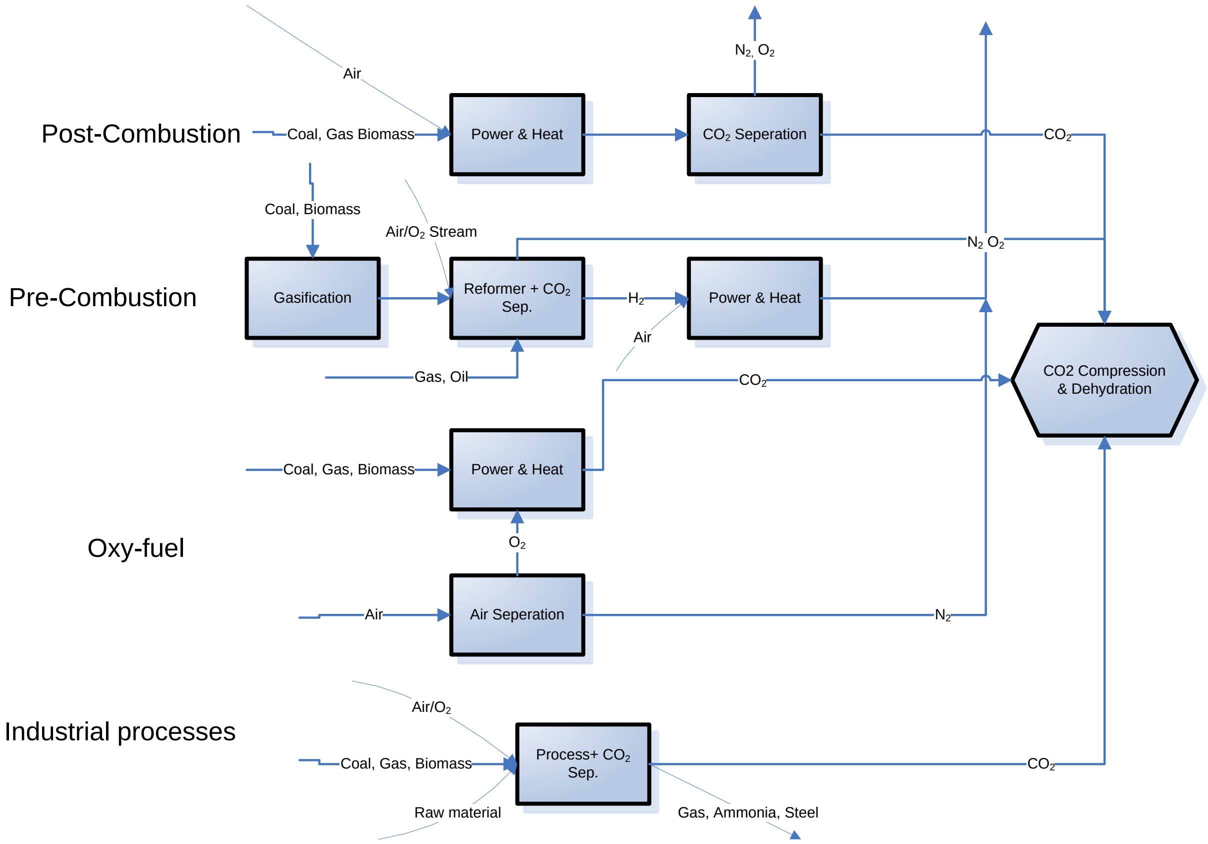
[95] Intergovernmental Panel on Climate Change, 2005, page 25

[96] Intergovernmental Panel on Climate Change, 2005, page25

vapour and carbon dioxide with significantly high levels[97] of carbon dioxide concentration. The water vapour is then removed by cooling and compressing the gas stream. Oxyfuel combustion requires the upstream separation of oxygen from air. Further treatment of flue gas may also be required to remove air pollutants and non-condensed gases from the flue gas before the carbon dioxide can be sent to storage. Oxyfuel combustion systems are currently in the research and demonstration phase[98].

In addition Carbon Dioxide capture is already used in industrial applications such as for large scale production of hydrogen in ammonia and fertilizer manufacture and also in petroleum refineries. These processes employ pre-combustion capture technologies. Similarly post-combustion capture technologies are also used in large scale to separate carbon dioxide from raw natural gas.

Fig 9: Schematic of Carbon Dioxide Capture Technologies[99]



The carbon dioxide capture systems require significant amounts of energy for their operation which directly affects the plant efficiency. This would mean that power plants will require more amount of fuel to generate each unit of energy produced. Capturing 90% carbon dioxide using the current technology would result in increase

97 Greater than 80% by volume

98 Source: Intergovernmental Panel on Climate Change, 2005, page 25

99 Source: Intergovernmental Panel on Climate Change, 2005, page 26

in fuel consumption in the range of 11-40%, the higher end of the range is for super-critical pulverized coal power plants[100]. Based on existing estimates of carbon dioxide capture at large power plants based on engineering design studies, it is estimated that carbon dioxide capture would increase the cost of electricity production by 20-85% for coal and gas power plants[101]. The higher end of the range will be for super-critical pulverized coal power plants and natural gas combined cycle power plants and the lower end of the range will be for IGCC power plants. While limited number of studies has examined the cost of retrofitting existing power plants with carbon dioxide capture, it is estimated that the costs of doing so would be considerably higher than a greenfield power plant.

3.4.2 Transport of Carbon Dioxide

Except on cases where the power generating or industrial plants are located close to a storage site, carbon dioxide must be transported from the point of capture to the storage location. The principal methods of carbon dioxide transport are:

- **Pipelines**: This is the most common method for transporting carbon dioxide. In this option gaseous carbon dioxide is typically compressed to a pressure above 8 Mpa and increase the density of carbon dioxide to make it easier and cost effective to transport. Carbon dioxide transport through pipelines has been operational in the US since the 1970s where more than 40 Mt of carbon dioxide is transported over 2500 km to Texas for use in enhanced oil recovery.
- **Ships**: Transport of carbon dioxide by ship can be attractive when the carbon dioxide needs to be moved overseas or over large distances. Carbon dioxide can be transported in the same way as Liquefied Petroleum Gas (LPG)[102] typically at 0.7 MPa pressure on a large scale by marine tankers. Current transport by ships of carbon dioxide takes place on a small scale due to limited demand however can be scaled up if there were to be demand as properties of liquefied carbon dioxide are similar to LPG.
- **Surface Transport:** Carbon dioxide can also be transported by road and rail tankers. These options transport carbon dioxide at – 20°C and at 2 MPa pressure. However these options are uneconomical compared to pipelines and ships and are unlikely to be relevant in large scale transport of carbon dioxide.

[100] Source: Intergovernmental Panel on Climate Change, 2005, page 27
[101] Source: Intergovernmental Panel on Climate Change, 2005, page 27
[102] Principally Propane and Butane

Costs of transporting carbon dioxide depend on the quantity and the distances transported. The cost of pipeline transport for a nominal distance of 250 km is expected to be 1-8 US$/t$CO_2$[103].

3.4.3 Storage of Carbon Dioxide

The carbon dioxide captured can be stored in geological formations, in deep oceans or chemical conversions to solid inorganic carbonates or used in industrial application. Various options for storing of carbon dioxide are explained below:

- **Geological storage**: There are three types of geological formations that can be considered for the geological storage of carbon dioxide which are oil and gas reservoirs, deep saline formations and coal beds. The geological storage is accomplished by injecting carbon dioxide in a dense form into a rock formation below the earth’s surface. Porous rock formations that have held natural gas or oil are potential candidates for carbon dioxide storage. Coal beds where it is unlikely that coal will be later mined and where permeability is sufficient can also be used for carbon dioxide storage. There are four large scale plants carrying out geological storage of carbon dioxide in Sleipner and Snøhvit in Norway, Salah in Algeria and Weyburn-Midale in Canada[104]. In addition 30 MtCO_2 is injected for enhanced oil recovery in Texas. In geological storage of carbon dioxide it is important to ensure that the overlying cap rock will provide an effective seal to ensure that carbon dioxide remains trapped underground. Estimates of costs of storage in saline formations and depleted oil and gas fields are in the range of 0.5 to 8 US$/t$CO_2$ injected[105]. There are also a number of long-term liability issues related to carbon dioxide storage such as local concerns about environmental impact as global issues relating to the leakage of carbon dioxide into atmosphere which have not yet been addressed.
- **Ocean storage**: A potential carbon dioxide storage option is to inject captured carbon dioxide directly into the deep ocean at depths greater than a kilometre. This requires transporting carbon dioxide through pipelines or ships to an ocean storage site where it is injected into the water column of the ocean. Ocean storage has not been deployed or demonstrated at a pilot scale and is still in the research phase[106]. The costs of the ocean storage options will largely be determined by the costs of the transportation distance from the shore to the storage site. The injection of carbon dioxide will also produce a measura-

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[103] Source: Intergovernmental Panel on Climate Change, 2005, page 30
[104] Source: International Energy Agency, 2010, page 12
[105] Source: Intergovernmental Panel on Climate Change, 2005, page 37
[106] Source: Intergovernmental Panel on Climate Change, 2005, page 37

ble change in the ocean chemistry depending on the amount of carbon dioxide injected. There are also legal issues relating to the international ocean storage of carbon dioxide which are yet to be resolved.

- **Mineral carbonation:** This option involves converting carbon dioxide into solid inorganic carbonates using chemical reactions. This involves the fixation of carbon dioxide using alkaline and alkaline earth oxides such as Magnesium Oxide and Calcium Oxide. The chemical reactions between these alkaline oxides which are found in naturally occurring silicate rocks produce Calcium Carbonate or Magnesium Carbonate. A commercial process of mineral carbonation would require the mining, crushing and milling of the mineral bearing ores and their transport to a processing plant receiving a concentrated carbon dioxide stream from a carbon dioxide capture plant. The carbonation process would require high amounts of energy and the requirements would be about 30 to 50% of the capture plant output[107]. Therefore a CCS plan with a mineral carbonation would require 60 to 180% more energy input per kilowatt hour than a reference electricity plant. The estimated costs of the best case of mineral carbonisation are in the range of 50-100 US$/t$CO_2$[108].
- **Industrial Use:** This option involves the use of carbon dioxide either directly or as a feedstock for the production of various carbon-containing chemicals. The industrial uses include chemical and biological processes where CO_2 is a reactant such as Urea and Methanol production. There are also industrial applications which use carbon dioxide directly such as horticulture, welding, refrigeration, food packaging, beverages and fire extinguishers. Current levels of industrial use of carbon dioxide are about 120 MtCO_2/year of which two-thirds is to produce Urea[109]. However the typical lifetime of most of the carbon dioxide used by industrial process has storage times of days to months after which the carbon dioxide is degraded and emitted to the atmosphere.

3.5 Nuclear Energy

The recent years have seen a renewed interest in nuclear energy globally. In the developed countries the renewed interest has been driven by the need for energy security and the imminent retirement and decommissioning of the several older generation operating nuclear power plants. The developing countries led by China, India and United Arab Emirates are actively pursing nuclear energy as an option to meet their increasing energy demand and to diversify their energy options. However the nuclear disaster at Fukushima Daiichi in March 2011following an earthquake and

[107] Source: Intergovernmental Panel on Climate Change, 2005, page 40
[108] Source: Intergovernmental Panel on Climate Change, 2005, page 40
[109] Source: Intergovernmental Panel on Climate Change, 2005, page 41

Tsunami and the subsequent release of radioactive material is expected to affect the revival of the nuclear power industry. Several European countries have reviewed their nuclear energy programmes and Germany and Switzerland have decided to shutdown all nuclear power plants by 2022 and 2034 respectively.

While the majority of reactors under construction will be using the second generation Pressurised water Reactors (PWRs), several advanced nuclear energy technologies are expected to play an important role in the expansion of nuclear power sector in the future. These are referred to as the generation III and III+ reactors and the generation IV reactors. An illustration of nuclear energy technology and reactor generations is shown in table 5.

Table 5: Generations of Nuclear Energy Technology[110] [111]

Generation	Description	Technologies	Timeframe
Generation I	Early Prototype reactors	Shipping port, Dresden, Magnox	1950-1970
Generation II	Commercial Power reactors	Pressurised water Reactors, Boiling water Reactors, CANDU	1970-2000
Generation III	Advanced Light Water reactors	CANDU6, System 80+, AP600	1995-2010
Generation III+	Evolutionary Designs	ABWR, ACR 1000, AP 1000, APWR, EPR, ESBWR	2010 - 2030
Generation IV	Revolutionary designs	Enhanced safety, minimisation of waste and better use of natural resources, economical, im-proved physical protection and proliferation re-sistance	2030 onwards

[110] Source: Nuclear Energy Agency, 2008, pages 18-39

[111] Source: Nuclear Energy Agency, 2007, page 16

3.5.1 Generation III and III+ nuclear technologies

The generation III nuclear rector designs are built on the principles of generation II Light Water Reactors (LWR) and aiming to increase the safety through use of simplified reactor designs. Generation III reactors feature a standardised design leading to reduced construction and operating costs. Generation III+ designs are an extension of generator III concept with additional improvements and passive safety features. These designs can maintain the reactor in a safe state during an unplanned event without the use of active control measures. The most notable generation III designs are the Advanced Boiling Water Reactor (ABWR) and the Advanced Pressurised Water Reactors (APWR). These are explained below[112]:

- **Advanced Boiling Water Reactor (ABWR)**: is a collaboration between General Electric and Hitachi and is currently operational in Japan. The ABWR design includes internal recirculation pumps eliminating the large diameter external recirculation pipes. ABWRs with a net output of 1350 MW are in operation in Japan with construction times lasting only 46 months. Two more ABWRs are expected to be completed in Taiwan.
- **Advanced Pressurized Water Reactors (APWR)**: are a generation II nuclear reactor developed by Mitsubishi Heavy Industries based on pressurised water reactor technology. It features several design enhancements, improved efficiency and improved safety systems including a combination of passive and active systems. The Mitsubishi APWRs are being built in Japan and is expected to enter service by 2017. A Mitsubishi APWR will also be build in the US by TXU at the Comanche Peak Nuclear generating station.

The leading generation III+ reactor designs include the European Pressurised water Reactor (EPR), Economic Simplified Boiling Water Reactor (ESBWR) and the AP-1000. These are explained below[113]:

- **European Pressurised Reactor (EPR)**: has been designed and developed by AREVA NP. The EPR design provides significant improvements to the previous pressurised water reactors. Two units are under construction in France and in Finland[114]. Concerns have been expressed over the increased radioactivity of the spent fuel of the EPR reactors which could have an impact on the storage systems that are required to store the spent fuel.
- **Economic Simplified Boiling Water Reactor (ESBWR)**: is also another collaboration between General Electric and Hitachi and is similar to the ABWR

[112] Source: Ebinger, 2009, pages 3-4

[113] Source: Nuclear Energy Agency, 2008, pages 374-375

[114] The Oilinko 3 nuclear power plant in Finland has run into significant time and cost over-runs.

and takes passive concepts even further. In an abnormal event, the core is cooled by condensers that take steam from the pressure vessel or the containment by natural circulation, condense it by transferring the heat to a water pool and then put the water back into the vessel.

- **AP1000**: this is a two-loop pressurised water reactor developed by Westinghouse Electric Company that can produce 1117 MW and received design approval in the US in 2006. The design builds on earlier technologies but uses significantly less number of components compared to generation II nuclear reactors. About 5 AP-1000s are in different stages of development in the US and two AP-1000s are under construction in China. AP-1000s also result in increased radioactivity of spent fuel similar to the EPR.

3.5.2 Generation IV Nuclear Technology

The generation IV set of reactor designs combine operational advances and potential security concerns. Thirteen countries viz. Argentina, Brasil, Canada, France, Japan, China, Korea, South Africa, Russia, Switzerland, UK and the US have formed the generation IV international forum. This forum aims to develop a future generation of nuclear energy systems that will provide competitive and reliable energy while addressing issues relating to nuclear safety, radioactive waste minimisation, improved physical protection and proliferation resistance. The initiative has carried out a comprehensive evaluation of nuclear energy concepts and has selected six generation IV concepts. Further research and development will be carried out to establish the technical viability and performance assessments. The six generation IV concepts selected are[115]:

- **Very High Temperature Reactor (VHTR)**: is a graphite moderated, helium cooled reactor with a once-through uranium fuel cycle.
- **Supercritical Water Cooled Reactor (SCWR)**: is a high temperature, high pressure water-cooled reactor that operates above the thermodynamical critical point of water.
- **Gas-cooled Fast Reactor (GFR):** is a fast neutron, high temperature helium cooled reactor with a closed fuel cycle.
- **Lead-cooled fast Reactor (LFR):** is a fast neutron, lead or lead/bismuth eutectic liquid metal-cooled reactor with a closed fuel cycle for efficient conversion of fertile uranium and management of actinides.
- **Sodium-cooled Fast Reactor (SFR):** is a fast neutron, sodium cooled reactor with a closed fuel cycle for efficient management of actinides and high conversion of fertile uranium.

[115] Source: Nuclear Energy Agency, 2008, page 376

- **Molten Salt Reactor (MSR):** is a system producing fission power in a circulating molten salt fuel mixture in an epithermal neutron spectrum reactor with full actinide recycling.

It can be seen that fast reactor designs with their ability to use reprocessed spent fuel as an input and to utilise long-lived nuclear waste could achieve better efficiency from the fission process and reduce stockpiles of spent fuel. However these fast reactor designs have operational and fuel-cycle related security considerations and there are questions about the economic viability of these concepts. The US government has since 2006 been encouraging priority consideration to fast reactor technologies such as GFR, LFR and SFRs. Countries like India are also pursuing a fast reactor programme with an aim to develop the Thorium fuel cycle which will allow India to use its vast reserves of Thorium. The technical characteristics of generation IV technologies are designed to enhance their resistance to proliferation threats and increase robustness against sabotage and terrorism threats.

Given the increased demand for energy globally, energy security concerns and an emphasis on low-carbon energy solutions, nuclear power was seeing a revival in both developed and developing countries till the Fukushima nuclear disaster. As a result of increased concerns about reactor-safety and European countries like Germany and Switzerland deciding to terminate their nuclear energy programmes, nuclear energy may see its short to medium term prospects affected. The effect of Fukushima nuclear disaster on the nuclear energy plans of developing countries is not evident. There is likely to be increased scrutiny of reactor-safety, fuel-cycle management, security and proliferation challenges associated with future nuclear energy programmes. There will also be a need for an adequate international regime to deal with civilian nuclear issues.

3.6 Smart Grid Technologies

3.6.1 Current Electricity Grid

The electricity grid is a collective term for all the electricity network consisting of all the cables, transformers and the infrastructure that transmits electricity from the electricity generation equipment to the end-users. In many countries, especially in the developing world, the electricity grid was build 40-60 years ago to serve an approach of centralised generation and distribution where centralised and large power plants – thermal, nuclear or hydro produced electricity in locations that were typically far away from the end users. This electricity was then transmitted at high voltages over long distances to the electricity consumption centers such as cities and towns and industrial facilities where a low-voltage distribution network distributed the electricity to individual households, shops and establishments. The transmission networks transmit electricity in large quantities over medium to long distances and are actively managed and generally operate from 345 KV to 800 KV over AC and DC lines. Local distribution networks traditionally supply electricity in one direction by distributing the electricity at lower voltages.

The electrical grid is an aggregate of multiple networks and multiple power generation companies with multiple operators employing varying levels of communication and coordination, most of which is manually controlled. The coordination and connectivity among the suppliers, networks and consumers has generally been sub-optimal in the past. The current electrical grids generally build in an overcapacity of generation capability to meet the unexpected surges in energy use. The current electrical grid also allows only one way communication from supplier to the consumer. The existing electrical grid in developed countries and some developing countries are equipped with Supervisory Control and Data Acquisition (SCADA) systems which provide some control over the electrical grid to detect the need for increase or decrease in generation and to respond to system instabilities. However SCADA systems of today have limited bandwidths and relatively slow data transmission rates which considerably slow down the response. Most SCADA systems also offer limited visibility below the substation[116] in the distribution network.

3.6.2 Technologies of the Smart Grid

A smart grid is an electricity network that uses digital technologies to monitor and manage the transportation and distribution of electricity from all generation sources to meet the varying electricity demands of the electricity consumers. The Smart grid is expected to provide the following benefits[117] [118]:

- ❑ Move towards a more robust, secure, reliable and low-carbon electricity system;
- ❑ Improve Operational Efficiency for the energy utilities through better control and optimisation of grid infrastructure assets;
- ❑ Enable active participation by customers and influence customer energy use behavior;
- ❑ Accommodate distributed and renewable generation options as well as distributed storage options;
- ❑ Enhance demand response, load control and enable new products and services;

The term smart grid refers to a number of classes of technologies which are expected to be part of the grid of the future. There are a number of varying and sometimes contradictory definitions of the smart grid by different agencies. From a low-carbon

[116] At the substation the high voltage electricity transmitted is stepped down to lower voltages to supply industrial customers, establishments and households.

[117] Pacific Northwest national laboratory, 2010, page 2.5

[118] Source: International Energy Agency, 2010, page 151

energy perspective, the classes of technologies that make up the smart grids are explained below.

3.6.2.1 Demand Response

Demand response technologies allow the utilities to communicate with electrical devices being used by the customers. Demand control technologies include load control devices, smart thermostats and home energy consoles. Demand response events can result in the curtailment of utility power demand. These technologies are explained below:

- **Smart Load Control (SLC)**: Smart Lead control technologies can be used with residential and commercial appliances such as air-conditioners, refrigerators, washing machines, dish washers, electric geysers etc.. The Smart Load controllers can detect the grid stress conditions and can either switch off the appliance or cycle the appliance into a low-power consumption mode.
- **Smart Thermostats or Programmable Communication Thermostats:** Smart Thermostats can be programmed to turn up or down air-conditioning or the heating system based on the information on electricity tariffs provided by electric utilities. The information on tariffs can be programmed based on time of use tariffs by the utility or in more advanced systems this information may be dynamically provided by the utility and the smart thermostats will respond based on how they have been programmed by the consumer.
- **Home Energy Consoles:** Home Energy Consoles provide consumers the ability to understand energy usage and costs and to control their costs and usage. Home Energy Consoles can communicate with other home devices such as smart meters, smart thermostats, and load controllers. The energy users and consumers can in turn set schedules and rules for energy use based on real-time, historic and individual appliance consumption. Home energy consoles are also able to provide information on predicted energy costs and also provide suggestions on energy saving measures.

3.6.2.2 Distributed Generation and Renewable Generation

Distributed generation is also called decentralised generation, on-site generation or embedded generation. Conceptually distributed generation would allow for embedding energy generation closer to the locations where energy is used. Such an approach does save investments in grid infrastructure relating to transmission and distribution and also saves energy lost as transmission and distribution losses.

Distributed energy systems are typically small-scale power generation systems in the range of few kWs to few MWs. Typical energy conversion technologies used as distributed generation options include[119]:

- Fuel Cells
- Combined Heat and Power (CHP) systems[120]
- Photovoltaic Systems
- Diesel, petrol or gas engine-generators
- Natural gas fired Micro-turbine generators
- Small wind power systems and
- Biomass energy

While distributed generation has been around for a while, their integration into the grid, especially embedding into distribution networks have been complicated by interconnection and integration issues. A significant potential exists for renewable energy systems such as photovoltaics, small wind and biomass energy to play a role in distributed generation. The prospects of intermittent power generating renewable energy options such as solar and wind have been constrained by the traditional grid and its ability to absorb intermittent power generation. The challenge of current grid integration of solar and wind resource based renewable energy is the inherently less controllable nature of the availability of resource which intermittently feed energy to the grid. This issue is more relevant for wind energy compared to solar energy.

The Smart grid will facilitate the seamless integration of renewable energy generation and other distributed energy generation due to advanced control and communications capability of a smart grid. The intermittency issues relating to wind and solar energy will also be solved by integration of location specific forecasting techniques for daily and hourly generation from solar and wind energy into utility dispatch planning in a smart grid to enhance frequency control and improve system stability.

However large scale integration of wind and solar energy into the grid also pose challenges associated with the remoteness of locations where large amounts of solar or wind electricity can be generated. Large scale generation of solar electricity in the scale of 100s of MWs will most likely use solar thermal electric technologies using parabolic dishes, parabolic troughs or heliostats which concentrate solar radiation. These large solar electric systems will most likely be located in locations with high levels of sunshine and large open areas typically in desert-like locations. In a similar way large scale generation of wind energy generation of the order of 100s or 1000s of MWs is possible in remote locations with land availability and high winds typically

[119] Source: Hansen, Ulf, 1998 pp 63-87

[120] Including small CHP systems referred to as MicroCHP systems

in mountain valleys or desert-like conditions. Evacuation of large amounts of power from these remote locations to the demand centers presents a challenge in large scale integration of renewable energy sources into the grid. High Voltage Direct Current (HVDC) electric power transmission systems use direct current for bulk transmission of electrical power. HVDC systems as part of a smart grid could help in integration of large-scale renewable power generation in grids systems of the future. Several such HVDC systems have been proposed as part of wide area super grids in Europe and in North America to act as inter-connectors between national electricity systems and linking large scale-renewable energy generators to national and international grids systems. Several initiatives by the American Renewable Energy industry associations[121] and the European Union[122] have proposed a new grid where local and national smart-grids will be connected to each other through HVDC interconnectors making a super grid.

3.6.2.3 Distributed Energy Storage

New and improved grid-scale energy storage technologies will also be part of the smarter grids of the future. Distributed electrical energy storage options allow for energy to be stored when electricity production exceeds consumption. The stored energy can be utilized when consumption exceeds production. Such electrical storage options interspersed as part of a smart grid will allow for electrical energy production to be maintained a constant level without the need for production to be scaled up or down to meet consumption at a given point of time.

Distributed grid energy storage will allow the integration of renewable energy sources such as solar and wind by addressing the intermittent nature of the energy production from these renewable energy sources. Energy storage will also allow traditional thermal power systems based on coal, oil or gas to operate at their optimal production level constantly providing fuel savings. There are a number of distributed energy storage technologies which could be part of a smart grid of the future and some of the key technologies are[123]:

- **Batteries**: Electrochemical storage options using batteries have been used in small mini-grids and off-grid systems extensively. For large scale grid level storage flow batteries and liquid metal batteries could offer a solution. Liquid metal batteries such as Sodium-sulphur batteries have been used for grid-energy storage in the US and in Japan. Vanadium redox batteries and other types of flow batteries are beginning to be used for grid electrical energy storage in Japan, Australia, Ireland etc. Batteries are rapid response storage me-

[121] American Wind Energy Association and Solar Energy Industries Association

[122] A plan to develop HVDC links between Ireland, Britain, Netherlands, Germany, Denmark and Sweden as well as a plan to link North Africa with Europe using HVDC interconnectors.

[123] Source: Department of Energy, 2009, page 19

dium and have high levels of efficiency but generally have high costs, limited lifespan and high maintenance requirements.

- **Pumped Storage:** Pumped storage hydro is used to even out generating load by pumping water to a high storage reservoir during off-peak hours and weekends using the excess base-load capacity from coal or nuclear generating systems. Pumped storage systems can recover about 75% of the energy consumed. The development of pumped storage is constrained by availability of locations with two reservoirs that are close and at considerably different heights. Pumped storage hydro also requires considerable capital expenditure. Pumped storage systems have high dispatchability[124]. There is over 90,000 MW of pumped storage capacity around the world[125].
- **Compressed Air:** In this approach electricity generated during the off-peak hours is used to compress air which is then stored in a geological feature of an old mine. During peak demand the compressed air is heated with a small amount of natural gas and then expanded through turbo-expanders to generate electricity.
- **Flywheels:** use mechanical inertia as the basis of the storage and energy is stored in the kinetic energy of the disc. The flywheels generally rotate in vacuum using magnetic bearings. Flywheels are generally used for improvements in power quality by smoothening out transient fluctuations in supply. There is an 18 MW flywheel system being used in Portugal to allow increased renewable energy use. In Australia flywheels have been used to increase the penetration of wind by upto 60% in wind-diesel decentralised grids.
- **Hydrogen:** can also be used as an electrical energy storage medium. In this approach hydrogen is produced and compressed or liquefied and then stored. Hydrogen can then be used as fuel for stationary power generation units. Hydrogen has the advantage that it has high energy density. The efficiency of the hydrogen storage option is lower than pumped storage systems. There are pilot systems testing community based renewable energy and hydrogen storage systems in Canada and Norway.
- **Superconducting Magnetic Energy Storage (SMES):** systems consist of a superconducting coil, power conditioning system and cryogenically cooled refrigerator. Once the superconducting coil is charged the magnetic energy can be stored indefinitely. The power conditioning system uses a rectifier to convert Alternating Current (AC) to Direct Current (DC) and uses an inverter to convert DC to AC. SMES systems are highly efficient with efficiencies greater than 95%. SMES is currently used for short duration energy storage and for

[124] They can come on-line very quickly in a matter of few seconds
[125] Source Department of Energy, 2009, page 18

improving power quality. SMES offers the technical potential for use by energy utilities where it can be charged during base load hours and could supply peak load energy demands. The high cost of superconductors is the primary limitation for commercial use of this energy storage option.

- **Storage by Electric Vehicles (EV):** can also be used for meeting peak demand and is comparable to the earlier option of batteries. A parked and plugged-in EV can sell the electricity from the battery during peak loads and charge during off-peak hours especially during night-time. When electric vehicles are mass produced, vehicle to grid technology can be employed in a smart grid of the future with each vehicle with its 20 to 50kWh battery back would be distributed energy storage. Storage of each electric vehicle could meet 2 to 5 days of energy requirements of a typical household. The use of electric vehicles for energy storage has limitations and needs to be investigated further.

3.6.2.4 Distribution Feeder Automation

Distribution Feeder Automation (DFA) is the remote monitoring and control of equipment installed on the distribution feeders on an electrical grid. The automation systems communicate with other intelligent devices within the distribution network. The typical automation applications associated with DFA are[126]:

- **Fault Location Isolation and Service Restoration (FLISR):** use electrically operable switches to automatically isolate a faulty feeder segment and restore service to as many customers as possible;
- **Feeder Load Balancing**: transfer load from heavily loaded feeders to lightly loaded feeders to lower electrical demand;
- **Reactive Power (VAR) dispatch**: Optimising the control of the feeder capacitor banks for reduced losses and improved voltage profile along the feeders;
- **Voltage Control**: reduce feeder voltage to achieve a corresponding reduction of feeder load;
- **Integrated Volt-VAR Control (IVVC):** Combination of VAR Dispatch and Voltage Control into a single fully coordinated system;
- **Equipment Condition Monitoring:** continuously monitor feeder equipment for early problem detection and elimination of routine inspections.
- **Remote Controlled Fuse Saving:** Switch protective relays between fuse saving and fuse blowing settings based on weather conditions.

[126] Source: National Institute of Standards and Technology, 2010, page 29

DFA is expected to be part of a smart grid of the future and will improve the quality of electrical service and the reliability of the electrical energy services.

3.6.2.5 Electric and Plug-in Electric Hybrid Vehicles

During the last few years, climate change and environmental concerns and the increase in the price of petro-products up until 2008 has lead to an increased interest in electric transportation infrastructure. Electric transportation technology involves using one or more electric motors for meeting all or part of the motive power of the vehicles. Electric vehicles especially cars have seen a significant interest in the last few years with the success of the first mass produced hybrid gasoline-electric vehicle the Toyota Prius. Plug-in electric vehicles are charged from the grid using a direct connection through an electrical cable and the electricity is stored on board the vehicle using a battery. A key advantage of the new generation of electric or hybrid electric vehicles is regenerative braking and suspension where energy normally lost during braking is recovered as electrical energy and stored in the on-board battery.

Electric vehicles typically charge from conventional power outlets or dedicated charging stations a process that typically takes hours. Solutions such as inductive charging and rapid charging as well as battery swapping have been proposed as solutions. Many electric vehicle designs have limited range due to the low energy density of batteries. Use of electric vehicles in cold climates could be an issue as considerable energy is used to heat the interior of the vehicle and to defrost the windows and currently with internal combustion engines this is accomplished by using the waste heat from the engine cooling circuit. Electric vehicles have high levels of energy conversion efficiency of about 90% compared to 30-35% for internal combustion engines. This makes the tank-to-wheels energy efficiency a factor of 3 higher than internal combustion engines. Regenerative braking systems make electric and hybrid vehicles more energy efficient and reduce the wear on braking systems. Regenerative braking is especially effective for start and stop city use. Electric motors provide high torque from rest and do not require gears and gearbox-es. Electric vehicles provide quiet and smooth operation and have less noise and vibration than internal combustion engines. Some of the key classes of electric vehicles that could be produced at a mass scale to transform transportation into an electric transportation system and supporting the development of a smart grid system would be:

- **Plug-in Electric Vehicle (PEV)**: is any electric motor vehicle that can be charged from an external source of electricity, typically from an electrical grid. The PEVs have lower transportation costs and in the US where the cost of gasoline is considerably lower than other developed countries, the cost per mile for a PEV is 2 to 4 cents and the cost per mile of a standard car is 8 to 20 cents. A number of PEVs are available in the market today such as the REVA Ai/G-Wiz, Tesla Roadster, BYD F3DM, Mitsubishi MiEV and TH!NK city. There are also a significant number of PEVs that are in field testing and pre-production state. Many of these are shown in table 6.

- **Plug-in Hybrid:** Also known as Plug in Hybrid Electric Vehicles (PHEVs) have one or two electric motors and an internal combustion engine and also having a plug to connect to the electrical grid. PHEVs can operate on several modes combining the vehicles two power sources. An advantage of the PHEVs is that it will allow for the internal combustion engine to be used optimally and the presence of the Internal Combustion (IC) engine eliminates the range anxiety factor i.e. the fear of being stranded by a depleted battery before reaching the final destination. The disadvantages include the higher costs and weight.

Table 6: A listing of Key Plug-in Electric Vehicles[127]

Model	**Type**	**Range**	**Price**	**Comments**
REVA Ai/G-Wiz	Electric	80 km	12,000 US$	Available in India, UK, Norway, Spain, etc.
Tesla Roadster	Electric	393 km	109,500 US$	Sold in the US and Europe 1000 units by Jan 2010
BYD F3DM	Hybrid	100 km	21,900 US$	Launched in 2008 in China
Mitsubishi MiEV	Electric	160 km	43,000 US$	Sales began in early 2010 in Japan and Hong Kong
Ford Escape	Hybrid	48 k m	NA	Sales scheduled in 2012
BYD e6	Electric	299 km	40,000 US$	Testing in Shen-zhen in 2010. sales in the US in 2010.
Prius PHEV	Hybrid	21 km	NA	Sales in 2012
Ford Focus	Electric	160 km	NA	Sales scheduled for 2011.
Chevrolet Volt	Hybrid	64 km	40,000 US$	US sales in Nov 2010
Nissan Leaf	Electric	160 km	32,780 US$	Sales in Dec.

[127] Source: Wikipedia –plug-in electric vehicle (accessed July 2010)

Model	Type	Range	Price	Comments
				2010
Reva NXR	Electric	159 km	15,000 US$	Sales in early 2011
Suzuki Swift	Hybrid	19 km	NA	Under field testing
Tesla Model S	Electric	260 km	56,400 US$	Sales in early 2012
VW Gold Blue-e-motion	Electric	150 km	NA	Sales in 2013

Electric transportation could revolutionise the transportation sector as well as energy markets and could help significantly in a low-carbon energy future. PEVs could also serve as distributed storage in a smart grid of the future. However challenges such as cost and energy density of batteries as well as the availability of recharging infrastructure need to be addressed.

3.6.2.6 Smart Meters and Meter Data Management

Smart meters and Meter Data Management (MDM) is part of the Advanced Metering Infrastructure (AMI). An AMI includes hardware such as Smart meters, software for data management, communications between the smart meter and the data processing software etc[128]. A smart meter measures and characterises electrical consumption in more detail than a conventional meter and communicates that information back to the local utility for monitoring and billing purposes. Traditional electrical meters measure total consumption and provide no information of when the energy was consumed. Smart meters can also record voltage, current and power factor to support distribution state estimation and facilitate IVVC. Some of the smart meters also have advanced power measurement and management capabilities such as switching power on or off to a customer, detect service outages, unauthorized use, change demand limits and change the billing plans of customers. Several smart meters also provide two way communications including to a home area network to communicate to smart thermostats and appliances.

An MDM system will import the data from the smart meters, validate and process it for analysis and billing. Benefits of MDM are better customer service and invoicing information, better peak load management at the bulk power systems level, better provision of ancillary services and distribution capacity management, power quality and outage management and analysis and optimization of utility business processes and operations.

[128] Source: National SCADA Test Bed, 2009, page 12

3.6.2.7 Building Energy Management Systems

Building Energy Management Systems that manage the consumption for home, commercial enterprises and industries will also be part of a smart grid. Such systems will have two-directional communication through the smart meter with the local utility and will also control the energy consuming equipment, devices and appliances within the building or facility.

While the technical area and the technologies for building energy management systems are still evolving, a building energy management system consists of software and hardware which controls the energy consumption of the residential, commercial or industrial building under management. The building energy management systems in commercial and industrial systems control the Heating Ventilation and Air-Conditioning (HVAC) and Lighting of the building which typically accounts for over 70% of the building energy use. In residential and commercial buildings the energy management system may also cover electrical appliances. While the building energy management systems in commercial and industrial buildings are supervised by professionals, the home energy management systems offer simple customer interfaces and built-in logic. Several IT Companies are also getting involved in this space and some of the recent initiatives include Intel’s Home Energy Management System[129] as well as Google’s PowerMeter[130], which is a free opt-in easy to use software which allows users to monitor and manage their energy use. Google has currently tied up with 8 energy utilities around the world including 6 in the US, 1 in Canada and 1 in India.

It is expected that there will be a large roll-out of smart energy monitoring and control devices in residential, commercial and industrial buildings in the immediate future and more and more hardware and software solutions will increasingly be available in the markets in the near term.

3.6.2.8 Cyber Security Technologies

The operation and control of the smart grids of the future will be operated by a complex network of computing hardware and software and communication technologies. This makes smart-grid systems prone to cyber attacks which can compromise the functioning of the smart grid causing damage to equipment and prolonged power outages with devastating human and economic consequences. Cyber attacks can also be launched from anywhere in the world and cyber vulnerabilities in the smart grids of the future should be recognized and addressed as part of the smart grid implementation.

[129] A user user-smart-grid interface based on the Intel Atom processor which allows home energy management by the user.

[130] Source: www.google.com/powermeter/about/index.html

Some of the new components of the smart grid such as smart meters, sensors and advanced networks can introduce cyber security issues. These include:

- **Smart Meter Security:** there are several ways to attacking wireless devices used in smart meters. Attackers could programme smart meters to simultaneously send messages that cause power demand to be reduced and then increased dramatically causing grid instability and power outages. The attackers can also extract data from memory of smart meters and can also insert malicious software in smart meters[131]. There needs to be significant levels of increase in smart meter security issues to protect the electricity system from cyber attacks.
- **Wireless Network Security:** the deployment of smart grid technologies globally will result in increased use of wireless communication. Some of the wireless networking standards being used in smart-grids such as ZigBee, WirelessHART, ISA 100.11 are in their early stages of development and security issues will need to addressed with these standards before larger deployment and roll-out[132].

Essentially smart-grid will allow for two-way communication for monitoring and control of the electrical grid and many of the nodes in the smart grid are relatively inexpensive and unprotected entry points for cyber attacks that could destabilise or shut down the electrical grid.

3.6.2.9 Interoperability Framework

Smart grids are a complex system where a common understanding about the major building blocks and how they inter-relate must be openly shared. An interoperability framework and associated standards and protocols will allow communication between various control domains in the smart grid such as System Operator, Transmission System Operators, Customers and Power Producers.

The smart grid will be a large system of interoperable systems which will be able to exchange and readily use information securely and effectively. Similar to the internet, the smart grid will be a composite of many system and sub-system architectures. Some of the desired attributes of smart grid architecture include[133]:

- Support a broad range of technology options including existing and new technologies; Accommodate traditional centralised generation and transmission resources and consumer distributed resources;
- Flexibility to incorporate regional and organisational differences and technological innovations;

[131] Source: National SCADA Test Bed, 2009, page 12

[132] Source: National SCADA Test Bed, 2009, page 12

[133] Source: National Institute of Standards and Technology, 2010, page 29

- Employ well-defined interfaces that are useful across industries and include appropriate security;
- Developed with modern system modelling tools and techniques that are used to manage the documentation and complexity of the smart grid;
- Architectural elements are appropriate for the applications that reside within the architecture.
- Support third party products that are interoperable and can be integrated into the management and cyber security infrastructures;
- Appropriate balance between top-down and bottom-up approaches to system design;
- Based on proven enterprise architecture, software and system design methodologies.

The US government (NIST, 2010) has also identified eight layers of inter-operability as Basic connectivity, Network interoperability, Syntactic Interoperability, Semantic Understanding, Business Context, Business procedures, Business Objectives and Economic/Regulatory Policy.

A large number of standards will need to be newly developed or significant gaps which need to be addressed. However there are several priority areas where standards need to be updated or developed to support the accelerated development of smart grids. These are[134]:

- Standards for smart meter upgradeability;
- Common specification for price and product definition;
- Common scheduling mechanisms for energy transactions;
- Common information model for distribution grid management;
- Standard demand response signals.
- Standards for energy use information;
- Transmission and distribution power systems mapping;
- Guidelines for use of IP protocol suite in the Smart Grid;
- Guidelines for use of wireless communication in the Smart Grid;
- Energy storage interconnection guidelines;
- Standards to support plug-in electric vehicles;
- Standard meter data profiles
- Harmonise power line carrier standards for domestic appliance communications

Several of these inter-operability standards are under development and are expected to be available in the public domain in 2011 or 2012.

[134] Source: National Institute of Standards and Technology, 2010, page 10.

4 Institutional Framework and Programmes

4.1 Institutional Framework for Low-Carbon Energy Innovation

A summary description of key organisations that are active in implementing, directing and carrying out innovation on low-carbon energy issues at the global level are shown in table 7 and described below.

Table 7: Institutions active in Low-Carbon Energy Innovation

Organisation	**Type**	**Low-carbon energy technologies covered**	**Activities**
Global Environment Facility	UN System	Renewable Energy, Energy Efficiency	Financing source for other UN agencies
United Nations Development Programme	UN System	Renewable Energy, Energy Efficiency	Capacity building, policy, energy access
United Nations Environment Programme	UN System	Renewable Energy, Energy Efficiency	Finance, policy, research and development
United Nations Industrial Development Organisation	UN System	Renewable Energy, Energy Efficiency	Industrial development, energy access
United Nations Foundation	UN System	Renewable energy, energy efficiency	Financing Source for UN agencies
World Bank	Multilateral Bank	Renewable Energy, Energy Efficiency, Clean Coal, Carbon capture and Storage	Financing energy infrastructure and technical assistance
European Union	Monetary Union	Renewable Energy, Energy Efficiency	Financing energy infrastructure and capacity building
Group of Eight	Intergovernmental Group	Renewable Energy, Energy Efficiency, Clean Coal, Carbon Capture and Storage and Nuclear	Policy guidance
International Energy Agency	Inter-Governmental Agency	Renewable Energy, Energy Efficiency, Clean Coal, Carbon Capture and Storage	Research and Policy advice

Organisation	**Type**	**Low-carbon energy technologies covered**	**Activities**
		and Nuclear	
International Renewable Energy Agency	Inter-governmental Agency	Renewable Energy	Research, Policy advice and capacity building.
World Energy Council	Global Association of Energy Organisations	Renewable Energy, Energy Efficiency, Clean Coal, Carbon Capture and Storage and Nuclear	Research and Policy advice
Renewable Energy Policy Network for 21st Century	Public-Private Partnership	Renewable Energy	Research and Policy advice
Global Bio Energy Part-nership	Public-Private Partnership	Renewable Energy	Research and Policy advice
Global Network for Energy for Sustainable Development	Public-Private Partnership	Renewable Energy, Energy Efficiency	Research and Policy advice
Collaborative Labeling and Appliance Standards Programme	Public-Private Partnership	Energy Efficiency	Research and Policy advice
Global Village Energy partner-ship	Public-Private Partnership	Renewable Energy	Implementation and policy advice
Mediterranean Renewable Energy partner-ship	Public-Private Partnership	Renewable Energy	Research and Policy advice
Renewable Energy and Energy Effi-ciency Partner-ship	Public-Private Partnership	Renewable Energy, Energy Efficiency	Implementation, policy, finance, regulatory advice

4.1.1 United Nations System

4.1.1.1 Global Environment Facility

The Global Environment Facility (GEF)[135] established in 1991, represents the largest source of financing for low carbon energy technology projects in developing countries and operates through the UN system and the multi-lateral and regional development banks. GEF is also the financial mechanism for the UNFCCC. GEF Secretariat is based in Washington DC and currently has 177 member governments. GEF provides grants to its implementing and executing agencies to support low-carbon energy projects in developing and transition countries. During the period 1991–2005, GEF allocated € 650 million to renewable energy projects which leveraged approximately an additional € 2.5 billion in co-financing, comprised mostly of public financing as well as loans and grants from the GEF implementing and executing agencies involved in sustainable energy programmes. The World Bank, United Nations Environment Programme (UNEP), United Nations Development Programme (UNDP), United Nations Industrial Development Organisation (UNIDO); African Development Bank (AfDB); Asian Development Bank (ADB), European Bank for Reconstruction and Development (EBRD) and Inter-American Development Bank (IDB) are the key implementing and executing agencies.

4.1.1.2 United Nations Development Programme

UNDP[136] is the UN organisation established in 1966, targets human development and operates through its presence in 166 countries with its headquarters in New York. One of the five goals of UNDP is 'Energy and Environment for Sustainable Development' under which a service line, "Access to Sustainable Energy Services", focuses on several dimensions of low carbon energy such as rural electrification, energy efficiency, capacity building, and integrating sustainable energy considerations into national development policy. The UNDP renewable energy portfolio is reportedly the largest among UN agencies at US$ 2 billion, including GEF co-financing. UNDP is also implementing over 800 energy projects in more than 50 countries under the UNDP-GEF small grants program. About 400 UNDP energy projects are now underway with $200 million in investments from UNDP's core resources. The UNDP also promotes energy efficiency by removing barriers to the large-scale application, implementation, and dissemination of cost-effective, energy-efficient technologies and practices. Such barriers lie in the lack of conducive policies, inadequate information and awareness, and insufficient access to financing. UNDP supports market transformation of energy-efficiency appliances and widespread adoption of energy-efficient technologies in industry and building sectors. UNDP has energy efficiency initiatives underway in Bulgaria, China, Egypt, India,

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[135] Source: www.gefweb.org

[136] Source: www.undp.org/energy

Malaysia, Pakistan, Russia etc. UNDP has not been active in other low carbon energy technologies such as clean coal, gas or nuclear.

4.1.1.3 United Nations Environment Programme

UNEP[137] is the UN organisation established in 1972[138] that is primarily responsible for environmental issues. UNEP is active in the research, development, and commercialization of renewable energy technologies, and collaborates with a number of partners in these program areas. UNEP’s renewable energy portfolio equals about US$35 million, and consists of partnerships with the finance community on various aspects of clean energy investment; with policy makers on renewable energy policy development and implementation; and with SMEs on enterprise development. UNEP is active in the research, development, transfer and commercialization of energy efficiency, and collaborates with a number of partners in these program areas. UNEP’s energy efficiency activities include support to Energy Service Companies in the industrial and commercial sectors in Eastern Europe, financial intermediation and investment advisory facilities for energy efficiency. The UNEP low carbon energy and climate change project portfolio consists of projects worth $135 million of financing.

4.1.1.4 United Nations Industrial Development Organisation

UNIDO[139] was established in 1966 and is responsible for industrial development and related technical assistance. UNIDO implements renewable energy and rural energy projects aimed at productive end uses, and is active in bio-fuels, biomass gasification, small hydro, and wind energy. UNIDO is also active in implementing renewable energy mini-grid projects in Cuba and Zambia. In addition, UNIDO is working on a US$40 million initiative on hydrogen energy involving establishment of an International Centre for Hydrogen Energy Technologies. UNIDO has technical cooperation projects in renewable energy in Africa and Asia. UNIDO also implements industrial energy efficiency projects in developing countries. The UNIDO industrial energy efficiency programme works with industries to implement a systems approach to lower energy consumption and result in significant energy efficiency gains. UNIDO’s work in energy efficiency also involves work on linking energy efficiency and carbon finance.

4.1.1.5 United Nations Foundation

The United Nations Foundation[140] was established in 1997 by a US$ 1 billion grant from Ted Turner and supports the various UN agencies in their development projects. UN Foundation is based in Washington DC. UN Foundation has funded low carbon

[137] Source: http://www.unep.fr/energy/Index.htm

[138] As an outcome of the UN Environment Conference in Sweden, 1972

[139] Source: http://www.unido.org/doc/24839

[140] Source: http://www.unfoundation.org/programs/environment/climate_change.asp

energy initiatives worth US$50 million since 1998 to UNDP, UNEP, UNIDO, and United Nations Department of Economic and Social Affairs (UNDESA).

4.1.2 World Bank

The World Bank[141] group was established in 1944 and consists of five organisations – International Bank for Reconstruction and Development (IBRD), The International Development Association (IDA), International Finance Corporation (IFC), Multilateral Investment Guarantee Agency (MIGA) and the International Centre for Settlement of Investments Disputes (ICSID). Of these the IBRD, IDA and IFC provide financial support to low-carbon energy projects. The World Bank Group represents the largest source of low-carbon energy finance among the development banks. Since 1990, the World Bank has committed over US$2.2 billion toward renewable energy projects—the Bank has been active in solar, wind, biomass, hydro, and geothermal energy. The share of IFC, the private sector window of the World Bank Group, in the total commitments has been estimated at $204 million. In 2004 at the Bonn Renewables Conference, the World Bank announced a 20% annual increase in support of renewable energy from current levels. The Asia Alternative Energy Unit (ASTAE), established in 1992, played an important role in influencing the power sector lending policies of the World Bank in Asia toward sustainable energy alternatives. ASTAE developed an alternative energy lending portfolio (including energy efficiency) of over $1.3 billion during 1992-2004. The World Bank group committed almost US$ 190 million for renewable energy in 2006.

The World Bank Group also represents the largest source of energy efficiency finance among the development banks. Since 1990, the World Bank has committed over US$2.8 billion towards energy efficiency projects. In the year 2006 alone the World Bank group committed almost US$ 450 million to energy efficiency projects. Some of the key types of energy efficiency interventions by the World Bank include Demand Side Management (DSM), District Heating Energy Efficiency, Industrial Energy Efficiency and transport energy efficiency.

4.1.3 European Union

The European Union[142] has served as a significant source of financing for low-carbon energy programs in developing countries. The average annual commitments to the energy sector by the European Union during 1997–2001 were US$795 million. Of this, 14.7% or about $117 million annually represents the share of renewable energy. The European Union Energy Initiative (EUEI) has created an energy facility Africa, Caribbean and the Pacific – European Union (ACP-EU) Energy Facility. This facility is financing several projects valued at about €200 million to finance renewable

[141] Source: www.worldbank.org

[142] Source : ec.europa.eu/energy/index_en.htm

energy, energy efficiency, and rural electrification projects in Africa, the Caribbean, and the Pacific. The Johannesburg Renewable Energy Coalition (JREC), a coalition of countries committed to increasing the share of renewable energy, has also set up the Global Renewable Energy and Energy Efficiency Fund (GEEREF) with an EU contribution of €80 million. The GEEREF is in the process to achieve financial closure and to make the first investments in 2010. Internationally the EU proposes to enter into a framework agreement with Brasil, China, India, Japan, Russia and the United States, which is planned to be done in collaboration with key institutions such as the World Bank and IEA.

4.1.4 Other key institutions and groupings

4.1.4.1 Group of Eight

G-8 is an international forum for the governments of Canada, France, Germany, Italy, Japan, Russia, the United Kingdom and the United States. Together, these eight countries represent about 65% of the world economy. The group's activities include year-round conferences and policy research focussing on key global issues such as climate change, conflicts, African development etc. culminating with an annual summit meeting attended by the heads of government of the member states, the last of which was at Muskoka in Canada in 2010. The European Commission is also represented at the meetings. Since the Gleneagles summit in 2005 five of the large developing countries – Brasil, China, India, South Africa and Mexico have also been invited to the meetings. The G-8 does not have an institutional structure or a permanent secretariat and each year one of the G-8 members assume the presidency and are responsible for planning and hosting the meetings and the summit. The recent meetings of the G-8 have placed an increasing emphasis on low-carbon energy within the climate change or energy security agendas. Several mandates have been made by the G-8 in their summit declarations and plans of actions on key institutions such as the World Bank, IEA, UN system, development agencies and public-private partnerships to accelerate the development of renewable energy. While G-8 itself does not have the organisational structure to implement or monitor these mandates, as the G-8 countries are major financiers of several key institutions such as the World Bank, IEA ad UN, these mandates serve as important guidelines for the operational strategy of these organisations.

4.1.4.2 International Energy Agency

The IEA[143] was established during the oil supply emergencies of 1973-74 and provides international energy policy analysis to its 27 member countries. The IEA is based in Paris and has a group of experts working on renewable energy statistics from the IEA member countries and regularly publishes statistics and policy papers

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[143] Source: www.iea.org

on renewable energy. IEA also holds several workshops and seminars covering important aspects of energy efficiency. Current work of IEA also focuses on climate change policies, market reform, energy technology collaboration and outreach to major producers and consumers of energy such as China, Russia and India. IEA's work on low-carbon energy involves buildings, appliances, transport and industry as well as end-use energy efficiency applications. IEA also maintains a database of national energy efficiency and renewable energy policies.

4.1.4.3 International Renewable Energy Agency

The IRENA[144] has been established in 2010 and will be headquartered at the Masdar city in Abu Dhabi. IRENA is an intergovernmental organisation consisting of 149 governments[145] and will focus on a rapid transition towards widespread use of renewable energy world-wide. IRENA plans to provide policy advice, serve as a knowledge base for renewable energy technologies and also helps in capacity building initiatives. IRENA is expected to play a pivotal role in the future development of low carbon energy sources – especially renewable energy.

4.1.4.4 World Energy Council

WEC was established in 1929 and has members spanning 94 countries. WEC is headquartered in London and promotes sustainable energy use and covers all forms of energy including low-carbon energy. WEC carries out a number of global studies on long term energy issues and implements a number of technical programmes on current issues and that are of a practical nature. One such current technical programme focuses on financing renewable energy projects. WEC also organises several events of which the key event is the World Energy Congress held every three years.

4.1.5 Public-Private Partnerships

4.1.5.1 Renewable Energy Policy Network for the 21st Century

Ren21[146] was formed as a consequence of the political declaration of the International Conference for Renewable Energy which took place in 2004. Ren21 Secretariat is based in Paris and the network focuses on three key themes – policy, advocacy and exchange. Under the policy theme, Ren21 encourages countries to increase renewable energy and follows up and reports on the over 200 specific actions that were announced at the 2004 renewables conference. Under the advocacy theme Ren21 develops and publishes policy issue papers on the contributions that renewable energy can provide. Under the exchange theme Ren21 has in co-operation with

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144 Source: www.irena.org

145 As on 20th July 2009

146 Source: www.ren21.net

REEEP established an information gateway for renewable energy information titled Reegle.

4.1.5.2 Global Bio Energy Partnership

GBEP[147] was launched in 2006 and brings together public, private and civil society stakeholders. GBEP focuses on bioenergy and focuses on bioenergy technology diffusion in developing countries. It aims to increase the visibility of bioenergy opportunities and issues at the international level. GBEP's work programme includes collaboration on bioenergy field projects, formulation of a harmonized methodological framework on GHG emission reduction measurement as well as awareness raising and information management.

4.1.5.3 Global Network for Energy for Sustainable Development

GNESD[148] is a network launched by UNEP in 2002 at World Summit on Sustainable Development (WSSD[149]), Johannesburg and is staffed by part-time staff from the UNEP-Risoe Centre in Roskilde, Denmark. GNESD brings together twenty one research organisations working on renewable energy issues relating to the Millennium Development Goals (MDGs) and carries out research on specific thematic issues. Some of the research themes where GNESD are active include energy access, renewable energy technologies and energy security.

4.1.5.4 Collaborative Labeling and Appliance Standards Programme

The Collaborative Labelling and Appliance Standards Programme (CLASP)[150] was a partnership launched in 2002 at the Johannesburg Renewable Energy Summit and focuses on energy efficiency standards & labels for appliances, equipment and lighting. CLASP originated from an initiative started in Lawrence Berkeley National Labs (LBNL) in 1996 and a subsequent project in 2000 by United Nations on standards and labelling. CLASP aim is to reduce 390 TWh of electricity per year and reduce 2% of CO_2 emissions globally, through standards and labelling programmes by 2030. CLASP is registered as a non-profit corporation and the headquarters is located in Washington DC, US. CLASP works with governments, industry, intergovernmental organisations, NGOs and technical support groups. CLASP received project funding support from UNDP/GEF, USAID, USEPA, APEC etc.

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[147] Source: www.globalbioenergy.org

[148] Source: www.gnesd.org.

[149] Global Intergovernmental meeting attended by heads of state, held once every 10 years to review the progress on sustainable development

[150] Source: www.clasponline.org

4.1.5.5 Global Village Energy Partnership

GVEP[151] was also launched at the WSSD in Johannesburg in 2002 and addresses the issue of energy access in developing countries. GVEP has been supporting developing countries with their energy planning and establishing linkages to poverty reduction strategy. GVEP is also planning to provide capacity building, technical assistance and financing to SMEs active in village electrification and plans to set up two funds in East and West Africa. GVEP also plans to carry out work in South Asia and Latin America. The partnership had also supported several projects addressing rural energy issues through the GAP Fund in collaboration with ESMAP of the World Bank. GVEP under a new Business Plan and strategy will work at two levels – at the national policy level and at the village level. At the national policy level, GVEP will work with governmental partners to integrate energy into national poverty strategy papers and to prepare national energy action plans. At the village level GVEP will support the capacity of enterprises working on energy access markets to create and expand energy service supply chains.

4.1.5.6 Mediterranean Renewable Energy Partnership

MEDREP[152]was launched by the government of Italy at the WSSD in Johannesburg in 2002 and the partnership focuses on renewable energy development in the Mediterranean region. Under the MEDREP framework, a Mediterranean renewable energy centre was also launched in 2004 and will be based in Tunis. MEDREP also carries out a joint programme with REEEP through co-financing of projects with REEEP in the Mediterranean region.

4.1.5.7 Renewable Energy and Energy Efficiency Partnership

REEEP[153] was launched by the Government of United Kingdom in 2002 at the WSSD in Johannesburg. REEEP currently consists of over 300 partners including 46 governments. REEEP supports renewable energy and energy efficiency projects in its priority countries of Brasil, China, India, Mexico and South Africa as well as African and Pacific LDCs. The key REEEP donors are Australia, Austria, New Zealand, Norway, Netherlands, Ireland, Italy, Spain, UK and US. REEEP has so far supported 129 projects with over € 10 million investment which has been able to leverage over €25 million in co-financing. REEEP projects are also implemented in 56 countries.

[151] Source: www.gvepinternational.org

152 Source: www.medrep.info Accessed September 2008

153 Source: www.reeep.org

4.2 Major low-carbon energy innovation and diffusion programmes

Globally there have been some major important and pioneering initiatives primarily at the national levels for diffusion of low carbon energy technologies in developed and developing countries. Some of the key programmes are shown in table 8 and described below.

Table 8: Major Low-Carbon Energy Programmes

Programme	**Period**	**Low-carbon energy technologies covered**	**Features**
Brasilian Biofuels Programme	Since 1975	Renewable Energy - Biofuels	Sugar cane based ethanol production to substitute import of fossil fuels
Ultra-Supercritical Coal in China	Since 2000	Clean Coal	R&D, Enterprise Development
German Wind Energy Programme	Since 1990s	Renewable Energy - Wind	Feed-in-Tariffs and subsidies
Japanese Top Runner Programme	1998-2006	Energy Efficiency	Portfolio efficiency targets
US Energy Star Programme	Since 1992	Energy Efficiency	Performance Efficiency Standards
European Union Energy Efficiency Programmes	2005-2020	Energy Efficiency	20% energy savings by 2020
Japanese Residential Photovoltaics Programme	1997-2005	Renewable Energy – Solar Photovoltaics	Household level system subsidies
United Kingdom Warm Front Programme	2000-2010	Energy Efficiency	Household level upgrade subsidies
Indian labeling Programme	2006 Onwards	Energy Efficiency	Standards and Labels

4.2.1 Brasilian Biofuels Programme

The Brasilian biofuels programme was a direct result of the Oil Crisis in 1973 which resulted in a significant increase in the oil import bill of Brasil from US$ 600 million to US$ 2.5 billion in a span of one year. This resulted in the inflation rate increasing to 34.5% in 1974 from 15.5% in the previous year[154]. As a result in 1975 the Brasilian Government launched two biofuels programmes – „Pró-Álcool“ to substitute gasoline with ethanol and „Pró-Óleo“ to substitute diesel with biodiesel. The producers of bio-ethanol were given soft credit facilities and the petroleum product distributors were mandated to distribute ethanol at the dispensing stations. The introduction of biofuels in the market had a significant impact and the sales of ethanol cars which were introduced in 1979 with tax incentives, picked up considerably. During the period 1983 to 1988 the sales of ethanol based automobiles accounted for over 90% of the automobile market peaking at 95% in 1985. The „Pró-Óleo“ programme was however discontinued in 1982 by the government.

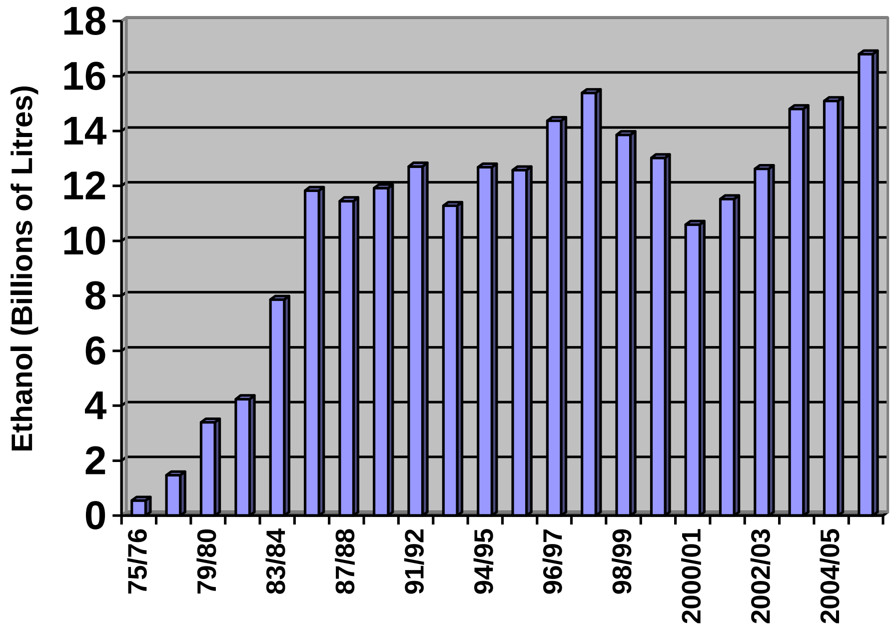
However the fall of petroleum prices globally from 1985 coupled with the increases in global sugar prices directly affected the business prospects of biofuels production. This resulted in sugar mills producing more sugar than ethanol resulting in ethanol shortages in late 80s. The ethanol market still continued to grow at a low rate till 2003, when the „flex-fuel” cars were introduced. The flex-fuel engines were introduced in the US as a solution to the limited distribution network of biofuels in the US and became very popular in Brasil. The market share which was 17% of the total vehicles sold in 2003 has increased to about 84% in 2007[155]. The introduction of the flex fuel engines coupled with the continued increase in prices of petroleum products since 2005 resulted in a renewed thrust in the biofuels market. As a result the demand and thereby production of bioethanol increased from 10.7 billion liters in 2000 to 17.7 billion liters in 2006.

The Brasilian Ethanol programme is a good example of a concerted and sustained effort by a government to develop the market for a renewable energy application. It is estimated that the benefits to the Brasilian economy of substitution of gasoline by ethanol during the period 1976 to 2004 are in the range of US$ 61 billion[156]. It is also estimated that use of ethanol has resulted in savings in the range of 400 to 600 million tonnes of CO_2e[157] to the Global Environment. The programme also developed a significant local industrial sector in Brasil which is estimated to directly employ approximately 1 million people and brings in significant level of export earnings to the

[154] Source: Vasconcellos, 2007, page 20
[155] Source: Vasconcellos, 2007, page 14
[156] Source: Vasconcellos, 2007, page 20
[157] www.nipeunicamp.org.br/proalcool/Palestras/16/Antonio%20de%20Padua%20Rodrigues.ppt#16

economy. The annual production of ethanol under the programme during the period 1975 to 2006 is shown in figure 10.

Fig 10: Annual Ethanol Production under the Brasilian Pró-Álcool Programme 1975-2006[158]



4.2.2 Ultra-Supercritical Coal Conversion Technology in China

As was stated previously coal dominates the power system in China. In late 2008 coal-power plants produced more than 80% of the country’s energy output. The average efficiency of operating coal power plants in china is 33%[159] which is equivalent to a requirement of 400 grams of coal to produce each kWh of electricity. It is estimated that supercritical coal technology plants in china operate with an efficiency of 41% and ultra-supercritical coal power plants operate with an efficiency of 48%[160].

China has placed an emphasis on R&D of supercritical and ultra-supercritical technology since the 90s. A feasibility study for ultra-supercritical coal was carried out by the State Power Corporation in 2000 and as a result ultra-supercritical coal technology was identified as a national high-tech research project and was accorded high priority. With government support three Chinese enterprises – The Shanghai Electric Group, Harbin Power Plant Equipment Group and the Dongfang Electric Group entered into international collaborations with international companies such as Hitachi,

158 Source. Miguez, 2007

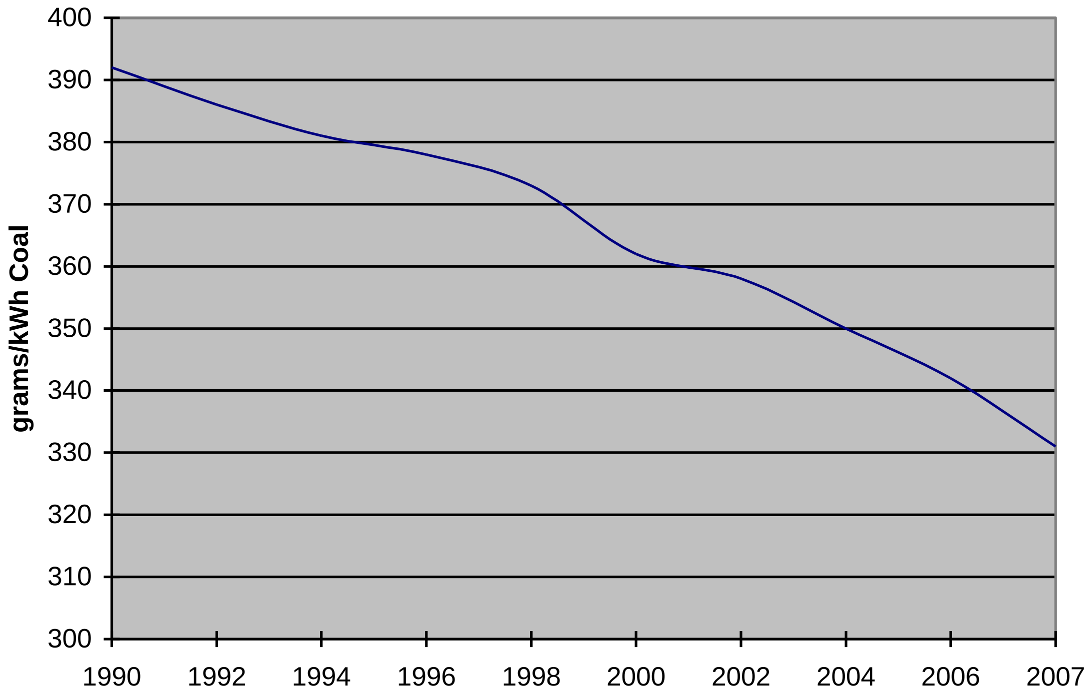
159 IEA, 2008

160 Source. Li, 2009, page 16

Mitsubishi, Toshiba, Siemens and Alstom. The technology transfer process adopted by these collaborations was technology import, joint-design and co-production.

The results have been impressive and today the three groups – Harbin, Dongfang and Shanghai have the capability to design and construct, operate and carry out improvements in ultra-supercritical coal power plants. An efficiency of 48% achieved by Ultra-supercritical power plants translates to a coal utilisation of 265 grams per kWh which represents a significant reduction from the baseline coal-power plant with 33% efficiency. Ten ultra-supercritical power plants are currently in operation along the eastern coastal regions and closer to the main demand centres. Currently the installed capacity of ultra-supercritical coal power plants is 8,800 MW. China is planning to add 60,000 MW of ultra-supercritical coal power plants in the next five years[161].

Fig 11: Specific Coal Consumption in China's Coal Power Plants[162]



Currently with high levels of indigenisation, the incremental investment is only 10% with about 10% increase in efficiency compared to a new coal power plant. This increased efficiency and the savings in fuel costs combined with the incentives for energy efficiency is able to more than compensate for the increased initial investments. The Chinese government has recently introduced a policy which requires all

[161] Source. Li, 2009, page 17

[162] Source. Li, 2009, page 18

coal-power plants above 600 MW capacities to use either ultra-supercritical or supercritical technology.

4.2.3 German Wind Energy Programme

The German wind energy programme started with the „Electricity Feed-in Law“ introduced in 1990. This law mandated the electric utilities to pay a feed-in-tariff to renewable electricity, which was equal to 90% of the retail residential electricity tariff. National Banks in Germany also offered „soft loans[163]“ for wind energy development which covered upto 75% of the project costs. There also existed a subsidy programme in the early 1990s where subsidies of 200 DM[164]/kW upto 150,000 DM/project was available for wind farms. This incentives framework helped to initiate and stimulate the growth of wind energy in Germany.

However there was a back-lash in the late 90s as the wind energy development which was initially concentrated in the Northern regions resulted in higher electricity tariffs for customers in the region. The protests from the utilities in these regions and some of the business troubles of some of the key wind energy manufacturers at the time, affected the market development during this period. Subsequently Germany passed a renewable energy sources act – „Erneuerbare-Energien-Gesetz (EEG) “ in 2001 which guaranteed a minimum feed-in-tariff in relation to the wind energy production at a specific site. Electricity produced from renewable energy sources was accorded priority for grid connection, access to the distribution and transmission levels and the utilities were obliged to bear the costs of grid infrastructure required for the grid interface. The feed in tariff was reduced by 2% on an annual basis and provisions were also introduced to equally share the cost burden associated with renewable electricity across all regions.

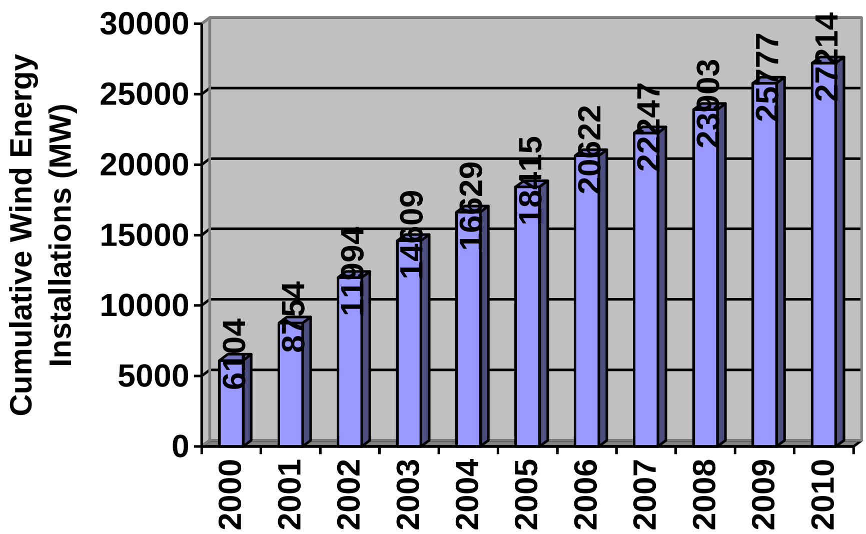
The European Union also issued the EU Renewables Directives in 2001, which provided the legislative framework for continued growth of wind energy in Germany. The EU Renewables Directive aims to raise the share of renewable electricity produced in the European Union from 15.2% in 2001 to 21% in 2010 and sets out indicative targets for member nations. The EEG was amended in 2004 and 2008. These developments have resulted in a significant growth of wind energy development in Germany and the installed generation capacity at the end of 2010 was 27,214 MW which represents over 16% of global installed capacity. Germany has also developed a strong wind energy industry which provides significant levels of direct and indirect employment and boasts of several leading manufacturers such as Enercon, Siemens, Nordex and REPower. There has been a recent slow down in the rate of development in the German wind energy market and one of the major reasons has been the non-availability of sites with adequate wind energy potential. The

[163] Loans that were 1 to 2% below the market interest rates for similar investments

[164] Deutsche Mark, the German currency at the time, which has since been replaced by the Euro.

current policies therefore provide added incentives for wind farms that are off-shore, where the costs of connecting the off-shore wind farm to the mainland grid is borne by the transmission system operators and a higher feed-in-tariff[165] is available for off-shore wind electricity. Similarly addional incentives such as prolonged initial tariffs are also available for repowering[166] of existing wind turbines. It is expected that the off-shore developments and the repowering will help in sustaining the development of the German wind energy market. The cumulative wind electricity generation capacity under the German wind energy programme during the period 2000 to 2010 is shown in figure 12.

Fig 12: Cumulative Installed Wind Energy Capacity in Germany 2000-2010[167]



The German wind energy programme is another example of a long term policy and regulatory support by a government to develop a renewable energy technology.

4.2.4 Japanese Top-Runner Programme

The Japanese top-runner Programme is an innovative approach which sets the standards as equal to as or more than the top value of efficiency of the class of products available in the market. The programme was introduced in 1998 and covered appliances and automobiles. The manufacturers whose products do not meet the top value of energy efficiency are given time of four to eight years to achieve the target to allow for technological progress and product development.

[165] A feed-in-tariff of ¢ 8.19 for off-shore wind farms as against 5.17 for on-shore wind

[166] Upgrading and retrofitting existing wind turbines with wind electric generation units of higher capacity and better efficiency.

[167] Source: Global Wind Energy Council, 2011, page 43

In order to evaluate the conformity to standards under the top-runner programme a weighted average method is used, which considers whether the average efficiency value of the product offerings by a manufacturer in a specific product class meets or exceeds the target value. The weighted average method allows the manufacturers to have the flexibility and offer both high efficiency and lower efficiency models as part of the product range. There are display obligations under the top-runner programme whereby the energy efficiency of the product should be displayed. In addition to the display obligations, a voluntary energy conservation labelling programme was launched in 2000. The labelling programme allows the customers to make informed decisions to purchase energy efficient products.

Japan’s Ministry for Economy, Trade and Industry (METI) has established an institutional arrangement consisting of an advisory committee, standards committees and working groups which help in developing the appropriate standards, consultations and manages the programme[168]. The results of the top-runner programme have been encouraging and a review of the targeted sectors and their efficiency in the year 2005 has shown that all the sectors have exceeded the original targets. These results are shown in table 9.

Table 9: Results of the Top-Runner Programme[169]

Sector	**Energy Efficiency Achievement**	**Energy Efficiency Target**
TV Sets	25.7%	16.4%
Video cassette Recorders	73.6%	58.7%
Air Contitioners	67.8%	66.1%
Refrigerators	55.2%	30.5%
Electric Freezers	29.6%	22.9%

4.2.5 Chinese Renewable Energy Programme

The Chinese renewable energy programme is the largest renewable energy programme globally with more than 62,000 MW of renewable energy capacity installed in end 2009. For several decades, there had been series of measures, regulations and financial incentives to encourage decentralised development of small hydro, biogas systems and other rural energy systems. These have resulted in large num-

[168] Source: Energy Conservation Centre Japan, 2004.

[169] Source: Yamaguchi, 2006

bers of decenetralised energy systems such as 42,000 small, mini and micro hydro power plants[170], 30 million biogas plants, 250,000 small wind generating systems etc.

Since the mid 1990s Chinese government has started encouraging grid connected renewable energy generation through concessions, soft-loans, low tax rates etc. These measures have resulted in China adding over 44,000 MW wind energy to the grid. In 2005 the national people’s congress adopted the Renewable Energy Law which will provide the framework for further accelerated development of renewable energy. Several implementing regulations and provisions have also been introduced by the National Development and Reform Commission (NDRC) such as feed-in-tariffs for grid connected renewable energy, subsidies for biomass power projects, competitive tendering for wind energy etc.[171].

The large-scale renewable energy development programme in China has also helped in creating a strong manufacturing base for renewable energy equipment in the country. The production capacity for solar photovoltaic modules currently stands at 2500 MWp, 30 companies are engaged in the manufacture of wind turbines, over 200 companies manufacturing biomass conversion systems. China is also the largest manufacturer in the world for small and mini hydro systems and small wind generators.

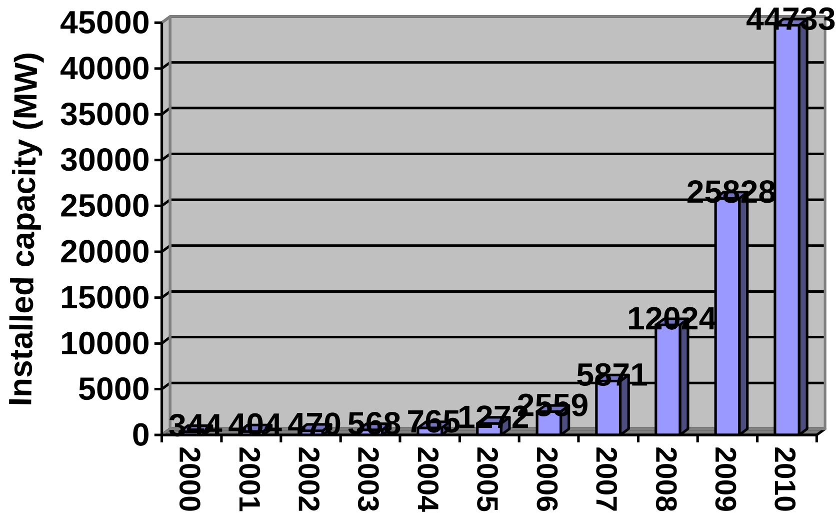
What is special about the china renewable energy programme is the planned implementation of a large number of rural and decentralised energy systems over a long period of time rather than a stimulated market growth as a result of targeted government policies. China presents a good example of decentralisation of planning and implementation of rural energy systems. China is planning to achieve a 15% share of renewable energy in the energy mix by 2020. This translates to a total of 362,000 MW of renewable electric capacity and specific targets of 30,000 MW for Wind and Biomass power, 200 MW of solar PV and 0.3 billion m^2 of solar thermal collectors[172].

[170] In operation with a total installed hydro capacity of 38500 MW

[171] Source: National Development and Reform Commission, 2007.

[172] Source. Li, 2009, page 14

Fig 13: Cumulative Installed Wind Energy Capacity in China 2000 -2010[173]



4.2.6 US ‘Energy Star’ Programme

The Energy Star programme was launched in 1992 by the United States Environmental Protection Agency (USEPA) as a voluntary labelling programme. Initially the scope of the voluntary labelling was limited to personal computers and monitors, and was in 1995 extended to other office equipments and residential heating and cooling systems. Since 1996, Energy Star works in collaboration with the United States Department of Energy.

Energy Star programme specifications currently cover more than 50 categories of products in the following product classes: appliances, heating and cooling systems, home envelope[174], home electronics, office equipment, lighting, commercial food service and other commercial products[175]. Apart from product standards, the Energy Star programme also covers new homes and home improvements, commercial buildings and industrial energy efficiency.

Energy Star program currently engages more than 9,000 businesses, manufacturers, retailers in the US to advance its programmes. It is estimated that energy efficiency improvements through the Energy Star programme since 1993[176] have resulted in the US energy users saving more than US$ 150 million in their electricity bills. These savings translate to half a billion tonne of CO_2e GHG mitigation. The Energy Star

[173] Source: GTZ, 2007 and Global Wind Energy Council, 2011, page 31

[174] Home sealing, roof products, windows doors & skylights

[175] Vending machines, water coolers, exit signs etc.

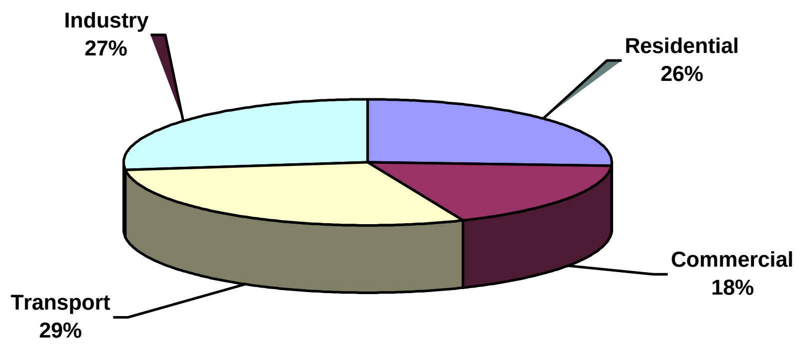
[176] This includes the cumulative savings that will persist till the year 2016.

programme has resulted in 5% to 90% average energy savings for qualified products in comparison with the standard products.

4.2.7 European Union Energy Efficiency Programmes

The EU has an ambitious programme to save 20% of energy in the EU primary energy consumption by 2020[177]. The amount of savings required is estimated to be 390 Mtoe. The major share of the savings is expected to come from transport, followed by industry[178]. The energy savings targeted by the EU action plan is shown in fig 14.

Fig 14: Sectoral Share of energy savings potential in the EU by 2020[179]



The EU plans to achieve these ambitious energy efficiency targets through a set of 10 priority actions. These priority actions address a range of key issues and a large number of measures are proposed to achieve the energy efficiency targets. Each of these 10 priority actions are described below[180]:

- **Appliance and equipment labelling and minimum energy performance standards**: plans are on anvil to develop minimum energy performance standards for 14 product groups[181] of appliances and other energy consuming equipment and the use of labelling to make the performance standards effective.

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[177] Source: European Commission, 2005

[178] Source : ec.europa.eu/energy/index_en.htm

[179] Source: European Commission, 2006

[180] Source: European Commission, 2006

[181] Boilers, water heaters, computers, imaging, televisions, standby, chargers, office-lighting, street-lighting, room air conditioning, motors, commercial refrigeration, domestic refrigeration and washing machines.

- **Energy Efficiency in Buildings**: EU-wide minimum performance requirements will be specified for new and renovated buildings, a strategy will be developed for low energy and passive buildings and the scope of the Energy performance of Buildings Directive will be substantially expanded.
- **Efficient power generation and distribution**: EU will develop minimum mandatory energy efficiency requirements for new electricity, cooling and heating capacity lower than 20 MW. A new regulatory framework for decentralised generation will also be established.
- **Efficient Transport**: EU will develop fuel efficiency standards for cars and will also propose labelling of cars to realise the energy efficiency potential in transport.
- **Financing and Energy Service Companies (ESCOs)**: EU will encourage the finance and banking sector to offer financing for Small and Medium Enterprises (SMEs) and ESCOs
- **Energy Efficiency in the new member states**: EU will use the structural and cohesion funds to finance and leverage financing for energy efficiency in the new member states and in multi-family and social housing sectors.
- **Tax incentives for Energy Efficiency**: EU will review the energy tax directive to facilitate a coherent and targeted use of taxes to encourage energy efficiency and in particular energy efficient appliances and equipment.
- **Awareness Creation**: EU will support education and training plans for energy managers in industry and utilities as well as teaching aides for primary, secondary and vocational educational curricula.
- **Energy Efficiency in Built Environment**: EU will demonstrate new energy efficient technologies in EU buildings, vehicles and procurement. EU will also establish a covenant of mayors to bring together mayors of 20-30 of Europe’s largest cities to encourage energy efficiency in cities and exchange and apply best practices.
- **International partnerships**: EU will propose an international framework agreement involving both developed and developing countries in collaboration with the UN, IEA, G8, WTO, World Bank and others. This framework agreement will strengthen co-operation on energy efficiency globally.

The EU programme on energy efficiency is quite comprehensive and ambitious and a number of measures will be put in place during the period 2007-2012 to realise the objective of 20% savings by 2020[182].

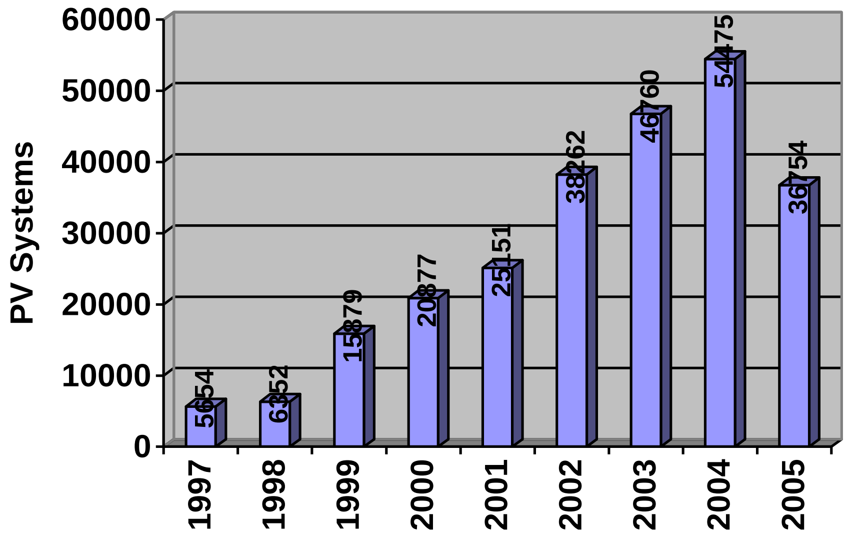
[182] Source : ec.europa.eu/energy/index_en.htm

4.2.8 Japanese Residential Photovoltaics Programme

Japan has one of the world's largest Photovoltaic Programmes and provides a good example of sustained government support creating a large domestic market and a manufacturing base for a new energy technology. A major driver in developing the domestic market for Photovoltaics was the government supported „Residential Photovoltaic System Dissemination Programme“. This Programme was launched in 1994 titled the „Residential Photovoltaic System Monitor Programme“ and was renamed „Residential Photovoltaic System Dissemination Programme“ in 1997. This programme continued till 2005 driving the growth of the Japanese and the global photovoltaic industry, which has since been discontinued.

The programme was implemented by Japanese Ministry of Economy Trade and Industry (METI) and provided subsidies amounting to 20,000 JPY/kWp to individual households, developers of housing complexes and to authorities responsible for public housing. The residential PV systems were in the range of 3 to 4 kWp and the larger systems in housing complexes and public housing complexes were in the range of 10 to 50 kWp. During the 12 years of the programme from 1994 to 2005 a total of 253,754 systems resulting in installations totaling 931.5 MWp. The annual numbers of installations under the programme during the period 1997 to 2005 are shown in figure 15.

Fig 15: Annual Installations under the Japanese PV Residential System Programme 1997-2005[183]



The programme apart from driving the domestic demand for Photovoltaic Systems also resulted in developing a local PV manufacturing industry which has become a world player. Four of the top ten PV manufacturers – Sharp, Kyocera, Sanyo and

[183] Source: Richert, 2007

Mitsubishi are based in Japan. These companies are also exporting significant volumes of production outside Japan. The Japanese PV Residential System programme is a good example of how government policies can be used to drive new energy developments and to create a local industry which can then supply the global demand.

4.2.9 United Kingdom Warm Front Programme

UK has a programme called warm front which targets energy efficiency in fuel poor households which spend more than 10% of their income on energy. It is estimated that the fuel poverty contributes to more than 30,000 deaths every year in the UK[184]. The government provides capital subsidies to fuel poor households especially households that are vulnerable[185]. The aim of the warm front programme which started in 2000 is to eradicate fuel poverty in the UK by 2010. It is estimated that UK has more than 2 million households which are energy poor.

The programme provides funding of upto 2700 Pounds for heating and insulation measures including repair and conversion. The Programme is managed by the Department of Food, Rural Agriculture and Environment (DEFRA) of the UK Government. The programme works through a process of verification of eligibility, advice on energy efficiency measures as well as over 100 installers who follow a harmonised pricing. From 2006, the warm front scheme also offers a 300 pound rebate for all householders aged over 60 who will install a central heating system[186]. The warm front programme is implemented by Eaga group plc.

The achievements of the scheme have been impressive. Warm front has assisted over 1.4 million households since the programme began in 2000. The average household saves close to 200 pounds/year on energy costs which results in a seven year payback for the average grant investment. It was also seen that the satisfaction level was quite high with over 94% of the customers being satisfied with the programme[187].

4.2.10 Indian Labeling Programme

In the year 2002, India was the 6th largest energy consumer in the world but the penetration of appliances in India was considerably lower than in similar countries. For instance the penetration of refrigerators was 13% in India compared to 40% in China and the penetration of air-conditioners was 1% in India compared to 24% in

[184] Source: Dhanak, 2006

[185] Household with a member aged 60 or above, a child under age of 16 or a member who has a long term illness.

[186] Dhanak, 2006

[187] Source: Sefton, 2004

China[188]. However the energy demand in India is increasing at the rate of 2.2% as a result of industrialisation, increase in income and population growth. As a result of these factors, significant rates of growth in penetration of refrigerators, air-conditioners and other appliances are expected in the future. The energy efficiency of the appliances will have a significant impact on overall energy use in the future.

In 2001, the Energy Conservation Act was enacted and the Bureau of Energy Efficiency (BEE) decided to introduce a comparative label which was consensus driven and collaborative in nature. It was decided to identify appliances that were commonly used, with high energy consumption and where potential for energy and peak electricity savings was high. The BEE identified 13 appliances to be covered under the labelling programme.

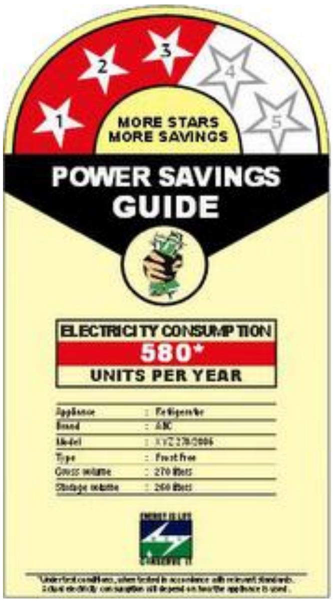
BEE launched the Energy Labels programme in 2006. The Indian labelling scheme is voluntary and currently includes the following appliances - refrigerators, tubular lights, air-conditioners and distribution transformers. Example of an Indian appliance label is shown in fig 16 below. Schemes for motors, fans, gas burners and standby power are also under preparation. The institutional arrangements in Indian labelling programme have also been defined and labels were designed on the basis of research carried out. The Bureau of Indian Standards (BIS) will be the standardisation agency and the Indian Standards (IS) will be used as the underlying test procedure. The National Accreditation Board for Testing and Calibration Laboratories (NABL) has accredited three laboratories which will support the check[189] and challenge testing[190] procedures under the labelling programme.

[188] Source: Tathagat, 2007.

[189] Check testing will be done after labeling and the appliance marketed and will consist of a check at the factory and at the retail outlets.

[190] Challenge testing will be initiated when a challenge is made on the label on an appliance by a third party.

Fig 16: Example of an Indian Appliance Label[191]



BEE plans to make the programme mandatory after providing enough time for the appliance manufacturers to prepare and the results with the initial voluntary programme has been judged to be positive. BEE estimates an energy consumption reduction potential of 18 billion kWh/year by the year 2012 through the labelling programme[192]. Currently the number of labelled products available in the market is small and the check and challenge testing procedure is being operationalised.

[191] Source: Tathagat, 2007.

[192] Source: Tathagat, 2007

5 Low-Carbon Energy Technology Prospects and Diffusion

This chapter examines the potential for various low-carbon energy technologies, achievements in key developing countries and also the potential for diffusion of these low-carbon energy technologies.

5.1 Renewable Energy Technology Potential

Renewable energy sources have immense technical potential which could meet the energy demands of the world several times. The potential for renewable energy (excluding solar) from just the key developing countries such as China, Brasil and India alone is 607,000 MW[193]. The potential for renewable energy from all the developing and developed countries is several times higher. However this technical potential is not always financially viable although the revenue from carbon finance flows[194], reductions in renewable energy installed costs and the high costs of fossil fuel based option is improving the financial viability. Several governments have offered policy and regulatory support as well as financial and fiscal incentives to help tap the available renewable energy potential. In recent years the energy security concerns spurred by high prices for petroleum products as well as the concerns about the global environment and climate change have helped to increase the level of efforts to realise the available potential.

5.1.1 Solar Energy

Energy from the sun represents a potentially enormous source for a variety of end-uses. Direct use of the sunlight for thermal energy has long been practiced. The earth continuously receives about 1.73×10^{14} kW[195] of power input from the sun. This translates to 1.5×10^{18} kWh/Year which is about 10,000 times the world’s annual energy consumption[196]. About 30% of the incoming solar radiation is not absorbed by the earth’s surface because of Albedo effect[197]. Atmospheric elements also affect the

[193] Source: GIZ, 2007

[194] The prices that certified emission reductions, emission reduction units and allowances under the Kyoto Protocol and the EU Emission Trading System are able to fetch.

[195] Source: Parthan, 1997

[196] Source: Parthan, 1997

[197] Albedo effect refers to the reflection of energy from an object. In this case, part of the incoming solar radiation is reflected back by clouds, atmospheric particles, and to a lesser extent by sand, water, and snow on the earth’s surface

amount of incoming solar radiation on the earth's surface. Water vapour, carbon dioxide, and ozone, in the atmosphere absorb as much as 10-15 % of earth bound solar radiation. Furthermore, solar radiation can also be reflected, or scattered by air molecules and dust particles, resulting in diffuse radiation which cannot be used by the applications of solar energy which require concentration[198].

The most important determinant in the amount of solar radiation reaching the earth is the length of the atmosphere through which the sun's rays must travel. The more atmosphere or air mass solar radiation must pass through, the energy content decreases because of increased absorption and scattering. The atmospheric length varies not only according to the time of day, the time of year, but also as a result of the earth's tilt, its rotational axis and also depends on the latitude.

Solar energy resources are particularly relevant to developing countries as most of them receive abundant amounts of sunshine. A large number of developing countries have 250-300 days of useful sunshine per year, whereas countries which are at higher latitudes receive 80-100 days of useful sunshine. The estimates of solar energy potential for some of the key developing countries are given in table 10 below:

Table 10: Solar Energy Potential[199]

Country	**Estimated Potential (Annual Mean Radiation)**
South Africa	4.5 to 6.5 $kWh/m^2/day$
Brasil	4.5 to 6.3 $kWh/m^2/day$
China	4 $kWh/m^2/day$
India	4.4 to 6.6 $kWh/m^2/day$[200]
Mexico	5 $kWh/m^2/day$

5.1.2 Wind Energy

The wind energy is an indirect form of solar energy, about 1 per cent of the total solar radiation that reaches the earth is converted in the atmosphere into energy of the wind[201]. Winds result from the differential heating of the earth and the atmosphere by the sun. The air circulates from cold to warm areas producing winds. The wind

[198] High temperature applications of solar energy such as solar thermal electricity involves concentrating solar energy and such technologies cannot use diffuse solar radiation.

[199] Source: GTZ, 2007.

[200] India's Ministry of New and Renewable Energy estimates a market potential of 20 MWp of PV/km^2 and 140 million m^2 of solar thermal collector area.

[201] Source: Parthan, 1997

resource is concentrated in certain regions and can vary a great deal with time and location.

The wind velocity and hence power, vary directly with height above the ground. Surface roughness slows the wind down. The rate at which the wind velocity increases with height varies with the degree of surface roughness. Therefore, wind velocities increase with height increasingly over rough terrain and at a very low rate over smooth terrain. Geographical features also accelerate or decelerate wind. Due to the absence of geographical features or terrain conditions, wind velocities are high over sea. The estimates of wind electricity generation potential for some of the key developing countries are given in table 11.

Table 11: Wind Energy Potential[202]

	Country	**Estimated Potential**
1	China	170,000 MW
2	Brasil	140,000 MW
3	India	45,000 MW
4	Mexico	7,000 MW
5	South Africa	26 TWh/year

5.1.3 Small Hydro

There is an increasing interest in small hydro power due to the possible environmental effects and longer gestation periods of larger scale hydro power developments. The principle of small hydro design is to select the appropriate features from different hydro-power technologies that minimise cost and still deliver reliable, high quality electrical power. The definitions of small hydro vary across the world and there is no globally accepted definition[203]. Small hydro sites can be broadly categorised into two types as:

- Sites on canal falls and dam toes in plains and steppes which are usually low head sites utilising large discharge[204];
- Medium or high head sites in hilly regions where small streams and run-of the river sites are available, with higher heads and lower levels of discharge.

[202] Source: GTZ, 2007.

[203] The definition of small hydro varies – in China and South Africa it is 50 MW, in Canada and Brasil it is 30 MW, India is 25 MW and Mexico is 10 MW.

[204] Recently attempts have been made to develop small hydro power plants on tail races of thermal power plant cooling towers.

The estimates of small hydro power potential for some of the key developing countries are given in table 12:

Table 12: Small Hydro Power Potential[205]

Country	Estimated Potential
China	125,000 MW
Brasil	14,000 MW
India	15,000 MW
Mexico	3,250 MW
South Africa	9.9 TWh/year

5.1.4 Biomass

Biomass offers great scope due to a wide spectrum of biomass available under different agro-climatic conditions. Out of the total solar energy on earth, plant life utilise about 0.1 percent annually, leading to an annual net production of 2×10^{11} tonnes of organic matter which has an energy content of 3×10^{20} Joules[206]. Biomass may be used to generate energy by direct combustion or by conversion to either a liquid or a gaseous fuel. Plant materials use the sun’s energy to convert atmospheric carbon dioxide to sugars during photosynthesis. On combustion of the biomass, energy is released as the sugars are converted back to carbon dioxide. Thus, energy is harnessed and released in a short timeframe, making biomass energy a renewable energy source. Biomass has been used as a source of energy for centuries, and even today is the major type of energy source in the developing world where significant share of energy for household cooking is provided by biomass in large parts of Africa and Asia. The estimates of biomass energy potential for some of the key developing countries are given in table 13.

Table 13: Biomass Energy Potential[207]

Country	Estimated Potential
China	5,500 TWh/year
Brasil	9,300 MW
India	73,000 MW

[205] Source: GTZ, 2007.
[206] Source: Parthan, 1997
[207] Source: GTZ, 2007.

Country	Estimated Potential
Mexico	1,160 MW
South Africa	17.7 TWh/year

5.1.5 Geothermal

Geothermal energy is the natural heat generated from within the earth. Underneath the earth’s crust in the core, there are radioactive elements like thorium, potassium and uranium which produce heat as part of their decay process. About 10% of world’s landmass contains accessible geothermal resources that could be used to produce heat and power. Geothermal energy is tapped using the earth’s natural fluids to extract thermal energy using conventional methods for oil and gas drilling. The primary use of geothermal resources is for electricity generation but can also be used for thermal applications in industry and homes. The global potential is estimated to be over 71,000 EJ. There is considerable potential for development of geothermal energy in the western parts of United States, Philippines, Japan, China (5,800 MW), India (10,000 MW) Mexico (1,500 MW)[208].

5.2 Renewable Energy Technology Diffusion

The estimated cumulative installations of global renewable electricity generation capacity at the end of 2009 were over 305,100 MW. This has excluded large scale hydro projects and only considers small hydro power[209]. Of this capacity over 195,000 MW was installed in the developed countries and 110,000 MW in the developing parts of the world. Table 14 below the gives the installed renewable energy capacity in the major developing countries.

Table 14: Installed Renewable Electricity Generation Capacity in end 2009[210]

Country	Installed Capacity
China	62,000 MW
Brasil	1,400 MW
India	16,000 MW
Mexico	1,350 MW
South Africa	135 MW

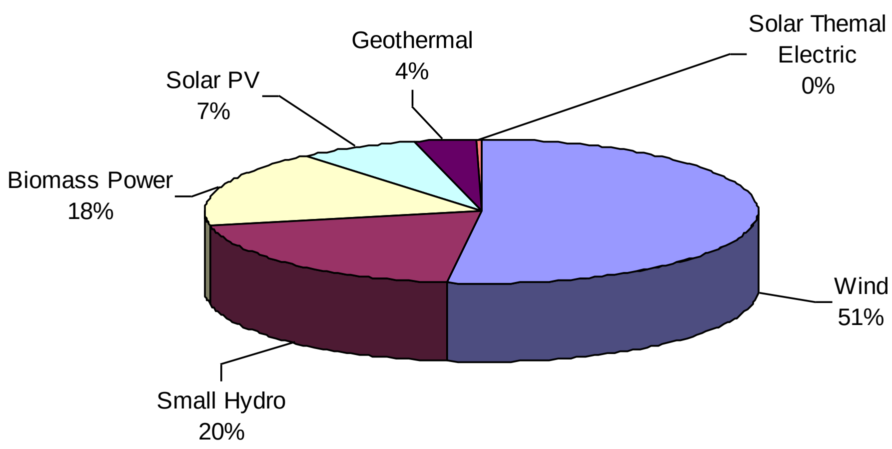
208 Source: GTZ, 2007.

209 Generally denoting a capacity less than 25 MW according to World Bank

210 Source: Ren21, 2010.

It may be noted that the current level of renewable energy achievements is a very small share of the existing potential. The figure 17 below shows the status of renewable energy achievements by sources.

Fig 17: Global Share of Renewable Energy Technologies – end 2009[211] [212]



The renewable energy technology diffusion in some of the largest renewable energy markets in developing countries are given in the following sections.

5.2.1 China

China had over 62,000 MW of renewable electricity generation capacity in the year 2009. A significant share of this is the mini-hydro power generation capacity of over 33,000 MW which is the largest in the world. China also has also has the world’s largest decentralised and rural renewable energy systems such as 8 billion m^3 of biogas digester volume or 12 to 17 million biogas systems and 80 million m^2 of solar thermal collectors. Table 15 below gives an overview about the renewable energy status in China. China is also making ambitious plans to increase the share of renewable energy in its energy system to 10% in 2010 and to 16% in 2020.

[211] Source: Ren21, 2010.

[212] Source: GTZ, 2007.

Table 15: Renewable Energy Status in China[213] [214]

Renewable Resource	**Cumulative Achievements** (end of 2009)
Mini-Hydro	33000 MW
Wind Electricity	26000 MW
Solar PV	400 MW
Biomass Power	3200 MW
Geothermal Power	45 MW
Biogas	30 million systems or 14 billion m^3
Solar Hot Water Systems	125 million m^2 of collectors
Bio-ethanol	2.1 billion litres

5.2.2 India

India had over 16,000 MW of grid connected renewable electricity generation capacity and over 150 MW of distributed renewable electricity generation capacity in the year 2010. A significant share of this is the large grid connected wind electricity generation capacity of 12,000 MW which is the fifth largest[215] in the world. There are also significant levels of small hydro and biomass electricity generation. India similar to China has also a large number of decentralised and rural renewable energy systems such as 3.8 million biogas plants and 1.9 million m^2 of solar thermal collector areas. Table 16 below gives an overview about the renewable energy installations in India. Indian renewable energy programme has been one of the earliest programmes and coordinated by the Ministry for New and Renewable Energy (MNRE).

[213] Source: Ren 21, 2010.

[214] Source: GTZ, 2007.

[215] After United States, China, Germany and Spain

Table 16: Renewable Energy Status in India[216]

Renewable Resource	Cumulative Achievements (as on June 2010)
Wind Electricity	12,009 MW
Biomass Electricity	2,312 MW
Small Hydro Power (upto 25 MW)	2767 MW
Biogas digestors	4.26 million
Village renewable energy systems	6867
Solar Home systems	603,307
Solar pumps	7,334
Solar Hot Water Systems	3.53 million m^2 of collectors
Bio-ethanol	0.2 billion litres

5.2.3 Brasil

Brasil had over 1400 MW of renewable electricity generation capacity in the year 2007. A significant share of this is the small hydro power generation capacity of over 740 MW. Brasil is also the world's largest producer of biofuels and it has very ambitious programmes of renewable energy based rural electrification and biofuels. Table 17 below gives an overview about the renewable energy status in Brasil.

Table 17: Renewable Energy Status in Brasil[217] [218]

Renewable Resource	Cumulative Achievements (end of 2009)
Small-Hydro	740 MW
Wind Electricity	237 MW
Biomass Power	414 MW
Solar PV	15 MW
Solar Hot water Systems	3 million m^2 of collectors
Bio-ethanol	26 billion liters

[216] Source: MNRE, 2007

[217] Source: Ren 21, 2010

[218] Source: GTZ, 2007

5.2.4 Mexico

Mexico had over 1300 MW of renewable electricity generation capacity in the year 2006. A significant share of this is the geothermal power generation capacity of 960 MW which is the second largest in the world. Mexico is in the process of developing and implementing a renewable energy law which is expected to provide a framework for further renewable energy growth. Table 18 below gives an overview about the renewable energy status in Mexico.

Table 18: Renewable Energy Status in Mexico[219] [220]

Renewable Resource	**Cumulative Achievements** (end of 2006)
Small-Hydro	59 MW
Wind Electricity	85 MW
Biomass Power	224 MW
Geothermal Power	960 MW
Solar PV	19.2 MW
Solar Hot water Systems	842,000 m^2 of collectors

5.2.5 South Africa

The renewable energy market in South Africa is in its early stage of development. South Africa had 135 MW of renewable electricity generation capacity in the year 2006. A significant share of this is the biomass power generation capacity of 105 MW. South Africa is currently developing a large scale solar hot water systems programme in the domestic, commercial and industrial sectors to achieve a large portion of the 10,000 GWh by 2013 target set by the government. Table 19 below gives the status of renewable energy development in South Africa.

Table 19: Renewable Energy Status in South Africa[221] [222]

Renewable Resource	**Cumulative Achievements** (in 2006)
Small-Hydro	15 MW
Wind Electricity	3 MW

[219] Source: Ren 21, 2006.
[220] Source: GTZ, 2007.
[221] Source: Banks and Schäfler, 2006
[222] Source: GTZ, 2007.

Renewable Resource	Cumulative Achievements (in 2006)
Biomass Power	105 MW
Solar PV	12 MW
Solar Hot water Systems	0.7 million m^2 of collectors

5.3 Energy Efficiency Technology Potential

Improvements in energy efficiency mean doing more with less and reducing the energy demand per unit of activity. A number of investments in energy efficiency are already cost-effective. Energy efficiency is inherent to innovation but historically the rate is about 1.7%/year. We would need to go beyond the 1.7% annual energy efficiency improvements for transitioning to a low-carbon energy system.

According to the IEA’s energy technology perspectives 2010, energy efficiency can make the biggest contribution in the transition to a low-carbon energy scenario by 2050. Energy efficiency can reduce upto 35% energy demand according to the IEA’s blue map scenario[223]. The potential for energy reductions is mainly in the transport sector (36%), followed by the buildings sector (35%) and the industry (29%)[224].

5.3.1 Transport

The transport sector is responsible for 26% of global energy use[225]. Of this energy use, about two-thirds are for passenger transport and the remaining for goods transport. The energy use in transport is increasing at a high rate in recent years and the rate of increase in developing countries is significantly higher than in developed countries. In the area of passenger transport, the car is the dominant means of transportation globally. All modes of transport are expected to increase in the future with the greatest increase occurring in the number of cars. It is expected that the energy used by the transport sector will double between now and 2050[226]. The road transport sectors growth is followed by the aviation sector.

In the developed countries the main mode of transport is the car and the developed countries also undertake significantly higher levels of air travel per capita. In comparison the developing countries have more modal shares for buses and motor cycles.

[223] The blue map scenario targets halving the global energy related carbon dioxide emissions by the year 2050 with the year 2005 as the baseline.

[224] Source: International Energy Agency, 2010, page 67-68.

[225] Source: International Energy Agency, 2010, page 256

[226] Source: International Energy Agency, 2010, page 256

The total number of cars[227] has increased at a rate of 3% annually since 1990 reaching about 780 million world-wide currently. Also across the world the total volume of goods transported through road and rail freight has been increasing. Shipping is the most energy efficient and low-carbon mode of transport of passengers and goods. Shipping is followed by railways, road transport and finally aviation. Within different road transport options buses represent the least carbon intensive option, followed by motorcycles and the car is the most energy and carbon intensive form of road transport.

The IEA estimates that between 2007 and 2050 the energy efficiency of new vehicles will increase by about 30%. In the low-carbon blue map scenario IEA expects the share of EVs and PHEVs to reach a share of 50% of the total vehicles market. It also expects a significant increase in the use of electricity to replace oil in the transportation sector where the share of electricity increases from the baseline scenario of 27 mtoe to 350 mtoe in 2050, primarily for EVs and PHEVs[228]. The shift from the internal combustion engines to the electric motor in the transportation sector will significantly improve the energy efficiency of the transportation sector and reduce the carbon dioxide emissions.

Air travel is expected to be the fastest growing mode of transport in the future, and IEA expects a four fold increase in passenger kilometres between 2005 and 2050. Efficiency gains are expected as a result of efficient new aircrafts and operational efficiency improvements through improvements in logistics management and efficient air traffic controls.

5.3.2 Buildings

The building sector consisting of residential, service sector and public buildings use over one third of the global primary energy. Between 1971 and 2007 the energy consumption in the buildings sector grew by 1.6% annually. Considerable potential for energy efficiency exists in the buildings sector in both the residential and service sectors. In the residential buildings significant energy efficiency gains can be made in the areas of space heating, water heating, appliances energy efficiency, cooking energy efficiency, cooling and ventilation efficiency and lighting energy efficiency. In the service sector significant energy efficiency potential exists in lighting energy efficiency, space heating, space cooling and ventilation.

According to IEA it is expected that there will be 67% increase in house-hold built up area between 2007 and 2050 and almost 200% increase in the floor area occupied

[227] Cars, Sport Utility Vehicless(SUV) and mini-vans combined

[228] International Energy Agency, 2010.

by the service sector[229]. However it may be possible to reduce the energy consumption by almost one third by using the following energy efficiency technologies[230]:

- Tighter building standards and codes for new[231] residential and commercial buildings. Building codes can reduce the heating requirements in cold climates and the cooling load in warm climates;
- Use of highly efficient heating, cooling and ventilation systems for space heating cooling and ventilation. HVAC systems such as gas condensing boilers and combined heat and power systems could be used,
- Improved lighting efficiency. There is considerable potential to reduce lighting through the use of tubular and compact fluorescent lamps as well as solid state lighting such as LEDs;
- Improved appliance efficiency awareness and use through the application of appliance standards and labels;
- Use of high performance building envelopes that reduce heating and cooling loads through shading, reflective surfaces, light coloured roofs, high levels of insulation/air tightness and high performance windows;
- Efficient cook stoves that use biomass more efficiently and switching to fuels such as biogas or biofuels for cooking which will reduce fuel consumption and improve indoor air quality.

5.3.3 Industry

About one third of global energy demand and about 40% of worldwide carbon dioxide emissions are due to industrial activities. The total final energy use by industry in 2007 was 3015 Mtoe in 2007 which represents almost a 100% increase since 1971[232]. Developing countries accounted for the majority of this increase. Five industrial sectors which account for two-thirds of total industrial energy use are iron and steel, cement, chemicals, pulp and paper and aluminium. According to IEA, energy efficiency and electricity supply side measures in industry could result in significant decreases in energy consumption and associated carbon dioxide emissions between 2007 and 2050.

The chemical and petrochemical sector is by far the largest industrial sector in terms of energy use accounting for almost 30% of all industrial final energy demand consuming about 879 Mtoe in 2007. There is significant scope for process heat savings,

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[229] Source: International Energy Agency, 2010, 205-206

[230] Source: International Energy Agency, 2010, 225-226

[231] In the developed countries, existing and old buildings will need to be refurbished to a low-energy standard.

[232] International Energy Agency, 2010, page 162

waste heat recovery, recycling and electrical energy efficiency technologies in the sector[233].

The iron and steel sector is the second-largest industry sector in terms of energy consumption. In terms of energy intensity the Electric Arc Furnace (EAF) is more efficient than the blast furnace/basic oxygen furnace. However the availability of scrap and the demand for higher grades of steel could pose a barrier to the uptake of the EAF. According to IEA, energy efficiency and recycling can play a significant role in reducing energy consumption and reducing carbon dioxide emissions in the steel industry between 2007 and 2050[234].

Cement production uses about 240 Mtoe of energy and is a significant energy consuming industry sector[235]. The cement industry has made significant strides in reducing energy consumption through the use of dry-process kilns with pre-heaters and pre-calciners.

The pulp and paper sector is the fourth largest industrial sector in terms of energy use, consuming 164 Mtoe of energy in 2007[236]. Most of the scope for energy efficiency lies in integrating pulp and paper mills in which waste heat recovered can be used in the process for uses such as paper drying. There will also be efficiency gains from recycling and recovered paper utilisation.

The energy consumption in the global aluminium industry in 2007 was estimated to be 93 Mtoe[237]. The Aluminium industry uses significant amounts of electricity, with primary aluminium smelters consuming significant amounts of electricity. The aluminium industry has improved energy efficiency steadily over the years and has also improved recycling rates.

5.4 Energy Efficiency Technology Diffusion

5.4.1 Transport

In china the transport sector accounted for 11% of total energy use in 2007 however this could rise to about 20% of energy use by 2050 as the car ownership levels increase from current level of about 25 cars per 1000 people to about 300 per 1000 people[238]. China has been tightening the fuel economy standards for cars and considering reforming of fossil fuel subsidies. China is a leader in EVs and battery manufacturing. The annual sales of electric two-wheelers – e-bikes and mopeds are

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233 International Energy Agency, 2010, pp 161-162

234 International Energy Agency,2010, page 176

235 International Energy Agency, 2010, page 181

236 International Energy Agency, 2010, page 189

237 International Energy Agency, 2010, page 194

238 Source: International Energy Agency, 2010, page 404

over 20 million today with the estimated electric bike stock of over 100 million. China also has a target for EV sales of about 500,000 by 2011. China currently has the world's longest high speed rail network with about 7000 km[239] of routes already in service. Currently 17,000 km of high-speed rail lines are under construction. The top speeds reached by the current Chinese high-speed trains are 350 km/hr[240] with plans for future lines using fast tracks and trains reaching 380 km/hr[241].

In India transport currently consumes only a small share of 11% of total energy use. Buses carried about 57% of passengers followed by 15% transported by two and three wheelers and cars transport only 6% of the population[242]. In a similar way 70% of the goods transport takes place using railways and the remaining using trucks. The Indian transportation system is generally fuel efficient and with low-carbon intensity but as the car ownership and air travel levels increase, and the volume of goods transported increase, the transport sector could consume a significant share of energy. Fuel economy standards, EVs and PHEVs and mass rapid transport systems are all expected to play a role in limiting the growth of energy use and carbon dioxide emissions in the Indian transport sector.

5.4.2 Buildings

In China the energy demand in the building sector has been increasing since 1990, however biomass and waste still dominate the energy supply. The share of coal and biomass has been decreasing and the share of electricity, oil and natural gas has been increasing. The service sector has also seen a significant increase in consumption where the share of electricity and oil has increased with decreases in the use of coal. In terms of end-use, water heating, space heating and cooking dominate the residential and end-uses. In the service sector space heating, water heating and lighting dominate the end uses. There are significant efficiency gains to be made in the residential sector in China by efficient cooking technologies and the use of liquid biofuels for cooking. Space heating energy efficiency can be achieved by building shell improvements and heating system improvements. High efficiency reversible air-conditioners could also help improve the efficiency of space heating as well as cooling. In the service sector significant electrical energy efficiency gains can be made from cooling, lighting and IT and other office automation equipment and devices[243].

[239] As of July 210

[240] The Wuhan-Guangzhou line

[241] On the Shanghai-Beijing line which will use the new 380A model train made by Changchun Railway Vehicles Co in China.

[242] Source: International Energy Agency, 2010, page 445

[243] Source: International Energy Agency, 2010, page 391-401

In India the share of the buildings sector decreased to 47% of final energy consumption in 2007, compared to 55% in 1990[244]. Biomass and waste constitute the major share of consumption in the residential and service sector buildings at 78% and 31% respectively. There is significant scope for energy savings from cooking and water heating. Also it is expected that there will be a diffusion of electrical appliances such as refrigerators, television, air-conditioners and washing machines in the Indian residential sector as incomes grow and standards of living improve. Appliance energy efficiency could play a significant role in the Indian building energy efficiency efforts.

5.4.3 Industry

Industrial energy use in China was 727 Mtoe in 2007 which accounted for 60% of total energy use[245]. This high share of industrial energy consumption is unique to Chinese economy. China is also the largest producer of cement, iron and steel and aluminium and these three sectors account for about 60% of total energy use in the Chinese industry. A number of initiatives such as benchmarking, energy audits, energy-saving action plans etc. have been undertaken by the Chinese government to target industrial energy efficiency improvements. It is expected that China’s industrial energy emissions will continue to rise significantly till 2030 and then rise moderately thereafter till 2050. A number of measures including energy efficiency and higher levels of recycling and energy recovery will be needed to reduce China’s industrial energy emissions.

Industrial sector used 150 Mtoe of energy in 2007 accounting for 38% of final energy used in India[246]. Certain industrial sectors such as cement and aluminium have relatively higher energy efficiency levels. One of the challenges for industrial energy efficiency improvements in India is the large number of small and medium sized enterprises and deployment of energy efficient technologies in the SMEs is more complex owing to incremental investment costs, management capabilities, longer capital stock replacement cycles etc. In general, energy efficiency, recycling, energy recovery measures as well as switching to low-carbon fuels are expected to reduce the energy consumption and carbon dioxide emissions.

5.5 Other Low-Carbon Energy Technology Potential

5.5.1 Clean Coal Technologies

The average global efficiency of pulverised coal plants are around 34% with the best examples reaching 39%. Advances in materials has resulted in deployment of Ultra

[244] Source: International Energy Agency, 2010, page 439
[245] Source: International Energy Agency, 2010, page 391
[246] Source: International Energy Agency, 2010, page 433

Supercritical Coal technology with operating steam temperatures in excess of 600°C with efficiencies in the range of 42- 47%. Further developments in materials[247] might make use of higher temperatures of the order of 700°C and higher and achieve efficiencies of upto 50%[248].

The surge of interest in the 70s and 80s in IGCC resulted in commissioning of four IGCC plants in Europe and the US. However concerns relating to the costs and reliability of IGCC have resulted in a lack of interest in IGCC since the late 90s. However there has been a revival of interest in the IGCC technology with increasing interest in CCS and its ability, flexibility to cater to a number of feedstocks and its ability to generate a number of products including electricity, hydrogen, transport fuels and chemicals.

The current and projected costs for clean coal technologies are shown in table 20.

Table 20: Costs and Efficiency for Clean Coal Technologies[249]

Technology	**Investment Cost** (US$/kW)		**O&M Cost** (US$/kW/Year)		**Efficiency** (%)	
	Current	**In 2050**	**Current**	**In 2050**	**Current**	**In 2050**
Ultra Super critical Coal	2200	1700	44	34	46	52
Integrated Gasification Combined Cycle	1400	1800	72	56	42	54

5.5.2 Carbon Dioxide Capture and Storage

The IEA estimates that the total global installed capacity of CCS will rise to 1000 GW by 2050. Coal fired CCS is expected to account for two-thirds of this deployment. The IEA’s CCS roadmap envisaged 100 large-scale CCS projects should be in operation by 2020 to enable widespread deployment. Significant amounts of funding collectively totalling US$ 26 billion have been committed by governments including those of Australia, Canada, Norway, South Korea, UK, US and the EU[250]. One of the critical elements in determining CCS potential is mapping of suitable storage reservoirs[251]. Countries such as Australia, Canada, China, European Union, Mexico and the United

[247] Such as Nickel based super alloys

[248] Source: Franco and Diaz, 2009, page 352

[249] Source: IEA, 2010

[250] Source: International Energy Agency, 2010.

[251] Source: Intergovernmental Panel on Climate Change, 2005

States have started mapping storage reservoirs and this mapping exercise is expected to accelerate over the coming decade.

The IEA estimates that the potential for CCS projects stands at 3400 projects of which 35% will be in developed countries and 65% will be in developing countries. IEA also envisages CCS applications going beyond clean coal to biomass and gas power plants, in the fuel transformation and gas processing sectors as well as in industrial sectors such as cement, iron and steel and chemicals. IEA also estimates that the level of project development so envisaged requires an additional investment of 2.5 to 3 trillion US$[252].

5.5.3 Nuclear Energy

Nuclear power is already in use in 30 countries and provides around 14% of global electricity supply. Nuclear energy capacity grew rapidly in the 1970s and 1980s driven by energy security concerns and to reduce the dependence on fossil fuels[253]. The growth of nuclear energy stalled in the 90s due to concerns about safety, high costs and poor performance as well as lower fossil fuel prices. The IEA projects that the installed nuclear capacity could reach 1200 GW in 2050 which will amount to an additional 290 GW between 2010 and 2050 increasing from the current 14% to 24% of global share of electricity production. Advanced nuclear energy technologies are expected to help this deployment potential by increasing the competitiveness of nuclear energy. Several of the advanced nuclear technologies under development are also expected to be ready for commercial deployment after 2030 when about 120 GW are expected to be added up until 2050[254]. The March 2011 Fukushima Nuclear disaster has increased the concerns about reactor safety in light of increased natural calamities. This has resulted in several European countries reviewing their nuclear energy programmes and safety features of nuclear reactors. Germany and Switzerland has decided to stop their nuclear energy programmes and shut down existing reactors. These developments are expected to adversely affect the prospects for nuclear energy in the short term.

5.5.4 Smart Grid Technologies

Deployment of smart grid technologies can reduce the peak demand by managing consumer demand, balances consumer reliability and power quality needs, will facilitate the proactive application of energy efficiency opportunities, improve the overall operational efficiency and integrate clean energy technologies. Smart grids have the potential to make the electricity system low-carbon directly and indirectly. Indirectly, smart grids are required for the accelerated diffusion of renewables and

[252] Source: International Energy Agency, 2010

[253] Source: Nuclear Energy Agency, 2008, pages 18-39

[254] Source: Ebinger, 2009, pages 3-4

EVs and PHEVs. Directly smart-grids can save energy through peak load management, increase the deployment of energy efficiency programmes; provide direct feedback on energy usage and influence consumer behaviour to use electricity efficiently and reduction in line losses through voltage control.

Deployments of smart grid technologies will in the coming decades also require deployment of direct large-scale electricity storage technology. The IEA estimates that by 2050 there will be a need for 122 GW of global storage required by combining electrical storage and by combining vehicle-to-grid (V2G) storage technologies[255].

5.6 Other Low Carbon Energy Technology Diffusion

5.6.1 Clean Coal Technologies

In China Coal will continue to dominate the Chinese electricity system for another twenty years or more. Replacing the old sub-critical coal power plants by new SCC, USCC and IGCC technologies are expected to result in more resource efficiency and lower levels of carbon dioxide emissions. This will also allow the plants to be retrofitted with CCS technologies as and when they become available.

Due to the flexibility and low-carbon potential of IGCC power plants, significant effort is being devoted to the development of IGCC technology in Developed countries such as the US and developing countries such as China. However a number of technical obstacles will need to be overcome before the wide deployment of IGCC in the developing world[256].

5.6.2 Carbon Dioxide capture and Storage

The IEA envisages that majority of the CCS capacity in 2050 will be deployed in developing countries with China and India taking up the major share of 36%[257]. The share of developing countries is expected to be 65% of the total potential. It is estimated by IEA that initial CCS demonstrations will be carried out in the developed countries which require investments at an average of 3.5 to 4 billion US$ annually between 2010 and 2020. IEA also proposes an international technology collaboration through which financing for CCS demonstrations in developing countries at an average annual level of 1.5 to 2.5 billion US$ between 2010 and 2020[258].

[255] Source: International Energy Agency, 2010, pp 282-3
[256] Source: Franco and Diaz, 2009, page 352
[257] Source: International Energy Agency, 2010.
[258] Source: International Energy Agency, 2010.

5.6.3 Nuclear Energy

In end-2009, 56 new nuclear power plants were under construction in 14 countries with the Chinese programme with 20 projects being the largest. Russia and India also have ambitious nuclear programmes.

Out of the total 718 GW of installed electricity generation capacity in China in 2007 about 1.2% is nuclear energy capacity. The IEA expects the share of nuclear energy in China to increase to 110 GW in 2050 increasing the share to 7.3%[259]. Advanced nuclear energy technologies are expected to play a role in the period after 2030. IEA also envisages the nuclear energy capacity to rise to 318 GW contributing a share of over 25% according to its ambitious nuclear technology roadmap[260].

In India the installed nuclear electricity generation capacity stands at 2.5% out of the installed capacity of 168 GW. The IEA expects the nuclear energy capacity in India to rise significantly to 33 GW increasing the share to 7% of total installed capacity in 2050[261]. According to its ambitious nuclear technology roadmap, the IEA expects the installed nuclear energy capacity in India to significantly increase to 122 GW in 2050 increasing the share in installed generating capacity to 27%[262].

5.6.4 Smart Grid Technology

Smart grid deployment could be of benefit to developing countries as the developing countries try to provide electricity access to more than 1.4 billion people who do not have access today. The developing countries may be able to leapfrog to smart grid technologies for energy access which will allow for better energy system management, integration of renewables, EVs and PHEVs[263]. Also in several developing countries the grid losses are significant. In India the grid losses are at 26% of the total generation[264]. Deployment of smart grids in developing countries such as India and Brasil can increase accountability and revenue collection. For instance in Rio de Janeiro in Brasil a local energy distribution company Ampia was able to reduce the revenue losses from 53% of energy supplied to 1.6% by implementing smart grid technology including remote monitoring and remotely disconnect culprits[265]. Also in locations such as Harbin province in China, with high possibility of ice storms smart

[259] Source: International Energy Agency, 2010, page 385

[260] Source: International Energy Agency, 2010, page 389

[261] Source: International Energy Agency, 2010, page 427

[262] Source: International Energy Agency,2010, page 432

[263] Source: The Climate Group, 2008

[264] This value is significantly higher than the technical losses possible and can be attributed to commercial losses or losses due to theft.

[265] Source: World Economic Forum,2009, page 15

grids create a dynamic and agile grid that enhances the resilience and ensures availability of supply[266].

According to the World Economic Forum (WEF), the key drivers for smart grids in developing countries are increasing the reliability and resilience to threats, increasing the diffusion of renewables, EVs and PHEVs, cost reduction, optimised consumption and preventing energy losses[267].

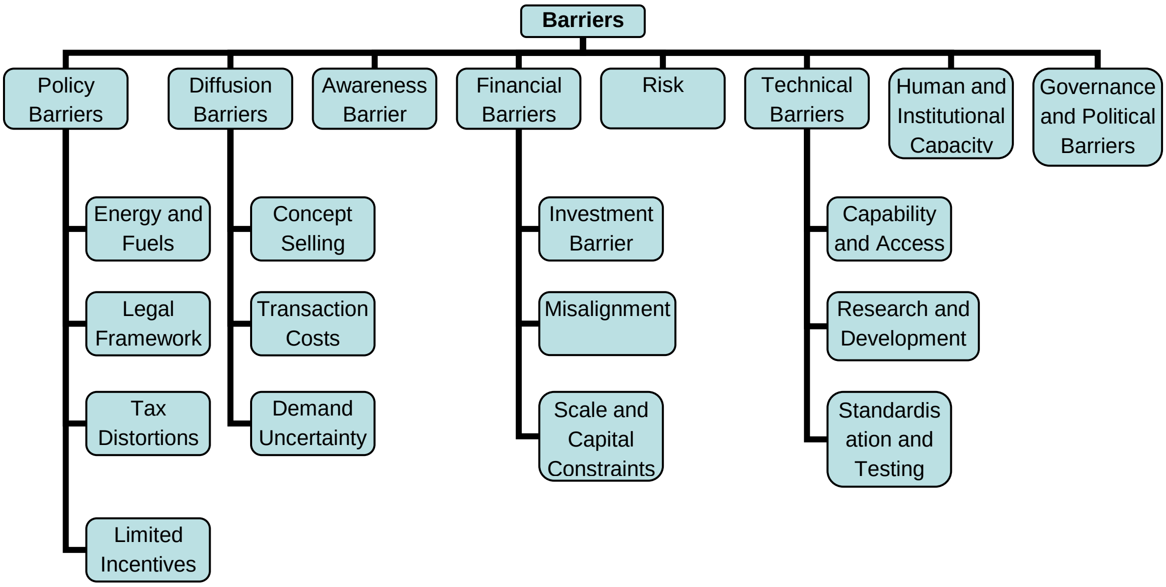
[266] Source: World Economic Forum,2009, page 17

[267] Source: World Economic Forum, 2009, page 15

6 Barriers and Lessons from Barrier Removal

Research was carried out on the barriers to low carbon energy technology innovation and deployment in developing countries. Innovation and deployment of low-carbon energy technologies in the developing countries face a number of significant barriers. The barriers faced by the low-carbon energy technologies according to published literature and experience of REEEP are shown in fig 18 below and explained thereafter.

Fig 18: Barriers to Low-Carbon Energy Technology Innovation and Deployment



6.1 Policy Barriers

6.1.1 Energy and Fuels Pricing

Energy pricing and especially electricity pricing decisions and fossil fuel subsidies across the world does not often reflect the true cost of the electricity service[268]. In many countries, especially developing countries, energy supply and heating and cooking fuels to households and electricity for agricultural applications are highly subsidised[269]. These pricing distortions adversely affect the financial prospects of

[268] Source: Blackman and Wu, 1999, Page 704

[269] In several Indian states farmers receive free electricity to power irrigation pumps.

clean energy[270] and encourage inefficient use of energy and significantly reduce the incentives for energy efficiency[271].

6.1.2 Legal Frameworks

Several policies and regulations in developing countries are oriented towards traditional energy technologies and are not conducive to development of low carbon energy technologies[272]. Energy efficiency projects in several sectors can be implemented by Energy Service Companies (ESCOs) using performance contracts. Such an approach allows for investments in energy efficiency to be made by an ESCO and the deemed revenues resulting from the savings to be shared between the ESCO and the energy user. These performance contracts provide a legal basis to quantify, monitor and verify the energy savings so that payments can be made by the user of energy service to the ESCO. In developing countries, the legal frameworks do not always facilitate performance contracting. The absence of these frameworks prevents development of energy efficiency projects using the ESCO approach. The legal frameworks in several developing countries do not allow performance contracting which is a pre-requisite for ESCOs.

6.1.3 Tax Distortions

The tax regimes in most countries do not differentiate between low-carbon energy systems and devices or energy efficient products such as cars and appliances against the conventional and less energy efficient products. One of the results is that energy consuming equipment or renewable energy devices are taxed based on either their financial value or capacity. In several cases the energy use is taxed at a lower rate than energy efficient end use equipment. Tax incentives such as reduced tax rates, or accelerated depreciation[273] benefits could influence purchase decisions towards more energy efficient equipment or low-carbon energy devices but these incentives are only available in a few countries.

6.1.4 Limited Incentives

In many countries there are little or no incentives for making investments in manufacturing low-carbon energy products. There are also limited incentives for marketing and promoting low-carbon energy products and systems in the market[274]. Similarly

[270] Source: Taleb, 2009, doi:10.1016/j.esd.2009.06.004

[271] Source: Owen, 2006, page 636

[272] Source: Painuly et al, 2003, page 663

[273] The option to depreciate the value of the asset at a faster rate than the normally allowed rate of depreciation.

[274] Source: Walekhwa et al, 2009, page 2761

little or no incentives are available for purchase or use of energy efficient equipment. While some level of direct or indirect incentives exist for renewable energy use in some developing countries, these are often inadequate to facilitate technology transformation[275].

6.2 Diffusion Barriers

6.2.1 Concept Selling

In most countries, low carbon energy markets are at an early stage of development and consumers are only becoming familiar with the concepts and products. Therefore low-carbon energy equipment manufacturers have to often sell the concept of renewable energy or energy efficiency or other low-carbon energy attributes and create the market as the demand for the products or low-carbon energy technologies does not exist or lave a limited track-record[276]. The market for energy service products such as white goods[277] is also based primarily on the features of the energy service and the functionality of the equipment and lower energy use or low carbon intensity are not an important element in the purchase decision. This situation makes the marketing of energy efficiency and renewable energy products difficult, lengthy and costly compared to regular electrical or energy service products as well as generation equipment based on liquid fossil fuel.

6.2.2 Transaction Costs

Within the low carbon energy technologies, the nature of the renewable energy and energy efficiency technologies mean that their diffusion involve small interventions that are spread over a larger geographical area and with different time periods of implementation. This nature of energy efficiency projects, especially in the end-use, transportation, buildings and agricultural sector as well as renewable energy technologies in the household, agriculture and transportation applications results in higher transaction costs which are disproportionately high compared to the investment costs[278]. For example the cost of an energy audit and development of a plan for energy efficiency technologies and measures for a house might be comparable to the final energy efficiency investments to be made by the household. Such high transaction costs significantly hamper the diffusion of several energy efficiency and renewable energy technologies.

[275] Source: Al-badi et al 2009, doi;10.1016/j.rser.2009.06.010

[276] Source: Kavouridis and Koukouzas, 2008, pp 693-703.

[277] Refrigerators, washing machines, dish washers

[278] Source: Mirza et al, 2009, page 929.

6.2.3 Demand Uncertainty

In the case of appliances and vehicles where manufacturers offer a number of variants of the same product, the manufacturers are uncertain about the demand for low-carbon and energy efficient models. This results in a conservative approach of limiting the production of low-carbon models of equipment and automobiles. In a similar way production of renewable energy equipment and devices happens in a limited scale without mass production and normally in a batch mode. This phenomenon happens as a result of the dependence on government programmes that drive the renewable energy market development. This demand uncertainty results in suppressing possible demand and limits diffusion of low-carbon energy technology[279].

6.3 Awareness Barrier

There is limited awareness of the opportunities available for low-carbon energy in the residential, lighting, transport and agricultural sectors. Many individuals and companies do not consider expenses on energy important and do not keep track of energy use and related expenditure[280]. When commercial, industrial or residential products are purchased emphasis is placed on the features offered by the product and its purchase price. Operating costs of equipment is given limited consideration during purchase decisions[281]. There is limited awareness about the economic or environmental benefits of low carbon energy technologies at the institutional, business and community levels in developing countries[282]. There are also incorrect perceptions about renewable energy technologies that it is generally costly and that it can only provide limited amounts of energy. Similarly there are perceptions that energy efficiency technologies compromise on the performance of the energy service.

Awareness and understanding of clean coal technologies and carbon capture and storage are limited in developing countries except for China, India and some of the other larger developing countries. In a similar way awareness and understanding on nuclear energy technologies are also limited to some key developing countries.

Awareness about low-carbon energy products, projects and their economics is limited in the finance and banking sector and renewable energy, energy efficiency and other low carbon energy technologies are considered to be riskier. At the policy and regulatory level, the characteristics of renewable energy and energy efficiency technologies and other low carbon energy technologies are not well understood. This

[279] Source: Almeida et al, 2003, page 687

[280] Source: Sardianou, 2008, page 1417

[281] Source: Nagesha and Balachandra, 2006, page 1973

[282] Source: Brown, 2001, page 1202

results in policies and regulatory instruments that are often designed with a limited appreciation of issues surrounding low-carbon energy technologies.

6.4 Financial Barriers

6.4.1 Investment Barrier

The capital costs of the low carbon energy technologies are often higher than the conventional energy technologies[283]. This is because of the absence of a carbon price signal and absence of a framework which internalises the externalities associated with climate change mitigation and environmental protection[284]. The higher upfront investment costs discourage investment away from low carbon energy technologies[285] into conventional, inefficient and high carbon energy technologies[286].

6.4.2 Misalignment

There is a structural misalignment in financing of energy efficiency in that the ones who make the decision about energy consuming equipment and devices are not the ones who pay the energy bills[287]. This misalignment means that mostly only price considerations go into purchase of equipment and devices[288]. This is particularly a major barrier in building energy efficiency where the investments in the building, insulation, equipment and electrical fixtures are made by the landlord and the energy bills are paid by the tenant.

Similarly there are structural misalignments in the way the conventional business and industry operates which does not suit investments in low carbon energy technologies. In the case of renewable energy stand-alone systems, the users usually have to invest, own and operate the system while for the conventional energy technologies users only pay for the energy service.

6.4.3 Scale and Capital Constraints

Manufacturers of energy efficient products, renewable energy equipment manufacturers and companies that provide renewable energy or energy efficiency services such as energy audits, advice and consultancy are relatively small in size and not adequately capitalised[289]. These companies also have limited collateral and limited

[283] Source: Nalan et al, 2009, page 1433

[284] Source: Owen, 2006, page 638

[285] Source: Rao, 2002, page 71

[286] Source: Kann, 2009, page 3145

[287] Source: Shove, 1998, page 1106

[288] Source: Rohdin et al ,2007, page 674

[289] Source: Elauria et al, 2002, page 45

track-record which also affects their ability to raise additional working capital[290]. The capital limitations also affect the ability of the manufacturers for investments in product development and the marketing of their products and services[291]. As for project financing because a number of low-carbon energy projects are decentralised and small, they do not have economies of scale[292].

6.5 Risk

Banking and financial institutions consider as risky the financial model for energy efficiency projects based on energy savings and without an additional revenue stream. The business model which is based on a shared savings contract is also considered to be riskier than normal business models. Uncertainties relating to the baseline, incremental cost of energy efficiency investments, protocols for monitoring and verification etc. increase the risk perception of the financial sector. Similarly the low-carbon energy projects especially renewable energy is considered riskier[293] as a result of limited track-record and resource variability.

The returns on low-carbon energy projects are low and long term compared to conventional high carbon energy projects. These high risk perceptions result either in the projects not being financed or being financed at a high risk premium. When renewable energy or energy efficiency projects are financed at a high risk premium the resultant increases in cost of funds affects the financial profitability of the projects.

Other low carbon energy technologies such as IGCC coal technology and carbon capture and storage are considered to be risky technologies as the track-record of these technologies are limited. This is especially true for carbon capture and storage as the carbon capture technology has not yet been demonstrated in normal commercial coal power plants and mapping of reservoirs are at an early stage.

6.6 Technical Barriers

6.6.1 Capability and Access

The manufacturers of low-carbon energy equipment generally do not have sufficient technological capabilities. Generally manufacturers also have limited capability to design or manufacture renewable energy or energy efficient products. The manufacturers especially in developing countries also have limited access to the state-of-the art renewable energy or energy efficient technologies. The operators of low-carbon

[290] Source: Schleich and Gruber, 2008, page 454

[291] Source: Lantz et , 2007, page 1838

[292] Source: Barry and Chapman, 2009, page 3364

[293] Source: Weiss et al. , 2008, page 1614

energy systems in developing countries also have limited capacity to own, operate and maintain energy systems[294]. This lack of capacity and limited access constrains the ability of manufacturers, especially in developing countries to develop the markets for energy efficiency and renewable energy[295].

Other low carbon coal energy technologies such as ultra-super-critical coal, integrated gasification combined cycle, carbon capture and storage are all advanced technologies. The technological know-how and the capacity to implement interventions in these clean coal technologies do not exist in a large number of developing countries. Generation III and III+ nuclear energy technologies and the availability and use of fissile material and their enrichment also require significant technical capabilities. While the nuclear energy technologies have been used to generate energy for decades the technical cooperation and technology transfer efforts have been complicated by the existence of the nuclear non-proliferation regime which seeks to limit the use of nuclear technology for armed conflicts. This has meant that capability to build nuclear reactors does not exist in most developing countries.

6.6.2 Research and Development

There are very limited investments for research, development and demonstration of energy efficient products and renewable energy systems and other low carbon energy technologies by the governments, research institutions and industry especially in developing countries[296]. Low carbon energy technology based applied R&D by key institutions is also limited[297]. These limited efforts constrain the innovation in low carbon energy technologies and further hamper the rate of diffusion in low carbon energy technologies.

6.6.3 Standardisation and Testing

There are limited numbers of low-carbon energy standards at national levels in many countries[298] and where available the standards are not always harmonised with the relevant global frameworks or comparable international, regional or national standards[299]. In addition, in many countries there are no independent test labs that have the capability to test and certify energy efficient or renewable energy equipment according to available national or international standards. Where laboratories do exist

[294] Source: Walker, 2008, page 4403

[295] Source: Elauria et al, 2002, page 45

[296] Source: Al-badi et al 2009, doi;10.1016/j.rser.2009.06.010

[297] Source: Junfeng et al, 2002, page 16

[298] Source: Aajjakulnukit et al , 2002, page 28

[299] Source: Jagadeesh A, 2000, pages 157-168

they are not always adequately equipped and staffed according to international norms[300] and the test equipment not adequately calibrated.

Similarly for clean coal and nuclear energy technologies, the technical and quality control frameworks does not exist in most developing countries and are only evolving. This situation is also true for nuclear energy technologies where the technical framework for nuclear safety and waste disposal does not exist in a large number of developing countries. Nuclear energy technologies also require the added safeguards mandated by the IAEA to prevent their use in armed combats.

6.7 Human and Institutional Capacity

There is usually a major constraint with the institutional arrangements in the national and provincial level in several developing and transition countries to promote renewable energy and energy efficiency technologies[301]. Normally the responsibilities for renewable energy or energy efficiency or other low carbon energy technologies in the government departments or agencies are unclear[302] and where there are specific divisions or departments which are responsible they are often understaffed. Added to the institutional constraints is the absence of qualified and experienced manpower for design, manufacture, installation, operation and servicing of the energy efficiency and renewable energy systems and other low carbon energy technologies[303]. There is a need for a robust technical and vocational training, evaluation and certification infrastructure which could provide human resources for the low-carbon energy innovation and diffusion initiatives.

As for clean coal and natural gas technologies there is generally an institutional framework for managing thermal power generation technologies. The levels of availability of human resource and the quality of the skill sets they possess vary amongst developing countries. Majority of the developing country institutions and manpower does not have the qualifications or the experience to manage advanced and clean coal technologies such as ultra-super-critical coal or integrated gasification combined cycle or carbon capture and storage. In a similar way majority of the developing countries lack the institutional framework and the human capacity to design, develop and construct nuclear power stations and manage the safety issues around the nuclear fuel cycle. These severe constraints in institutional and human

[300] ISO/IEC/EN 17025. (Formerly ISO Guide 25 & EN45001). General Requirements for the Competence of Calibration and Testing Laboratories.

[301] Source: Clark, Alix , 2000, page 33

[302] Source: Weber, Lukas, 1997, page 834

[303] Source: Wang et al, 2008, page 1881

capacity hamper the diffusion of low carbon energy technologies in developing countries[304].

6.8 Governance and Political Barriers

Although not well documented in literature, during the empirical studies relating to the research, it was found that several low carbon energy technologies were facing difficulties that are related to the transparency and objectivity of the energy sector, banking sector or policy making bodies in developing countries. There seemed to be vested interests that prevented or severely retarded the diffusion of low carbon energy technologies and initiatives irrespective of the soundness of the technological plans. Similarly several low carbon energy deployments could not progress because of changes in governments and the new governments considering the projects or initiatives with a political prejudice[305].

A large number of developing countries also demand substantial amounts of financial resources and technology transfer mechanisms under the UNFCCC to change their energy development paths towards low carbon energy sources. This is a major barrier for deployment of low-carbon energy technologies such as generation III and III+ nuclear, ultra-super-critical coal, integrated gasification combined cycle, smart grids and carbon capture and storage.

6.9 Lessons from Barrier Removal[306]

REEEP’s experience with three low-carbon energy technologies – renewable energy, energy efficiency and smart grids and addressing barriers such as Policy, Financing, Diffusion, Risk, Technical, Awareness, Human and Institutional capacity and Political and Governance barriers in the last 5 years in over 50 countries have also provided several lessons in barrier removal which are illustrated below. These lessons were part of a publication by Parthan et al in 2010. The lessons are examined here with a view to consider the elements of the quantitative framework for measurement of energy technology innovation initiatives:

6.9.1 Importance of Failures

While projects that have failed to achieve their objectives represent a small share of the REEEP portfolio, failures provide very valuable lessons for market transformation.

[304] Source: Jaber, 2002, page 392

[305] Source: Parthan and Bachhiesl, 2008

[306] cf. Parthan B, et al, 2010, pp 83-93

REEEP requires the independent experts to spend 50% more time carrying out the assessment of failed projects and to examine the reasons and the lessons from the failures. From a process perspective, REEEP would encourage implementing agencies to acknowledge that failures do happen and to accept that some initiatives and projects will fail.

Analysis by REEEP shows that most failed projects did so due to inadequate risk management. Several of the projects were subject to external risks, such as political risks, which were not adequately captured in the risk identification and assessments during the proposal development stage. When the risks precipitated, implementing organisations were unable to manage the fallout. The level of funding was not seen as a reason for failure. This calls for better risk assessment in the proposals and for ensuring that the organisations proposing project concepts have the capacity to manage risky situations.

6.9.2 Engagement of key Stakeholders

The key stakeholders in REEEP’s programme themes of policy, regulation, finance and business are governments, regulators, financial institutions and energy businesses. These stakeholders have a key role in low carbon energy transformation in developing countries. REEEP’s direct engagement of these stakeholders is currently at 22%. REEEP needs to directly engage more government agencies dealing with low carbon energy issues, as well as energy regulators, banking and financial institutions, and energy businesses. The share of key stakeholder segments needs to increase within REEEP’s portfolio. Where it is not possible to directly engage these stakeholder groups, other organisations such as consulting companies, NGOs, research and academic institutions may be engaged as intermediaries, provided that key stakeholders demonstrate full output ownership through formal commitment and financial and in-kind contributions.

6.9.3 Impact Measurement and Verification

The themes supported by the programme are policy, regulation, finance and business. The types of activities that REEEP supports and their outcomes do not generally lead to direct low carbon energy generation or to a reduction in GHG emissions. REEEP does not usually support hardware and the creation of physical infrastructure; a small 6% percent of REEEP projects do result in clean energy production and GHG mitigation. Such projects typically involve renewable energy devices such as cook stoves and PV systems, a small number of which are implemented as part of project activities. Therefore, the majority of project activities have impacts in the realms of capacity building and market development impacts. The current logical framework approach that REEEP adopts for impact assessment is not able to reliably attribute the project impacts because projects are largely unable to influence outcomes beyond direct project outputs. This challenge of attribution arises because REEEP projects support policies, regulations and measures in finance and business – activities which typically have a shorter timeframe. REEEP and its consultants have considered 16 different Measurement Reporting and Verification (MRV) approaches such as Clean Development Mechanism (CDM) methodologies, Global Environment Facility (GEF) methodologies, Most Significant Change (MSC), Results Based Monitoring (RBM), United Nations Development Programme (UNDP) Capacity Assessment Framework, Clean Technology Fund (CTF) Results Measurement System, World Business Council for Sustainable Development (WBCSD) Framework, Outcome Mapping, Logical Framework approach, etc. The current thinking is to develop a new synthesis model which combines the Logical Framework Approach with Outcome Mapping (LFA+OM). Under this proposed approach, OM will be added to the current LFA being followed by REEEP and this integration is expected to address the attribution gap. The OM will identify key stakeholders, or “Boundary Partners,” and will track changes in approach and actions of these boundary partners using an objective and graduated set of indicators. This approach is currently under development and is expected to be tested for REEEP projects before large-scale implementation. The proposed results measurement framework is expected to provide a better basis for measuring project success, as it will be based on the impacts rather than on current approach which is based on outputs.

6.9.4 Ownership

Ownership of project outputs and outcomes by the key stakeholders are important to achieve the desired impacts. REEEP’s partnership approach in working directly with key stakeholders is resulting in higher levels of ownership, especially in rapidly emerging developing countries such as Brasil, China and India. By assuming a supervisory position and encouraging prospective implementing partners to play a role in programme framework development, REEEP’s bottom-up, broad-based approach to developing its programme framework strongly contributes to increasing key stakeholder interest in REEEP programmes.

This contrasts the approach taken by several development agencies, especially bilateral development agencies, where donor country-based organisations and experts define the framework and deliver the outputs. The procurement procedures of several bilateral development agencies either limit or give preferential treatment to services and goods from the donor country. While organisations and experts from recipient countries are involved in implementation, their roles remain peripheral in most cases.

6.9.5 Technology Neutrality

REEEP’s approach is similar to some of the other development agencies, in that it maintains technology neutrality and offers implementing partners the choice of low carbon energy technology. Experience from energy initiatives in developing countries show that international, national, regional or sectoral market development approaches which are focused on a specific technology have had limited success and tend to be restrictive in terms of resources and energy conversion. Therefore, REEEP advocates technology neutral approaches and refrains from picking technology winners before implementation. The technology neutrality is enshrined in the programme framework development process by ensuring that the regional and global priorities remain technology neutral. The criteria for project concept short-listing and proposal ranking are also technology neutral.

Advocates of low-carbon energy technologies generally tend to prefer specific technologies and sometimes exaggerate the low carbon and economic benefits of the technologies under consideration. Such practices result in low-carbon energy technologies being applied in inappropriate situations. REEEP takes an unbiased and balanced approach in advising partners on the choice of the technologies and discourages the use of specific low-carbon energy technology in situations where they are not appropriate.

6.9.6 Carbon Finance

The key lessons from REEEP’s experience with carbon finance are:

- The Clean Development Mechanism (CDM) has helped grid-connected renewable energy projects and industrial energy efficiency projects to benefit from carbon finance. These low carbon energy projects, which were previously mainly promoted by larger corporates and industries in developing countries, were able to organise themselves to take advantage of CDM.
- The CDM has not succeeded in making any significant difference to smaller renewable energy and energy efficiency systems, such as small and household renewable energy and end-use energy efficiency. The CDM modalities and procedures, especially the additionality testing, remain a major barrier to household energy and end-use energy efficiency projects.
- The barriers faced by household renewable energy and end-use energy efficiency projects strongly attribute to CDM’s inability to achieve a geographical balance. In several Least Developed Countries (LDCs) and Small Island Developing States (SIDS), the only opportunities to benefit from CDM are in those low carbon options which are geographically dispersed.
- Several household energy projects and end-use energy efficiency projects are benefiting from the voluntary carbon markets and are using instruments such as the CDM Gold Standard to obtain higher prices for renewable energy and energy efficiency technology-based emission reductions.

6.9.7 Financing

Key lessons from REEEP’s experience in local finance include:

- Supporting the establishment of funds and finance facilities is a high-risk, high-impact theme for REEEP and other low carbon energy market development agencies. Some of the ways to manage the risk with such initiatives is to ensure that the project pipeline is credible, that there is evidence of serious commitment from early stage investors in the fund, and that the promoter company has a strong past track-record.
- In general, significant local financing is available on the wholesale level in most developing countries for energy investments, partially from institutions such as local development banks, commercial banks, and agricultural development banks, and in other cases from specialised low carbon energy finance institutions, such as REEEP partner Indian Renewable Energy Development Agency (IREDA). Generally missing are finance and risk mitigation instruments and retail-level institutions for channeling the finance.
- The absence of risk mitigation facilities is constraining the flow of private finance to low carbon energy investments in large developing countries. Guarantee funds have been used effectively in early stages of market development, but need to be designed in a way that the guarantee fund is replenished and sustained over the long run. There is a significant gap in terms of risk insurance products covering the performance and energy meteorological risk.
- Micro-finance can play a major role in development of markets for small low carbon energy systems and devices, but the achievements have so far been in market niches. The three critical factors to be addressed to scale-up the role of micro-finance in low carbon energy are the management of transaction costs, credit risk management, and the availability of low-cost long term financial resources.
- The finance and banking sector in the commercial, development and agricultural sectors need significant capacity building in low carbon energy finance and economics and feasibility analysis, reflecting the need for decision support tools. For example, RETScreen, which is supported by REEEP and is the worlds most widely used clean energy analysis software with 300,000 users in over 140 countries, is significantly contributing to financial sector capacity building.

6.9.8 Low-carbon Energy Business Models

Key lessons from REEEP’s experience in business models include:

- Due to renewable energy products and efficient end-use equipment not being readily available to general customers in developing countries, there is a need for supply chains and marketing networks to make low carbon energy systems and devices in a consumer purchasing context.

- Low carbon energy businesses in developing countries active in marketing, sales, installation and service remain relatively small and are often managed by first-generation entrepreneurs without business backgrounds. To increase the scale, there is a critical need for developing and incubating energy enterprises that can market, sell, install and service low carbon energy systems and devices.
- In contrast to an incorrect perception that both urban/peri-urban and rural poor people cannot pay for low carbon energy, most poor people pay for energy in absolute terms that are quite significant, considering their total incomes. An additional inaccurate perception is that low carbon energy delivery services are more suited to not-for-profit organisations, but we see that providing energy services to the poor is a profitable business with a bigger role for for-profit principles and enterprises.
- Energy Service Companies (ESCOs) in developing countries are often being implemented in niches and generally on a relatively small scale, possibly dependant on public expenditure on energy efficiency. Most ESCO businesses are under-capitalised and small; many focus on selling equipment rather than services. There is a need to mainstream and increase the scale of operations of ESCOs to realise its potential in developing countries. Financing mechanisms such as securitisation or forfeiting are needed to provide funding to the ESCO businesses that are not supported by local banks and financial institutions.

6.9.9 Low-Carbon Energy in Buildings

Key lessons from REEEP's experience in low carbon energy in buildings include:

- Solar flat plate collectors are a mature, appropriate, financially viable and ready technology for a large-scale rollout in developing countries.
- Appliance standards and labels are a very effective policy and regulatory instrument. Their role will increase as people in developing countries increasingly acquire energy-consuming equipment such as refrigerators, air conditioners, washing machines, etc. There is also a need to expand the scope of standards and labels to include thermal energy appliances such as gas room heaters and gas cooking stoves.
- The direct and indirect subsidies on electricity and heating fuels are a major barrier to achieving low carbon energy transition in buildings in developing countries. Reform of administered prices and rationalisation of subsidies in

electricity and fuels is a pre-requisite to achieving significant gains in energy efficiency and renewable energy in the built environment.

6.9.10 Rural Energy

Key lessons from REEEP’s experience in rural energy include:

- Rural energy programmes often focus only on electricity and ignore the thermal and mechanical energy needs of rural areas without modern energy.
- Biomass remains a key resource for meeting the thermal energy needs of rural population today. Future efforts in rural energy will need to put adequate emphasis on thermal and electrical energy conversion technologies based on biomass.
- Many rural energy programmes have restricted their impacts by focusing on a single technology, such as energy conversion or end-use energy service technologies. A technology-neutral approach, which would include technologies such as gas stoves and the use of fossil fuels such as liquefied petroleum gas, is recommended for interventions in this sector.
- Rural energy business is a long-term, low-return prospect; private businesses are unlikely to be significant players unless required by regulation. In the absence of strong regulation, governments and utility companies will need to play a more active role in low carbon rural energy.
- Rural energy business in the public and private sectors will need financial and fiscal incentives to service the rural population without access. These incentive frameworks should encourage energy service delivery, rather than buying down capital costs.

6.9.11 Low-carbon Energy Regulations

Key lessons from REEEP’s experience in low carbon energy regulation include:

- In developing countries, significant capacity constraints with energy regulators act as major barriers to transitioning to a low carbon energy system. The regulators generally have little or no experience with renewable energy sources or low carbon energy technologies. There is also a dearth of instruments for regulating low carbon energy.
- Governance is a key barrier in infrastructure regulation, affecting also the energy sector. Governance issues have affected energy access, services quality, and mainstreaming low carbon energy. Energy governance needs to improve to ensure a low carbon energy transition in developing countries.

6.9.12 Low Carbon Energy Policy

Key lessons from REEEP’s experiences in low carbon energy policy include:

- The number of people living in urban centers in developing countries is increasing, and more urban centers are being developed. Cities and towns provide a good opportunity for transition to a low carbon energy system through a focused, area-based approach. Low carbon energy planning needs to be integrated into urban planning and should cover topics such as transportation, building, and water supply as well as electricity and heat.
- Policy instruments such as feed-in-tariffs have helped in increasing the share of renewable energy in electricity systems. However, feed-in-tariffs should be carefully designed to ensure economic efficiency and long term sustenance of the low-carbon energy market. Feed-in-tariffs are not relevant to off-grid energy systems, thermal energy, or energy efficiency market development. Mechanisms such as bidding systems and certificate systems (renewable energy certificates, white/EE certificates, etc.) provide an alternative market-based mechanism, but new institutional frameworks should still be established before they can be implemented.
- Buildings energy performance standards and codes are key policy instruments for low carbon energy transition in buildings.
- Corporate policy and corporate social responsibility have not played a significant role in low carbon energy market development in developing countries. As traditional and new businesses grow in developing countries, the role of corporate policy will increase, relative to government policies. Several reporting initiatives, such as the Carbon Disclose Project (CDP) supported by REEEP, are beginning to sensitise corporate policy to low carbon energy opportunities.
- Technology roadmaps, when owned by the developing country government and with the right incentives, technical frameworks, and targets can result in effective market transformation and technology leapfrogging.

7 Technology Innovation and its Measurement

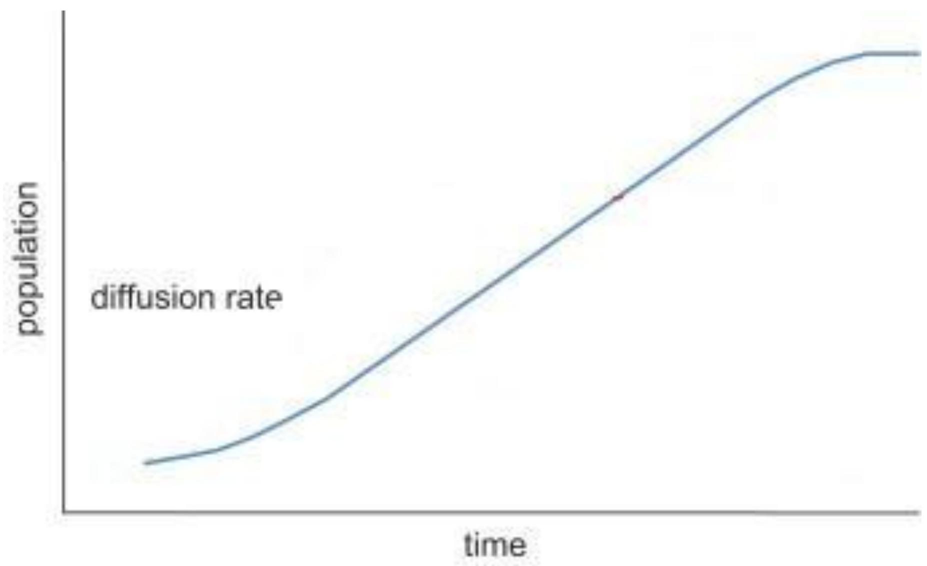
7.1 Technology Innovation

7.1.1 Innovation Process

According to the linear model of innovation by Schumpeter, technological change in the low-carbon energy technologies happens in three broad stages as follows:

- **Invention** of a new product or process or a configuration or a composition of matter (E.g. fuels) which provides a way to generate energy with lower levels of GHG emissions than the existing alternatives.
- **Innovation** is the transformation of the invention to a commercial stage through continuous improvements and refinements within a community of a small number of firms or individuals in the energy sector. This could be within a sub-sector or a country or a sector within a country which is relatively small.
- **Diffusion** is the process by which a low carbon energy innovation is adopted by other firms or individuals in the energy sector across countries and across sub-sectors over time. The diffusion or deployment of innovations happens over a time and typically follows an S-shaped sigmoid curve as shown in fig 19.

Fig 19: Diffusion of Low Carbon Energy Innovations[307]



[307] Source: Rogers, 2003, page 11

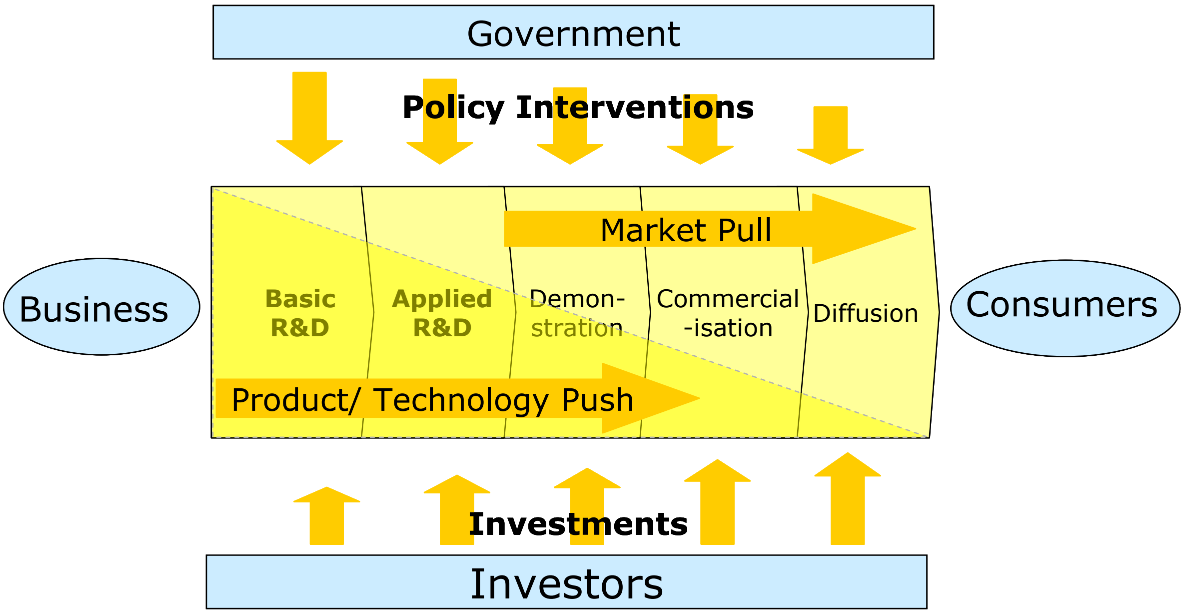
The uptake of innovative technologies including low-carbon energy technologies begins slowly with promotion by early adopters consisting of an energy community or a small number of firms within the energy sector. Over a period of time the low-carbon energy technology diffusion takes off and accelerates to a stage of rapid diffusion. The rate of diffusion gradually slows down when the low-carbon energy technology reaches a saturation stage where most of the market and population have been covered. The later adopters embrace the innovation closer to the saturation point.

In the low-carbon energy technology context the invention stage can be expanded into three phases of basic Research and Development (R&D), applied R&D and demonstration. Grubb differentiates and qualifies the demonstration as market demonstration where the technology performance, viability and market prospects are tested and demonstrated. Similarly, the innovation stage can be expanded into the commercialisation and market accumulation phases[308]. The commercialisation phase consists of adoption of the low-carbon energy technology by established firms or establishment of new ventures based on the technology. The use of the low-carbon technology expands in niches or protected markets during the market accumulation phase. Progress along this innovation chain stages results in reduction in costs as well as improvements in the low-carbon energy technology. There are also two driving forces which influence the different stages – technology push and market pull. As is illustrated in fig 20, technology push influences the invention stage of the technical change process and market pull influences the innovation stage that is closer to the market. Investments from business and finance community and the government[309] and policy interventions from government institutions.

[308] Source: Grubb Michael, 2004

[309] Grubb (2004) hasn’t considered the influence of public funding on invention and innovation.

Fig 20: The Innovation Chain[310] [311]



There are three broad approaches to understanding the technological change and innovation which are induced innovation, evolutionary theory and path dependency. These approaches are explained below:

- **Induced innovation** approach emphasises the role and influence of the market pull as a catalyst for technological change. According to this approach market factors such as prices for raw materials, labour, energy, water, land, environmental regulations etc result in innovations and technological change to economise and conform.
- **Evolutionary theory** assumes that firms will carry of incremental improvements in techniques and imitation of practices of other firms and can arise without a profit maximising assumption. However the empirical basis for this approach is relatively weak.
- **Path dependency** assumes that the innovation and uptake of new technology depends on the path of its development including initial market characteristics, institutional and governing factors and consumer expectations.

7.1.2 Learning

The three approaches to technological innovation all emphasise the role of learning as a key part of the innovation process. Technological learning is also a key factor in

[310] Source Grubb, 2004

[311] Stern, 2007, pages 347-376

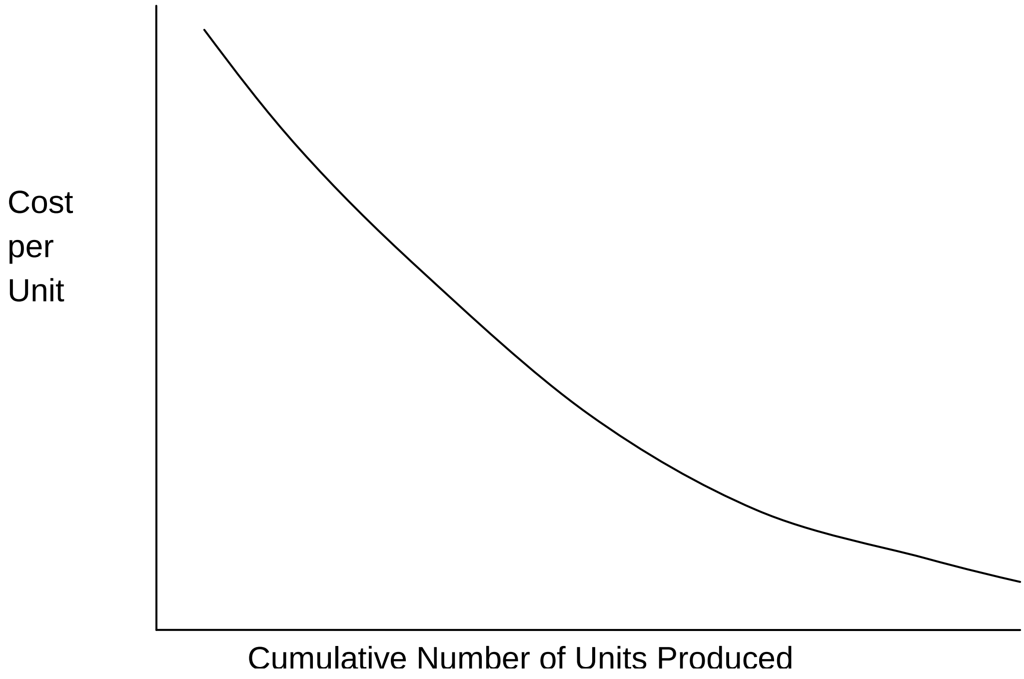
the diffusion of low-carbon energy technologies also as new and emerging technologies are assumed to have better performance and lower costs in future compared to current technologies. Experience and learning increases with increases in market shares of a new technology. Learning or experience curves capture the reduction in unit costs of energy technologies with cumulative increases in production. For technologies in the early stages of development learning rates of 10-20%[312] have been observed. Three main ways through which learning occurs are learning by doing, learning by using and learning by interacting:

- **Learning by doing** approach assumes that the productivity of the firm increases as the cumulative output for the industry grows. The quality of the low-carbon energy products and services improves and achieves cost reductions as more experience is gained.
- **Learning by using** assumes that for certain types of products such as the durable goods with long life and for products that are technologically complex where the performance in operating environments varies from controlled conditions, feedback from users is essential for performance improvements. Therefore gains in knowledge are generated as a result of use of the project.
- **Learning by interacting** argues that lines of communication are needed between the needs of users and capabilities of producers, in order to effect mutually beneficial learning, which in turn aids low-carbon energy product or process innovations. This approach emphasises that low-carbon energy technology innovations through learning are not only driven by price but through interactions involving mutual trust and respect.

Learning or experience curves show that there will be cost reduction of unit costs in low-carbon energy technologies with cumulative production. As the learning through market experience reduces prices for various low-carbon energy technologies, the experience and learning curves can be used by energy policy makers to set design policies to make low-carbon energy technologies commercial. Learning curves provide the quantitative relationship between prices and cumulative production of a technology. The learning curves are useful in determining the support required for low-carbon energy technologies to become competitive. A learning curve is shown in fig 21 for illustrative purposes.

[312] Source: International Energy Agency, 2000

Fig 21: The Learning Curve



The learning cost of the new low-carbon energy technology is the difference between the costs of the new technology and the existing technology. The learning cost needs to be borne by the early adopters in niche markets or through public or private funding.

7.1.3 Classes of Innovation

Four classes of innovation can be observed for low-carbon energy technologies. These are explained below[313]:

- **Incremental Innovations** these innovations occur continuously through learning by doing or learning by using and not as a result of specific research and development.
- **Radical innovations** are small and localised innovations that are a result of research and development or arise out of other firms, often small applying existing practices differently.
- **System Changes** are significant and profound changes that are normally technology innovations combined with organisation and managerial innova-

[313] Source: Rogers, 2003, page 11

tions. These can be clusters of radical and incremental innovations and can affect a number of firms.

- **Technological Revolutions** are changes in the prevailing techno-economic paradigm and the effects extend beyond the low-carbon energy technology and affect the various elements throughout the economic system. Examples of technological revolutions include the steam powered mechanisation of industry and transport which started in Liverpool and Manchester in 1830s and affected the railways, machine tools, alkali, iron and coal industries. Another technological revolution was the information technology revolution started in the late 1960s and early 1970s which affected all industries, information management, telecommunications etc.

Incremental innovations can occur in existing technological regimes but radical innovations are generated in niches. Niches also provide spaces where learning by doing, learning by using and learning by interacting to occur and act as incubators of innovation. Niches can be the first step in innovations which can facilitate sustainable shifts in low carbon energy technology regimes.

7.1.4 Institutions and National Innovation Systems

Institutions which create a framework for low-carbon energy and other technology innovations have a key role in the performance of the innovation systems. The institutions have a role in establishing the framework that governs the interactions between the stakeholders in the innovation system. The ideas about national systems of innovation which encompass the institutional, technological and organisational aspects of innovation evolved in the late 80s and early 90s. The concepts of National Innovation Systems (NIS) were based on the Japanese economy. NISs are defined as a network of public and private sector institutions that initiate, import, modify and diffuse new technologies.

The institutional set-up of NIS vary across countries in terms of systems of university research and training, industrial research, financial institutions, management skills, public infrastructure, national economic and trade policies. The NIS approach is popular in Scandinavian countries and Western Europe and emerged as a response to the threat posed to the developed world by Japan’s industrial innovation system. OECD is also using the NIS concept as part of the technology innovation perspective for developed countries. The NIS concept is relevant in the context of rapidly changing market conditions where the technological innovations happen at a rapid rate. In an environment characterised by rapid changes in market conditions and technology innovations no individual stakeholder can deliver the needed innovations and hence the justification of nationally coordinated innovation and knowledge production networks as NIS. The concept of NIS is relevant in the context of demands on the energy industry placed by climate change concerns and the need to move to low-carbon pathways.

7.1.5 Knowledge Spillovers and Property Rights

Once a new knowledge has been created it can be passed on a no or low cost to other stakeholders. Such knowledge externalities or ‘Spillovers’ significantly reduce the economic benefit that innovators are able to gain and can limit the investments in low-carbon technology innovation. The spillovers can be cross-border for technologies that have a global market such as low-carbon energy technologies. The spillovers also offer an incentive for stakeholders to free-ride on innovators and early adopters who incur the learning costs. From a climate change and low-carbon energy transition perspective the cross-border spillovers might be a positive factor in accelerating the transition, but this practice is likely to result in limited innovation by individual firms.

There are two policy approaches to spillovers. The first is the public funding of technological innovation, particularly the stages of basic R&D and applied R&D. The basic principle of public funding of R&D has generally been accepted globally and can take forms such as investments in the higher education system, funding of research in universities and academic institutions and also offering financial and fiscal incentives to firms for research and development. The second is through the economic instruments to protect private property rights through patents and other forms of protection for the innovator. International patent arrangements such as the Trade Related Intellectual Property Rights (TRIPS) [314] also protect against cross-border spillovers. Patents and copyrights are useful for individual products and also industries such as pharmaceuticals which require large investments and long lead times and can be reverse engineered easily. Patents and copyrights also slow the process of innovation by preventing competing firms by building on each others technological progress. Patenting, copyrights and intellectual property protection may be counterproductive if it acts as barriers to potential competitors and can lead to excessive prices and can slow down technological innovation compared to conditions under which knowledge can be freely exchanged. The threat of dangerous climate change and the need to transition to a low-carbon pathway calls for encouraging the public funding for low-carbon technology related research and for encouraging spillovers across firms and borders.

7.1.6 Technology Leapfrogging

Technology leapfrogging is a concept which has gained currency in the context of climate change and low carbon energy transition. Technology leapfrogging is appli-

[314] An international treaty administered by the World Trade Organisation (WTO) applicable to all WTO member countries.

cable to technology diffusion stage and describes diffusion and implementation of a new and up-to-date technology in the technology sector in which at least one previous version or type of the technology has not been deployed[315]. The technology leapfrogging cannot be limited to the product or the physical infrastructure and also includes the human and institutional capacity and the organisational framework. An example of leapfrogging is the diffusion of mobile phones in developing countries in African continent. Several developing countries in Africa which did not have a fixed telephone service infrastructure covering its land area and majority of population centres were able to have rapid diffusion of mobile phones by skipping the fixed land telephone connections. According to some estimates the African continent had growth rates of over 60% in mobile phone subscriptions between 1999 and 2004, the highest in the world.

Technology Leapfrogging is a relevant issue in the discussions on low carbon energy transition, as several developing countries that are industrialising can diffuse the state-of-the-art modern technologies in the primary, industrial and tertiary sectors and leapfrog over one or more versions of technologies that developed countries currently use or have used. This is relevant in the efforts to mitigate climate change and transition to a low carbon energy system as developing countries can skip the versions of technologies that are highly carbon intensive. Examples include developing countries developing an energy system that is distributed and based on renewable energy, use of clean coal technologies such as IGCC and CCS and deployment of smart grid technologies while developing a grid network.

7.2 Measurement of Technology Innovation

Measuring technology innovation is difficult as it does not have a defined physical presence or a price definition. Therefore efforts to measure energy innovation have adopted indirect methods. There have been a number of approaches to measure technological innovation and technical capability at the country level as an input to public policies on technology promotion and innovation. Businesses are also using these measurements and rankings to drive business decisions and processes.

7.2.1 Factors considered

The different approaches consider factors that influence innovation and diffusion of technologies. Some of the factors and indicators that are considered as part of methodologies to measure technical innovation or technological capability include[316]:

- **Patents** are considered to be a solid indicator of national innovative capacity and the data on patents is available relatively easily compared on data on

[315] Source: Sauter and Watson, 2008

[316] Source: Archibugi and Coco,2003, pp 629-654.

R&D. However the quality of patents and the procedures for patenting vary significantly across countries. There is a tendency to rely on the patents granted by the UN Patent Trademark Office (USPTO).

- **R&D expenditures** are another indicator of technology innovation as it is measured in monetary values and therefore can be compared across countries. However this indicator is available only for a small number of countries and is not available for a large number of developing countries.
- **Scientific Publications** are an output indicator which is associated with the public R&D expenditure input. The limitation is similar to patents in that the quality and the Sectoral distribution of publications vary across countries. Also since the vast majority of the journals monitored by the Institute for Scientific Information are in English, English speaking countries have an advantage.
- **Royalties and Licence Fees** are an indicator for creation and acquisition of technology. However the royalties and licence fee payments can be biased by the financial transactions between different branches, subsidiaries of companies which do not always represent royalties and licence fees;
- **Infrastructure indicators** are also used in certain methodologies to rate technology innovation and diffusion and indicators such as number of research institutions in each country, electricity consumption, internet, telephone lines etc. have been used.
- **Trade indicators** such as exports of non-primary exports or medium and high-technology exports, manufactured exports per capita. However the limitation of the trade related indicators is that it does not take into account the size of the economy and smaller economies tend to be more open to trade than larger ones.
- **Human resources** are another set of indicators as the human capital is one of the most important drivers of technological innovation. Human resource indicators that are commonly used are the tertiary enrolment, number of scientists and engineers, literacy rate etc.
- **Economic indicators** are used by some methodologies to indicate competitiveness and indicators such as the performance of the manufacturing industry, level of national public institutions etc.

7.2.2 Methodological Approaches

There have been a number of approaches to measure technological capabilities at the country level. Eight of these indices have been considered during the research and are elaborated below.

7.2.2.1 Technology Achievement Index[317]

The Technology Achievement Index (TAI) was published by the UNDP in the 2001 Human Development Report. The TAI is an eight-factor measure of technological innovation. The objective of the index is to capture technological achievements of a country in four dimensions:

- **Creating new technology** which is measured by the number of patents granted to residents per capita and by receipts of royalties and licence fees from abroad per capita;
- **Diffusing new innovations** which is measured by the number of internet hosts per capita and the share of high-technology and medium-technology exports in total goods exports
- **Diffusing existing technologies** which is measured by telephones (landlines and mobile phones) per capita and electricity consumption per capita
- **Human skills** measured by the mean years of schooling in the population aged 15 and older and the gross tertiary science enrolment ratio.

The UNDP has grouped countries into four groups based on the TAI as leaders, who have a TAI of more than 0.5, potential leaders who have a TAI of 0.35 to 0.49, dynamic adopters who have a TAI between 0.2 to 0.34 and finally the marginalised countries who have a TAI of less than 0.2. The information content, validity and results of the TAI and the Human Development Index (HDI) were quite similar and the added value of TAI was questioned[318]. It appears that UNDP has since discontinued the assessment of TAI.

7.2.2.2 Global Innovation Index[319]

The Global Innovation Index (GII) was developed by INSEAD and it measures a particular countries ability to adopt and benefit from leading technologies. The GII considers both outputs and inputs and looks at a large number of quantitative and qualitative variables grouped under eight classes as shown in table 21[320].

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[317] cf Desai, Fukuda-Parr, Johansson and Sagasti, 2002, pp 95-122.

[318] cf. Arcelus, Sharma, and Srinivasan, 2005, pp1-5

[319] Not to be confused with the WilderHill New Energy Global Innovation Index (NEX) which is an index consisting of share market performance on 86 listed low-carbon energy companies. For more information go to www.newenergyfinance.com

[320] cf. Dutta and Caulkin, 2007.

Table 21: Components of the Global Innovation Index[321]

Class of indicator (Pillars)	Type	Indicators
Institutions and Policies	Inputs	Independence of judiciary, demanding regulatory standards, prevalence of laws relating to ICT, Quality of IPR, Soundness of Banks, Quality of scientific research institutions, quality of management/business schools, legal obstacles to foreign labour, time required to start a business, time required to obtain licenses, rigidity of employment index, investor protection index, ICT priority for government
Human Capacity	Input	Brain Drain, quality of human resource approach, quality of mathematics and science education, graduates in engineering, graduates in science, Population 15-64, urban population, schools connected to the internet
General and ICT Infrastructure	Input	Quality of general infrastructure, quality of national transport network, quality of air transport, fixed telephone line penetration, mobile phone penetration, internet penetration, international bandwidth, ICT expenditure, personal computer penetration, mobile price basket
Business, markets and Capital Flows	Input	Access to loans, Sophistication of financial markets, issuing shares in local share market, Corporate Governance, Buyer Sophistication, Customer Orientation of Firms, Domestic Credit to Private Sector, FDI net inflows, Gross private capital flows, Gross capital formation, Extent of clusters, Commercial service imports, private investment in ICT, informal economy estimate
Technology and Process Sophistication	Input	Country’s level of technology, E-participation index, E-government index, Government procurement of advanced technology, internet use by businesses, competition among ISP providers, company technology absorption, secure internet servers per 1,000 people, spending on R&D, royalty and license fee

[321] Source: Dutta and Caulkin, 2007.

Class of indicator (Pillars)	Type	Indicators
		payments Business/University R&D collaboration
Knowledge	Output	Local specialized research and training, nature of competitive advantage, quality of production process technology, high-tech exports, manufactured exports, ICT exports, insurance and financial services, patents registered (domestic and non-domestic), royalty and license fee receipts
Competitiveness	Output	Growth of exports, intensity of local competition, reach of exporting in international markets, commercial services export, merchandise exports, goods exported, service exports, listed domestic companies
Wealth	Output	Final consumption expenditure, GDP per capita PPP, GDP growth rate, Industry value added, manufacturer value added, services value added, international migration stock, value of stocks traded, FDI net outflows.

The GII uses a number of objective data available from public and private sources as well as qualitative data available from the World Economic Forum’s annual Executive Opinion Survey. The GII presents a complex multi-criteria index which considers 83 factors which is a significant number. GII also has limitations in that a significant number of factors are subjective and based on an annual executive survey and also a large number of factors – 18 are directly related to the ICT technology and industry.

7.2.2.3 Knowledge Economy Index (KEI)

The World Bank Institute has developed the knowledge assessment methodology which relies on twelve indicators that have been grouped into four classes. These indicators are shown in table 22.

Table 22: Components of the Knowledge Economy Index[322]

Class of indicator (Pillars)	Type	Indicators
Economic and Institutional Regime	Input	Tariff and non-tariff barriers Regulatory Quality

[322] Source: World Bank Institute, 2008.

Class of indicator (Pillars)	Type	Indicators
		Rule of Law
Education and skill of population	Input	Adult literacy rate Gross secondary enrollment rate Gross tertiary enrollment rate
Information Infrastructure	Input	Telephones per 1000 people Computers per 1000 people Internet users per 1000 people
Innovation System	Output	Royalty payments and receipts Technical journal articles per million people Patents granted to nationals by the USPTO per million people

The KEI measures a country ability to generate, adopt and diffuse knowledge and considers the economic and institutional regime, education and skills, ICT infrastructure and the innovation system. World Bank uses the index to track the relative performance of the countries in two points of time to see the relative effect on development investments.

7.2.2.4 UNCTAD Innovation Capability Index

The UN Commission on Trade and Development (UNCTAD) in its World Investment report 2005 introduced the UNCTAD Innovation Capability Index (UNICI). The UNICI consists of two sub-indices the Technological Activity Index (TAI) and the Human Capital Index (HCI). The components of the UNICI are shown in table 23.

Table 23: Components of the UNCTAD Innovation Capability Index[323]

Class of indicator (Pillars)	Weight	Indicators
Technological Activity Index	Equal	R&D personnel per million population US patents granted per million population Scientific publications per million population
Human Capital Index	1	Literacy rate as % of population
	2	Secondary school enrolment as % age group
	3	Tertiary enrolment as % of age group

[323] Source: United Nations Conference on Trade and Development, 2005

Class of indicator (Pillars)	Weight	Indicators
UNCTAD Innovation Capability Index	Equal	Technological Activity Index Human Capital Index

The UNICI divides the countries into three groups high, medium and low on the basis of their innovation capabilities. The UNICI is based entirely on quantitative variables and applies weights for the human capital index depending upon the level of education with the logic that higher levels of education are considered more important for technical and managerial innovation.

7.2.2.5 Competitive Industrial Performance Index

UNIDO's Competitive Industrial Performance (CIP) Index captures the ability of countries to manufacture and export competitively. The CIP was established in 2002 and has been published by UNIDO on an annual basis thereafter. CIP index uses four main dimensions of industrial competitiveness which are shown in table 24.

Table 24: Components of the Competitive Industrial Performance Index[324]

Indicator	Description
Industrial Capacity	Manufacturing value added per capita
Manufactured Export Capacity	Manufactured Exports per capita
Industrialisation Intensity	Measured as the average of two indicators: The share of manufacturing in GDP and The share of medium and high technology activities in the Manufacturing Value Added
Export quality	Measured as the average of two indicators: The share of manufactured exports in total exports and The share of medium and high technology exports in total exports

The emphasis by UNIDO is on manufactured goods and their exports and does not consider the innovation system, human resource etc. which are a key determinant of the outputs of industrialisation and manufacturing.

[324] Source: United Nations Industrial Development Organisation, 2009.

7.2.2.6 ARCO Technological Index

The ArCo technological index was developed by Daniele Archibugi and Alberto Coco in 2004 as an alternative to the TAI and the CPI. The three classes of technological capabilities considered by the ArCo index are the creation of technology, the technological infrastructures and the development of human skills. The components of the ArCo index are shown in table 25.

Table 25: Components of the ArCo Technological Index[325]

Class of indicators	Indicators
Creation of Technology	Patents at USPTO Scientific articles
Technological Infrastructure	Internet Penetration Telephone penetration Electricity Consumption
Development of human skills	Tertiary science and engineering enrollment Mean years of schooling Literacy rate

The ArCo technology index identifies four groups of countries as leaders (ranks 1 to 25), potential leaders (ranks 26 to 50) latecomers (ranks 51 to 111) and marginalised (ranks 112 to 162). The ArCo index tries to address the limitations of some of the previous efforts at ranking technological capabilities of countries.

7.2.2.7 WEF National Innovative Capacity Index

The national innovative capacity index measures a country’s capacity to produce a stream of commercially relevant innovations. The national innovative capacity is composed of four broad elements of context for firm strategy and rivalry, factor (input) conditions, demand conditions, related and supporting industries that shares the ability of a company to innovate for the global market. The components of the National Innovative Capacity Index are shown in table 26.

[325] Source: Archibugi and Coco,2003, pp 629-654.

Table 26: Components of the National Innovative Capacity Index[326]

Sub indices	Indicators
Science and engineering manpower sub-index	Share of total employment accounted for by scientist and engineering employment.
Innovation Policy sub-index	Effectiveness of intellectual property protection Size and availability of R&D tax credits and subsidies for the private sector Costs of tariff restrictions
Cluster innovation environment sub-index	Sophistication of domestic customers Extent of locally based competition Extent of product and process collaboration
Innovation linkages sub-index	Local availability of specialized research and training institutions Availability of venture capital for innovative but risky projects
Company operations and strategy sub-index	Degree to which competitive advantage depends on introducing unique goods and services Extent and sophistication of marketing Degree to which pay is linked to productivity

The national innovative capacity index presents a private sector and a corporate perspective on the national innovation capacities and answers the question on which country offers the better conditions for technology investments. The index costs of several factors that are subjective and collected through a survey.

7.2.2.8 Science and Technology Capacity Index

The Science and Technology Capacity Index was developed by Wagner et al (2003) for the RAND Corporation for a set of 76 countries for the year 2002. The Science and Technology Capacity Index measures the extent to which a country can absorb and use scientific and technical knowledge. The components of the Science and Technology Capacity Index are shown in table 27.

[326] Source: Porter and Stern, 2003.

Table 27: Components of the Science and Technology Capacity Index[327]

Class of indicators	Indicators
Enabling Factors	Per Capita GDP Tertiary science enrolment
Resources	Number of scientists and engineers in R&D per million Number of research institutions per million inhabitants R&D expenditure by public and private sector as a percentage of Gross Domestic Product
Embedded Knowledge	Patents and science and technology journal articles per million inhabitants Comparative share of each country's internationally co-authored papers

The index measures the Science and Technology Capacity index for 76 countries and classifies them into four groups as advanced countries (with a score of over 1), proficient countries (with scores between 0.0 and 1.0), developing countries (with scores between 0.0 and -1) and lagging countries (scores of less than -1)

7.2.3 Observations on measurement of Innovation

The following observations can be made from a research on the current approaches to measurement of technological innovation and technical change:

- **Country level:** All the approaches currently try to rate technical change or technology innovation at the country level. It is however not clear whether this should be the level at which innovation should be measured. The choice of country at the level at which innovation or technical change is measured seems driven by the fact that many of the organisations who have developed the institutions are development agencies and work at the country level in their development assistance efforts. The easy availability of data at the country level is also one of the considerations for settling at this level. Measuring innovation at the level of the firm is considered to be more appropriate than at the country level;
- **Military and defence research** budgets in countries often distort the indicators such as R&D budgets, patents and scientific publications. This is because

[327] Source: Wagner, Horlings and Dutta, 2003.

defence expenditure is related to national security issues and not related to scientific and technological capability. Countries with large military research budgets may denote technological change also more considered to be a solid indicator of national innovative capacity and the data on patents is available relatively easily compared on data on R&D. However the quality of patents and the procedures for patenting vary significantly across countries. There is a tendency to rely on the patents granted by the US Patent Trademark Office (USPTO).

7.2.4 Other relevant measurement approaches

In this subsection some measurement approaches that are relevant to the development of low-carbon energy technologies in developing countries are examined. These indicators are more relevant to sustainable development and environmental protection than to energy or technology innovation.

7.2.4.1 Sustainable Society Index

The Sustainable Society Index (SSI) has been developed by the Sustainable Society Foundation based on the Brundtland commissions definition on sustainability and has been published since 2006. The SSI measures the level of sustainability of a country by integrating aspects about sustainability and quality of life and uses 22 indicators grouped into five classes. The components of the Sustainable Society Index are shown in table 28.

Table 28: Components of the Sustainable Society Index[328]

Class of indicators	**Indicators**
Personal Development	Healthy Life Sufficient food Sufficient to Drink Safe sanitation Education Opportunities Gender Equality
Healthy Environment	Air Quality Surface Water Quality Land Quality
Well-balanced Society	Good governance Employment

[328] Source: Kerk and Arthur, 2009.

Class of indicators	Indicators
	Population Growth Income Distribution Public Debt
Sustainable Use of Resources	Waste Recycling Use of Renewable Water Resources Consumption of Renewable Energy
Sustainable World	Forest Area Preservation of Biodiversity Emission of GHGes Ecological Footprint International Cooperation

The SSI has been published since 2006 and is being calculated for 151 countries in 2008. The countries are rated from 1 to 151 based on their SSI scores. It is understood that SSI is being used in Albania as an instrument for public policy (Kerk, 2009).

7.2.4.2 Environmental Performance Index (EPI)

The Environmental Performance Index (EPI) was developed by the Colombia University and Yale University, USA in collaboration with the World Economic Forum, Switzerland and the EU-Joint Research Centre, Italy. The EPI focuses on environmental stresses to human health and promoting ecosystem vitality and sound natural resource management. The components of the EPI are shown in table 29.

Table 29: Components of the Environmental Performance Index[329]

Class of indicators	Indicators
Environmental Health	Environmental Burden of Disease Adequate sanitation Drinking Water Indoor Air Pollution Urban particulates Local Ozone

[329] Source: Esty, et al, 2008.

Class of indicators	**Indicators**
Air Pollution	Regional Ozone Sulfer Dioxide Emissions
Water	Water Quality Index Water Stress
Biodiversity & Habitat	Conservation Risk Index Effective Conservation Critical Habitat Protection Marine Protected areas
Productive Natural Resources	Forestry Growing Stock Marine Tropic Index Trawling Intensity Irrigation Stress Agricultural subsidies Intensive cropland Burnt Land Area Pesticide Regulation
Climate Change	Emissions per capita Emissions per unit of electricity Industrial carbon intensity

The EPI has been published since 2006 and covers 149 countries and is intended to provide an empirical basis for comparing environmental performance of the countries analysed. The EPI is intended to provide comparison about environmental policies and to highlight the leaders and the laggards and also to highlight the best practices.

8 A new approach to measuring Low-Carbon Energy Innovation

8.1 Limitations with existing approaches

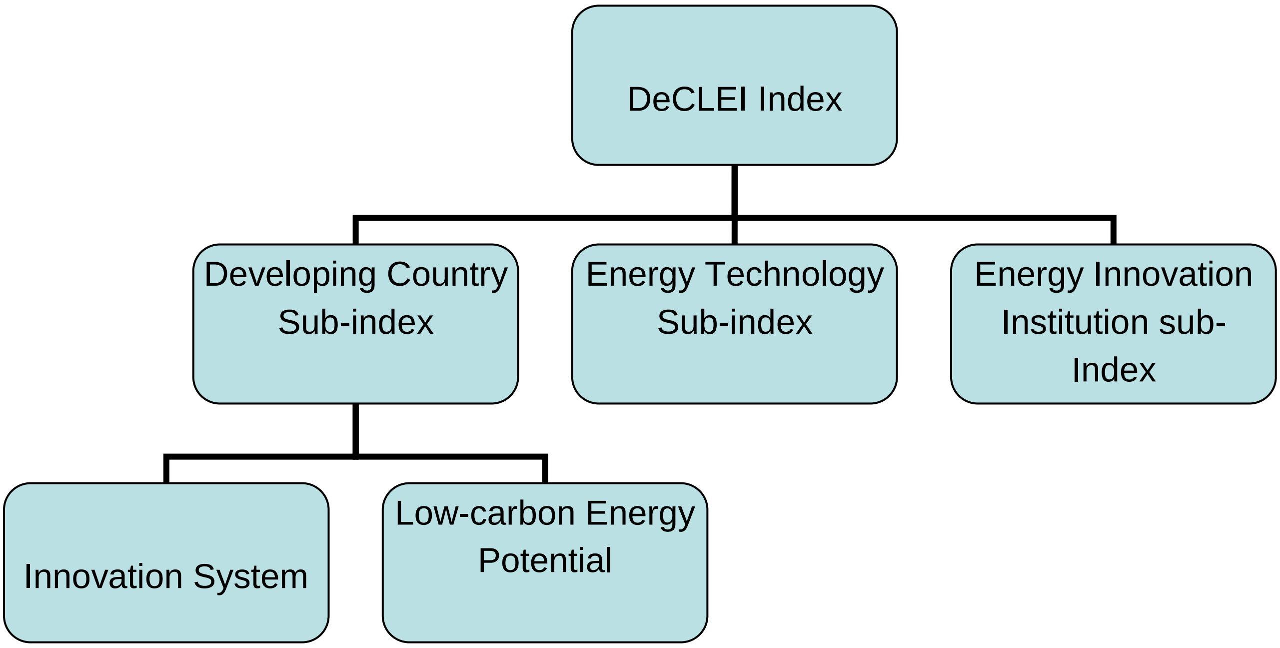
The existing approaches to measuring technology innovation and low-carbon technology innovation evaluate the environment at the country level. These indicators are useful in national and global public policy involving energy issues and to see how countries with comparable socio-economic characteristics perform with respect to technology innovation and diffusion. The indices and measurement approaches are also helpful in assessing the progress between two points in time of a country in response to public policy interventions. However for assessing low carbon energy innovation in developing countries and to optimise resource allocations for energy technology innovation, it is important to go beyond the national innovation capacity and consider the institutional capacity and the technology involved. This approach overcomes the following shortcomings of the current approaches to measure low-carbon energy innovation:

- Most measurement approaches consider all types of technologies similar and environments required for technology innovation are considered the same. The exceptions has been the TAI, GII and the KEI which focuses on information and communication technologies;
- The role of institutions is important in technology innovation and the characteristics of the institution which carries out the energy research and innovation is not adequately captured by the indices and measurement approaches;
- Most of the indices also do not capture the potential for application of the technology innovation in a country in the index. From the perspective of low-carbon energy technologies, the carbon intensities of the economy and the energy system needs to be considered.
- Most of the indices and measurement approaches can be applied to all the countries – developing and developed countries. Such an universal approach often results in selection of indicators for which data is widely available in developed countries and where significant data gaps exist in developing countries.

8.2 Structure of DeCLEI Index

The Developing Country Low-Carbon Energy Innovation Index (DeCLEI) consists of three major components – the Developing Country Sub-index, the Energy Technology sub-index and the Energy Innovation Institution sub-index, which is illustrated in fig 22 below.

Fig 22: The DeCLEI Index

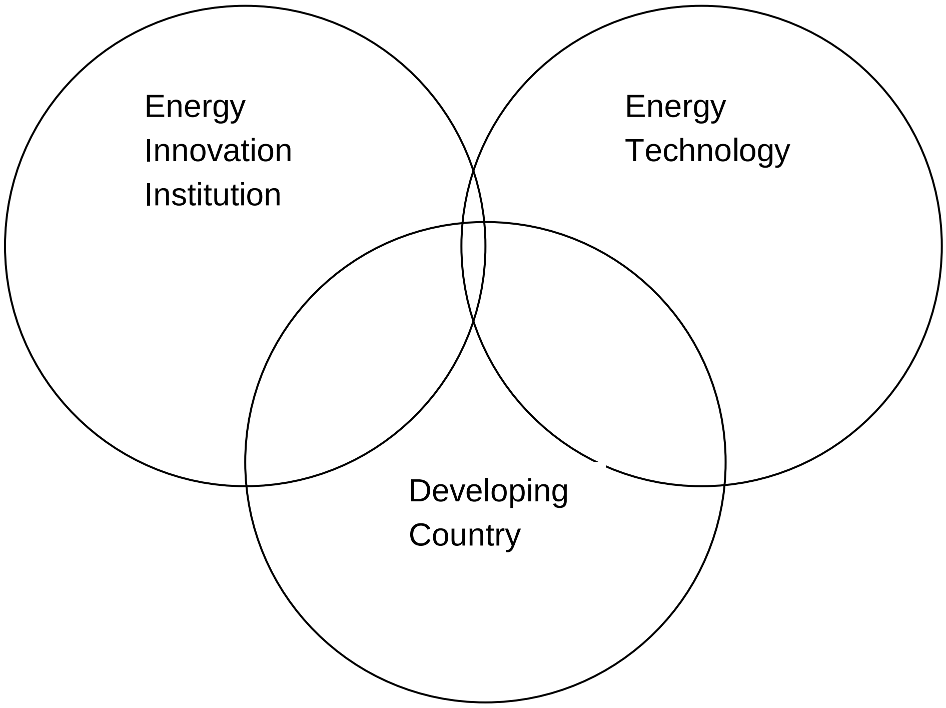


The DeCLEI index looks at the three key pillars of the energy innovation in developing counties:

- **Developing country:** At the country level DeCLEI looks at the low-carbon energy innovation potential and the national innovation system;
- **Energy Technology:** At the technology level DeCLEI looks at the GHG mitigation potential of the technology;
- **Energy Innovation Institution:** At the institution level DeCLEI looks at the institutional capability and track-record in energy innovation.

The DeCLEI framework is conceptualised in fig 23 below showing the three pillars and the nine indicators that are used to measure low-carbon energy technology innovation in developing countries.

Fig 23: The DeCLEI Framework



8.3 Components of DeCLEI

The components of the DeCLEI Index are shown in table 30.

Table 30: Components of the Developing Country Low Carbon Energy Innovation Index (DeCLEI)

Class of indicators	**Indicators**
Innovation system in a developing country	Royalty payments and receipts per million people (a1) Technical journal articles per million people (a2) Patents granted to nationals by USPTO per million people (a3)
Low-Carbon Energy Potential in a developing country	Energy emissions factor (b1) Emissions per capita (b2)
Energy Technology	Low-carbon mitigation factor (c)
Energy Innovation Institution	Management and expertise (d1) Technical journal articles per researcher (d2) Level of funding/financial turnover per researcher (d2)

8.3.1 Indicators

The DeCLEI consists of nine indicators and each of these indicators is explained below:

- **(a1) Royalty Payments and Receipts (US$ Millions/ million population)**: The royalty payments and receipts provide a good and reliable indicator of creation as well as acquisition of technology in an economy. These payments and receipts between residents in a developing country and non-residents for the use of intangible, non-produced, non-financial assets and property rights such as patents, copyrights, trademarks, industrial processes and franchises and for use through licensing agreements of produced originals or prototypes (World Bank, 2008). The data for payments and receipts of royalties and licence fee are available from balance of payments statistics. Both the payments and receipts in US$ millions is added together and divided by million population.
- **(a2) Technical Journal Articles (no/million population)**: This output indicator considers the scientific and engineering articles published in the technical fields of physics, chemistry, mathematics, clinical medicine, biomedical research, engineering and technology and earth and space sciences. This indicator is closely associated with public R&D expenditure inputs and is a reliable indicator. The number of articles published in a year in these technical fields is totalled up and are divided by million population.
- **(a3) Patents Granted by USPTO (no/million population):** The number of patents give a good indicator of national innovative capacity. This output indicator considers the patent documents granted to nationals of a developing country by US patents and trademark office. This indicator considers utility patents, design patents, plant patents, reissue patents, defensive publications and statutory invention registrations. The number of patent documents in a year is divided by million population.
- **(b1) Energy Emissions Factor (tCO_2e/kWh):** This indicator reflects the GHG intensity of the energy sector in the country. The Energy emissions factor shows the tonnes of CO_2 equivalent of GHG emissions per unit of electricity and heat output. Countries that have a high GHG intensity for their energy supplies will score higher for this indicator and those countries which have low GHG intensities for their energy supply will score lowly against this indicator. This indicator gives an impression of the potential to decarbonise the energy sector in a country using low-carbon energy technologies. The information for this indicator is available from the UNFCCC national communications and IEA statistics.

- **(b2) Emissions per Capita (tCO_2e/person):** This indicator is calculated as sum of the emissions of GHG gases and emissions and emission reductions attributable to Land Use, Land Use Change and Forestry (LULUCF). A country which achieves low emissions per capita will have relatively low contributions to climate change per person and the countries with higher emissions per capita will be contributing more per capita to global climate change. Countries which have high emissions per capita will score high against this indicator and countries with low emissions per capita will score low. The indicator gives information about the industrialisation level and the GHG intensity of the economy and also the potential for application of low-carbon energy technologies. The information for this indicator is available from UNFCCC national communications and IEA statistics for GHG inventories and the population data is available from IMF’s World Economic Outlook.
- **(c) Low Carbon Energy Technology Index:** This indicator is specific to the low-carbon energy technology which is considered as part of the initiative. The mitigation factor represents a dimensionless number which represents the GHG mitigation potential of the technology over the baseline technology. A high mitigation factor indicates a very low carbon or zero carbon technology and a low mitigation factor indicates a technology with relatively higher carbon pathway. The calculation of the Low Carbon Energy Technology Index is explained further in section 8.3.3.
- **(d1) Management and Expertise**: This indicator looks at the managerial and technical credentials of the energy innovation institutions team leader, managers and team members in the energy innovation institution which will implement the low-carbon energy technology innovation programme. Demonstrated ability of the energy innovation institution to produce innovations consistently in changing environments will be a key determinant. The metrics for this indicator is explained further in section 8.3.2.
- **(d2) Technical Journal Articles (no/researcher/year)** This output indicator considers the scientific and engineering articles published in the low-carbon energy and related fields by the researchers from the energy innovation institution. This is weighted by the number of researchers to account for variations in the size of the energy innovation organisation.
- **(d3) Level of funding ($/researcher/year).** This output indicator considers the average funding available to the energy innovation institution to carry out its research for the past 5 years. Where innovation institutions are active in technologies other than energy, only funding and turnover relating to energy and directly related innovation work should be considered. This is divided by the number of researchers to account for variations in the size of the size of the energy innovation organisation.

DeCLEI uses a normalization process that most indices use so that indicators and variables that are measured in different units and scales are comparable. This process is done for eight of the nine indicators – except for Management and expertise (d1). The other eight indicators are normalized using the following approach:

Normalised (x) = 100* (1-Nh/Np)

Where:

x = Actual data;

Nh = Number of entities[330] with a higher value;

Np = Number of entities in the population

8.3.2 Management and Expertise

The management and expertise criteria should be applied to measure the innovation team and the management systems in the Energy Innovation Institution and should be scored on a scale of 1 to 100. Some of the important considerations to be given to gauge expertise of the team include the past track-record of the innovation team manager in managing teams of researchers and innovators, the qualifications and experience of the innovation team members and work culture in the institution. Some of the considerations to be given to gauge management include the management systems and procedures that encourage innovation and performance, allow independence with accountability and a merit based rewards and promotion system. It is suggested that expertise of the innovation team be scored on a scale of 1 to 70 and the management systems be scored on a scale of 1 to 30. Both these scores should be added together to arrive at the total scores for management and expertise.

8.3.3 Energy Technology

Measuring the Low-carbon Energy Technology Index is done by conservatively considering the GHG mitigation potential of each of the low carbon energy technologies that have been considered. The approach is to identify a baseline scenario[331] and arrive at a mitigation factor for the low-carbon energy technology. The mitigation factor would be similar to the emission factors which are used to quantify the emission reduction potential of a project intervention. IPCC emission factors[332] have been used to arrive at the Low-Carbon Energy Technology Index. The approach has been to identify an appropriate baseline in a conservative manner, estimate the emission

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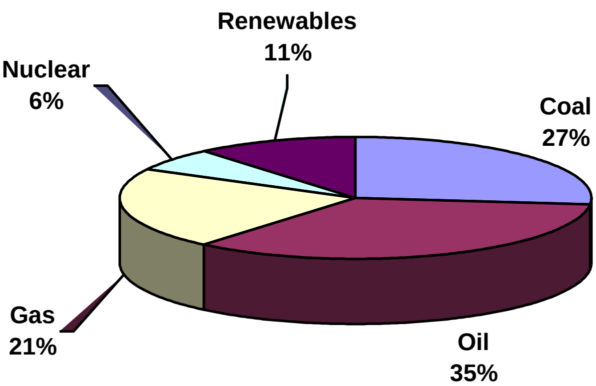
330 Developing Countries or Energy Innovation Institutions

331 A hypothetical construct of a scenario which would have happened in the absence of the low-carbon energy technology application.

332 IPCC 2006, 2006 IPCC Guidelines for National Greenhouse Gas Inventories and IPCC Emission Factor Database - http://www.ipcc-nggip.iges.or.jp/EFDB/main.php accessed in November 2009.

reduction potential and normalize that into the index. For zero emissions technologies such as renewable energy, nuclear energy and energy efficiency, a baseline which is similar to the fuel mix of the world primary energy supply as of 2007 is considered. The assumption for this being that the new zero energy supply will be reducing emissions which are similar to the GHG intensity of the current energy mix. This approach is called the “Operating Margin” approach. This is shown in fig 24.

Fig 24: Baseline Assumption for Zero Emission Technologies



A similar approach is taken for smart-grid technologies as these technologies improve the utilization and distribution of energy from existing electrical systems. For advanced clean-coal technology[333] and for carbon capture and storage the baseline is taken as 100% coal based generation. The assumption being that the low-carbon energy technologies will be directly replacing or be retrofitted[334] to existing coal power plants.

Technology emission factors for Renewable Energy, Advanced Nuclear Energy and Energy Efficiency are taken as zero. While there are upstream and downstream emissions associated with nuclear energy and upstream emissions associated with renewable energy, these are not considered in a similar manner as upstream emissions for coal are not considered. The average efficiency of coal fired power plants is currently 28%[335] and the efficiency of Ultra-supercritical and IGCC power plants are in the range of 40-45%. A 1% point improvement in the efficiency of pulverized coal

[333] Ultrasupercritical coal technology

[334] In the case of Carbon Capture and Storage

[335] Source: World Coal Institute, 2009, http://www.worldcoal.org/coal-the-environment/coal-use-the-environment/improving-efficiencies/, accessed November 2009;

power plants results in a 2-3% reduction in CO_2 emissions[336]. Therefore assuming a conservative value of 40% efficiency for Advanced Clean Coal and 2% reduction in CO_2 emissions per 1% increase in efficiency, there would be a 24% reduction in CO_2 emissions. This would result in a technology emissions factor of 71.9 tCO_2e/TJ.

For CCS there are several possibilities for emission reductions of CO_2. The typical capture efficiencies for CO_2 capture for post-combustion capture systems and pre-combustion capture systems range from 85% to 96% percentage. There are also fugitive emissions from the systems that are used to transport CO_2 from the captured site to the injection site. The emissions would be a function of the transportation mode (pipelines, ships etc.) and the distance of transportation. There will also be fugitive emissions from the injection systems and also from the end-containment[337]. While there are emission factors available for transportation systems, the distance of transportation will depend on the location of application of CCS and the distance between the site of capture and location of storage. So an assumption of 5% fugitive emissions from transportation is made. As for the fugitive emissions from injection and storage, IPCC does provide methodological approaches to estimate the same; however the body of work on this issue is evolving. Therefore an assumption of 5% fugitive emissions from injection and storage is also taken. Considering a conservative value of 85% collection efficiency and applying 5% fugitive emissions in transportation and injection and storage 76.7% of emissions can be reduced. This will correspond to a technology emissions factor of 22.7 tCO_2e/TJ.

Smart grid technologies – both hardware and software has substantial potential to reduce electricity sector emissions. It is estimated that smart grids can reduce 15% of energy sector emissions by 2020[338]. Since smart grids consists of a large number of technologies and measures and the application patterns may vary from one location to another, a structured methodological approach to determining the technology emission factor is complex. Therefore it is assumed that it is possible to reduce 15% emissions in the energy system using smart grid technologies. Based on this assumption, the technology emissions factor for smart grids is determined as 48.67 tCO_2e/TJ.

The Low-Carbon Energy Technology Emission factors are calculated by determining the emission reductions per unit of energy – Terra joules or Kilo watt-hour and then normalizing using the procedure described above. The low carbon-energy technology indices calculated in this manner are shown in table 31.

336 Source: World Coal Institute, 2009, http://www.worldcoal.org/coal-the-environment/coal-use-the-environment/improving-efficiencies/ accessed November 2009;

337 Source: IPCC, 2006.

338 Source: Climate Group, 2008, pp 45-51

Table 31: Low-Carbon Energy Technology Index[339] [340]

Technology	Baseline	Technology Emissions factor	Baseline Emission factor	LCET index
Renewable Energy	26% Coal, 34% Oil,21% Gas, 6% Nuclear and 11% renewables[341]	0	57.26 tCO_2e/TJ or 15.9 tCO_2e/kWh	83.33
Advanced Nuclear Energy	26% Coal, 34% Oil,21% Gas, 6% Nuclear and 11% renewables	0	57.26 tCO_2e/TJ or 26.28 tCO_2e/kWh	83.33
Advanced Clean Coal	100% Coal	71.9 tCO_2e/TJ	94.6 tCO_2e/TJ	33.33
Carbon Capture and Storage	100% Coal	22.7 tCO_2e/TJ	94.6 tCO_2e/TJ	100
Energy Efficien-cy	26% Coal, 34% Oil,21% Gas, 6% Nuclear and 11% renewables	0	57.26 tCO_2e/TJ or 15.9 tCO_2e/kWh	83.33
Smart Grids	26% Coal, 34% Oil,21% Gas, 6% Nuclear and 11% renewables	48.67 tCO_2e/TJ	57.26 tCO_2e/TJ or 15.9 tCO_2e/kWh	16.66

These rankings indicate that CCS has the highest Low-Carbon Energy Technology index, followed by Energy Efficiency, Renewable Energy and Nuclear Energy. This group of zero emission technologies is followed by Advanced Clean Coal which is followed by Smart Grids. The reason why CCS has the highest LCET index is a direct function of the emissions intensity of a 100% coal baseline.

[339] Source: International Energy Agency, 2009.

[340] Source: IPCC, 2006.

[341] The baseline scenario corresponds to the sources supplying World Primary Energy demand in 2007, reference WEO 2009 from IEA.

9 Application of DeCLEI

The index is structured in a way that it can be applied in three[342] ways as follows:

- **Developing Country Level**: The Low-carbon Energy Innovation sub-index can be applied independently to developing countries to assess and rank them in terms of their capacity and potential to carry out low-carbon energy technology innovation. Such a ranking should be able to explain why some countries are more active in efforts towards low-carbon energy technologies than others.
- **Energy Innovation Institution Level**: The index can also be applied at the institution level where the indicators from energy innovation institution index are applied. This approach can be used to compare energy innovation institutions across countries. Such an approach can be used in identifying key developing country institutions which could be part of international and inter-regional collaborative efforts on energy innovation.
- **Energy Innovation Initiative Level**: The DeCLEI Index can be applied to rank low-carbon technology innovation plans, initiatives or proposals in a specific energy innovation institution in a specific developing country or across a number of developing countries. Such an approach using all the nine indicators will be able to rank initiatives within a developing country or across developing countries which will allow allocation of resources to plans and proposals that show the highest promise on low-carbon energy technology innovation and deployment.

9.1 Application to Developing Countries

The Developing Country sub-index can be applied at the country level. These rankings indicate the potential and the capacity at a country level to carry out low-carbon energy technology innovation. A total of 81 developing countries for which data was available have been evaluated and the results are presented at table 32 below.

[342] DeCLEI can also be applied in other combinations but the three discussed are considered to be the most plausible ways.

Table 32: Developing Country Index

Country	**Low-Carbon Energy Potential**	**Innovation System**	**LCEI Index**
United Arab Emirates	98.77	95.05	**100**
South Africa	87.65	97.53	**98.77**
Qatar	88.89	93.83	**97.53**
Trinidad & Tobago	90.12	90.12	**96.30**
Kuwait	97.53	77.78	**95.06**
Malaysia	79.01	96.30	**95.06**
Oman	96.30	76.54	**92.59**
Bahrain	100	67.90	**91.36**
Guyana	92.59	75.31	**91.36**
China	81.48	83.95	**88.89**
Botswana	95.06	62.96	**87.65**
Saudi Arabia	91.36	60.49	**86.42**
Jamaica	72.84	79.01	**86.42**
Jordan	64.20	86.42	**83.95**
Swaziland	83.95	66.67	**83.95**
Fiji	69.14	80.25	**81.48**
Mexico	60.49	88.89	**81.48**
Thailand	59.26	87.65	**79.01**
Argentina	45.68	100	**77.78**
Lebanon	71.60	71.60	**76.54**
Mauritius	86.42	54.32	**75.31**
Iran	67.90	72.84	**75.31**
Chile	40.74	98.77	**72.84**
Venezuela	49.38	85.19	**71.60**
Indonesia	82.72	46.91	**70.37**
Uruguay	46.91	82.72	**70.37**
India	62.96	65.43	**67.90**

Country	**Low-Carbon Energy Potential**	**Innovation System**	**LCEI Index**
Brasil	37.04	91.36	**67.90**
Mongolia	74.07	48.15	**65.43**
Panama	38.27	81.48	**64.20**
Algeria	65.43	51.85	**62.96**
Bolivia	75.31	41.98	**62.96**
Angola	61.73	53.09	**60.49**
Benin	76.54	37.04	**59.26**
Morocco	58.02	55.56	**59.26**
Mauritania	85.19	27.16	**56.79**
Tunisia	34.57	74.07	**55.56**
Djibouti	93.83	11.11	**54.32**
Costa Rica	9.88	92.59	**53.09**
Zimbabwe	50.62	50.62	**51.85**
Syria	54.32	45.68	**50.62**
Côte d’Ivoire	66.67	29.63	**49.38**
Egypt	27.16	69.14	**49.38**
Colombia	23.46	70.37	**46.91**
Cambodia	70.37	22.22	**45.68**
Sudan	77.78	13.58	**44.44**
Ecuador	29.63	61.73	**44.44**
Sierra Leone	80.25	9.88	**41.98**
Yemen	53.09	34.57	**40.74**
Peru	25.93	59.26	**39.51**
Nicaragua	56.79	23.46	**38.27**
Dominican Republic	39.51	40.74	**38.27**
Philippines	20.99	56.79	**35.80**
Sri Lanka	13.58	64.20	**35.80**
Tanzania	51.85	24.69	**33.33**
Senegal	32.10	38.27	**32.10**

Country	Low-Carbon Energy Potential	Innovation System	LCEI Index
Namibia	24.69	43.21	**30.86**
Honduras	22.22	44.44	**29.63**
Eritrea	44.44	20.99	**28.40**
Kenya	7.41	58.02	**28.40**
Burkina Faso	48.15	12.35	**25.93**
Guatemala	43.21	17.28	**25.93**
Rwanda	55.56	1.23	**23.46**
Viet Nam	19.75	35.80	**22.22**
El Salvador	6.17	49.38	**22.22**
Madagascar	28.40	25.93	**19.75**
Pakistan	14.81	39.51	**19.75**
Cameroon	17.28	33.33	**17.28**
Laos	33.33	16.05	**16.05**
Zambia	30.86	18.52	**16.05**
Guinea	41.98	6.17	**13.58**
Nigeria	16.05	30.86	**12.35**
Nepal	11.11	28.40	**11.11**
Myanmar	35.80	2.47	**9.88**
Uganda	2.47	32.10	**8.64**
Ghana	8.64	19.75	**7.41**
Bangladesh	18.52	8.64	**6.17**
Malawi	12.35	14.81	**6.17**
Mozambique	3.70	9.88	**3.70**
Haiti	4.94	7.41	**2.47**
Ethiopia	1.23	3.70	**1.23**

The United Arab Emirates (UAE) tops the Low-Carbon Energy Innovation index, followed by South Africa, Qatar, Trinidad & Tobago and Kuwait which make up the top 5. It can be seen from the above table that Asian countries and especially countries in the middle-east have high Low-carbon Energy Innovation index scores. There are 7, 11 and 15 countries in the top 10, 20 and 30 respectively from Asia. Asian countries score high on both the Low-carbon energy potential and Innovation system and seem to present the best opportunities for investments in low carbon energy technologies. South Africa is the only African country in the top 10 and there is no country from Latin America in the top 10. An interesting observation is the high low-carbon energy innovation index scores by Caribbean Island nations such as Trinidad and Tobago and Guyana both of which figure in the top 10.

While there are notable exceptions, generally several countries in Africa score low in the Low-carbon Energy Index. Latin American countries have average scores which are higher than African countries. Asian countries have relatively high scores compared to the Latin American and African countries. The average score of Asian countries is 63.85, average for Latin America is 50.54 and that for Africa is 41.02. It can therefore be concluded that Asian countries offer the greatest potential for low carbon energy technology innovation followed by Latin America. Countries in Africa offer the lowest potential amongst the three continents for low-carbon energy technology innovation.

9.2 Application to Energy Innovation Initiatives

The DeCLEI Index can also be applied to evaluate a group of low-carbon technology innovation plans, initiatives or proposals across a number of developing countries and across a number of energy innovation institutions. This approach involving all the nine indicators will be able to rank several initiatives and will allow allocation of resources to plans and proposals that can have the highest level of impacts on low-carbon energy technology innovation.

30 proposals for low-carbon energy innovation involving primarily renewable energy and energy efficiency initiatives and projects that were supported by REEEP were selected for application of the DeCLEI Index.

9.2.1 Renewable Energy and Energy Efficiency Partnership (REEEP)[343]

The REEEP was established in 2002 by the UK government, together with other committed governments, businesses and NGOs, to deliver WSSD commitments. One of the objectives was to take forward the key recommendations of the G8 Renewable Energy Task Force. REEEP was formally launched at a ceremony in London in 2003 and was subsequently established in June 2004 as an association in Austria, founded by the governments of UK and Austria. The interest in REEEP and its activities have grown considerably since 2004. It currently consists of over 300 partners of which 46 are national governments. REEEP supports three sub-networks

[343] cf. Parthan B, et al, 2010, pp 83-93

– Sustainable Energy Regulators Network (SERN) focusing on clean energy regulation, Renewable Energy and International Law (REIL) focusing on international renewable energy laws and the Energy Efficiency Coalition (EEC) focusing on building energy efficiency. REEEP also maintains a search engine and information gateway - Reegle which provides information about renewable energy and energy efficiency. REEEP also supports about 129 projects in 56 countries globally.

REEEP started funding projects in 2004 and has consistently increased the level of its funding over the years. Table 33 provides an overview of the projects supported by REEEP since 2005[344].

Table 33: Growth in REEEP Projects

Year	**Projects supported**	**Funds deployed (€)**	**Countries covered[345]**
2005-06	18	1.12 million	19
2006-07	28	1.94 million	31
2007-08	35	3.15 million	19
2009-10	48	4.6 million	23
	129	**10.83 million**	**56**

As of early 2010, REEEP has supported 129 projects under its programmes targeting low-carbon energy interventions in renewable energy and energy efficiency covering 56 countries. The support to these projects has been facilitated by generous contributions to REEEP by the partner governments of United Kingdom, Norway, Ireland, Australia, Italy and New Zealand. The € 10.8 million of REEEP financial support to projects has also leveraged € 26.7 million through co-financing from the implementing partners and other development and market transformation agencies. Typical REEEP financing to a project is about € 100,000[346] and projects can be supported in four thematic areas of finance, policy, regulation and business.

REEEP employs a bottom-up and broad-based process to develop its programme framework. Every year regional preparatory meetings are organised in regions where REEEP supports projects – East Asia, Latin America, Pacific and Southern Africa[347]. These meetings bring together REEEP partners in the region, including national and regional governments, finance and business organisations, NGOs and other key

[344] A number of projects were supported by the UK Government under a REEEP between 2002 and 2004, before REEEP was established as a legal entity. These projects are not considered.

[345] One project may cover multiple countries

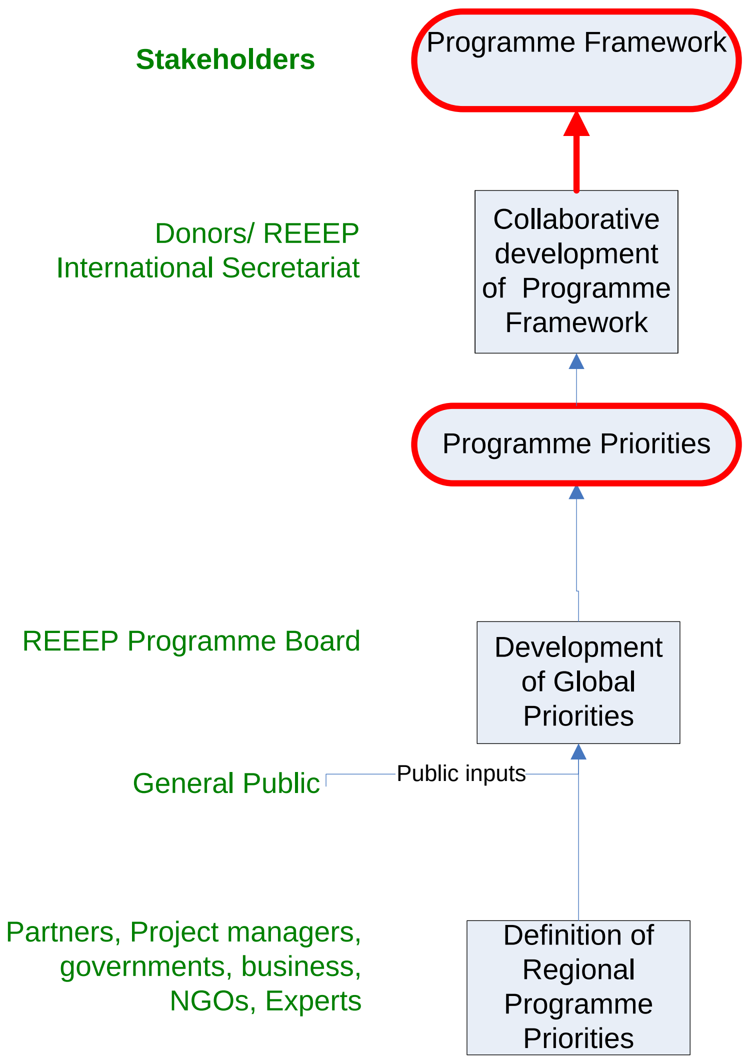
[346] The maximum REEEP contribution till 2007 was € 70,000.

[347] Till 2007, REEEP also used to support projects in Eastern Europe and Russia and the Former Soviet Union.

experts. These experts identify the needs for REEEP interventions in the region, taking into account opportunities within REEEP’s four thematic areas, past work done by REEEP and the resources available for programming. The general public and the partners who are unable to attend the regional stakeholder meetings are also invited to provide inputs towards defining the programme priorities through an open public invitation. The regional priorities are then discussed and refined by the REEEP Programme Board which consists of the regional members, members from NGOs, business and finance and donor governments. The Programme Board develops the REEEP’s Global Programme Priorities based on the regional and public inputs. The Global Programme Priorities form one of the two key building blocks in the REEEP Programme Framework. The other being the donor priorities, which are specified by the Programme donors and primarily define the countries where donor funds may be used[348]. The programme framework thus developed through a bottom-up and broad-based process forms the basis for selection of the projects that REEEP supports. This process of programme framework development is illustrated in fig 25.

[348] Donors such as the United Kingdom and Norway show considerable flexibility to support good projects outside their priority countries.

Fig 25: Development of REEEP Programme Framework[349]

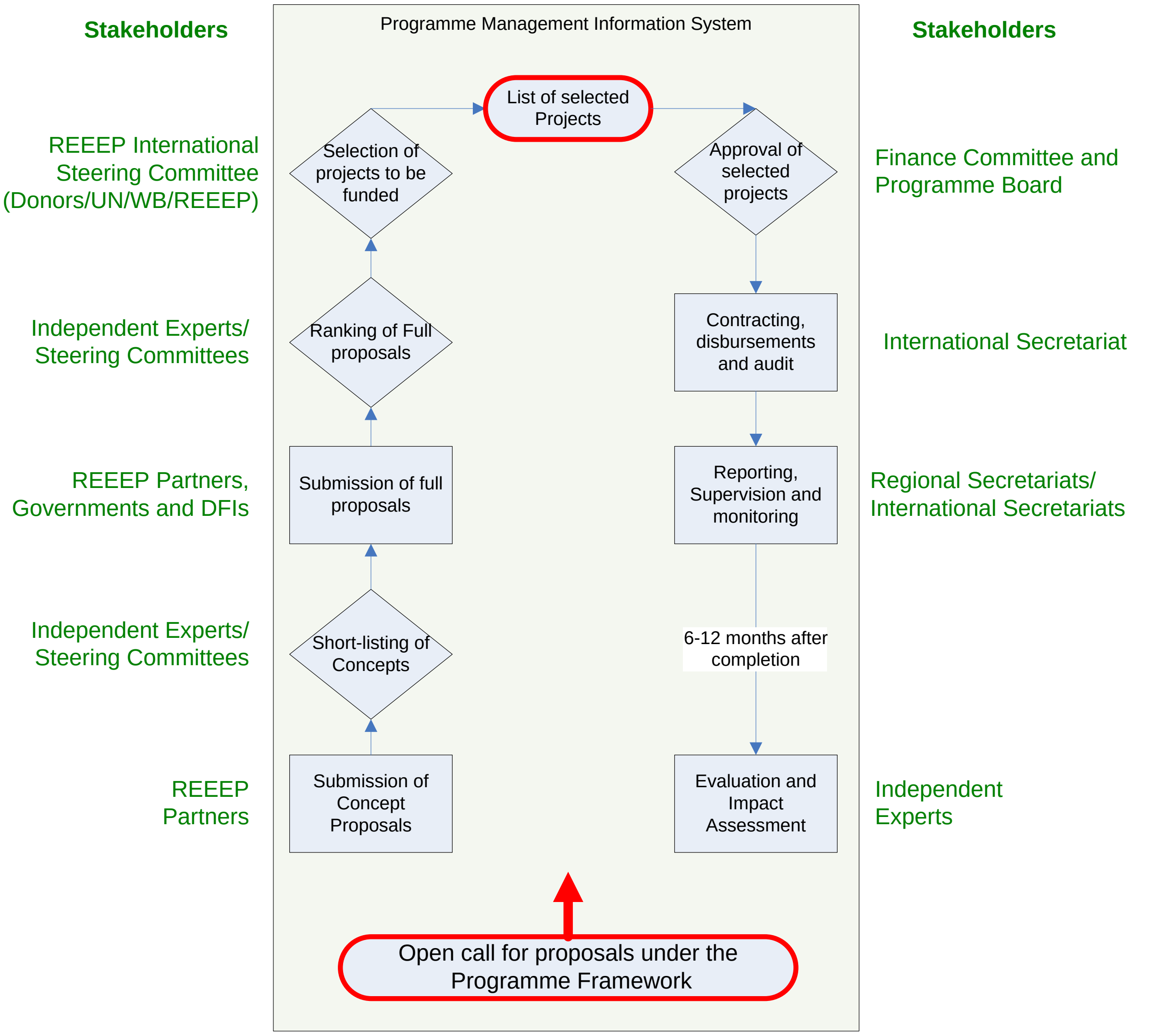


The projects that are supported are identified through an open and transparent process. This is illustrated in fig 25. Any organisation which has a concept for an intervention or a project addressing the REEEP programme priorities can submit a concept for consideration. The concepts are submitted on-line through the REEEP's Programme Management Information System[350] (PMIS). All the criteria for assessing the proposals and their weights during the concept and full proposal stage are announced to the public during an open call for proposals. The concepts submitted are assessed on-line by committees consisting of REEEP staff, steering committee members and independent experts using the pre-defined assessment criteria. At the short-listing stage the emphasis is conformity to REEEP and donor priorities. The

[349] Source: Parthan B, et al, 2010, pp 83-93
[350] Available online at pmis.reeep.org

results are based on the average ratings by the different experts and a pre-specified number of project concepts are short-listed and invited to submit fully developed proposals.

Fig 26: REEEP Project Cycle[351]



The short-listed project concepts are also provided with suggestions and advice from the REEEP experts to improve proposals and align them with REEEP priorities. The short-list is also shared with other partnerships, WB, UN etc. for inputs to ensure synergies and to avoid duplication. Typically the short-listed project concepts are given one month to submit full proposals. Direct submissions of full-proposals can also be made by Governments, Development Financial Institutions and also by past successful projects which are seeking to replicate or scale-up past efforts. The full proposals are appraised and ranked by REEEP experts on a second set of criteria looking at development impacts, innovativeness, financing and institutional aspects with the emphasis being on the impacts the projects may achieve. The ranked full-

[351] Source: Parthan B, et al, 2010, pp 83-93

proposals are considered for final selection by a committee consisting of REEEP staff, programme donors, UN and World Bank representatives. The key criteria for selection are the ranking and inputs from other implementing agencies are also considered, especially relating to duplication and overlap.

The selected projects go through final approvals via the REEEP internal governance system and are contracted to implement the proposed activities. During the typical implementation period ranging from 12 to 24 months, the project progress is monitored on the ground by REEEP staff or regional secretariats and both strategic and operational guidance is given regarding activities, outcomes and possible linkages. Important outputs from the projects are made available to other partners and public through the REEEP digital library[352] available on the REEEP website. REEEP also promotes the activities under its programme through press-releases highlighting key achievements and milestones of specific projects and also publishes the profiles of each of the projects on its website and as a publication. REEEP also produces think pieces and cases based on the projects around specific issues (micro-finance for renewable energy, rural electrification etc.) which are promoted through specialised media focusing on low-carbon energy, climate change or environment. When all project activities are completed, an independent evaluation of the project is carried out by the implementing partner before the final reporting and closure. Use of independent experts is encouraged by REEEP and provides a panel of independent experts to the implementing partners on request. REEEP also carries out impact assessments by independent experts after the projects are completed and after providing enough time for the impacts to be achieved. The implementing partners are given an opportunity to reflect and comment on the impact assessments before they are finalised and lessons are synthesised for improvement of programme processes and frameworks.

9.2.2 Energy Innovation Initiatives being analysed

All the 30 energy innovation initiatives which are being analysed are described in the following sub-sections. These initiatives cover 21 developing countries and generally involve resources in the range of 27,500 to 1,572,000 Euros to carry out work in the areas of low-carbon energy policies and regulation, establish and support finance facilities and instruments and establish business models. The projects were implemented over a 12 months to 24 months period. The total financial outlay of these projects and initiatives were about 8.8 million Euros. All the initiatives and projects were implemented during the period 2005 to 2008

[352] Available online at toolkits.reeep.org

9.2.2.1 Brasilian Energy Efficiency Fund[353]

The initiative involved the development of a structured energy efficiency (EE) program for the implementation and financing of EE projects in the commercial and industrial sectors of Brasil. Petrobras, the Brasilian energy utility has struggled to penetrate the EE market in Brasil. A lot of opportunities came up, but taking them one by one was not a good solution. The idea to develop a more structured approach, integrated in a well designed program that would target all aspects related to EE market barriers, including the financing, seemed more attractive. In this context, Petrobras developed a partnership with Econoler International to design, develop and implement a complete and structured EE program for the Brasilian markets.

The project was expected to create new opportunities for private participation in EE activities and to constitute a new step in the development of the EE market in Brasil. The project also aimed at enhancing the skills of Petrobras, allowing them to understand, design, implement, monitor and prioritise EE projects linked to climate change. The proposed program also attempted to stimulate the development and implementation of EE projects throughout Brasil and will therefore create a whole new market for all actors involved in these projects, i.e., engineering firms, ESCOs, equipment distributors, etc. The project focussed on the development and initial start-up of an EE program for the Brasilian commercial and industrial markets on activities involving:

1)Develop the strategic plan of the program;

2)Identify the focus markets of the program per sector and regions;

3)Structure acceptance criteria for project approval by the program;

4)Prepare the detailed business plan of the program;

5)Develop a marketing strategy for the program, including partnerships with financial institutions and other organisations;

6)Initiate the dissemination strategy of the program and

7)Develop a final report for REEEP on the project realisation.

The expected impacts included:

1) An operational and sustainable initial EE program, including an adapted EUR 8 million EE fund to cover its financing needs;

2) If the pilot phase goes well, an increased level of funding and of activities for the program will be realised, furthermore leveraging the REEEP initial investment and

[353] cf Renewable Energy and Energy Efficiency Partnership, 2006, pp 76-77

3) Capacity building of Petrobras employees and information dissemination to potential beneficiaries and other potential stakeholders.

In March 2008, Petrobras Distribuidora , in collaboration with Light Esco, and Ecoluz created the joint venture “EBL Companhia de Eficiência Energética S.A. as an SPV to implement energy efficiency projects in 33 buildings of the Oi Group. This appears to have been the only major project undertaken by the firm which was established as a Special Purpose Firm. There was not too much publicity about the firm since it was setup as an SPV (Special Purpose Vehicle). No further projects have since been implemented by the SPV or the ESCO.

9.2.2.2 Central American Electrical Energy Efficiency Programme[354]

The project focussed on the removal of the main financial barriers that inhibit the implementation of energy efficiency investments in the industrial and commercial sectors in Central America, by the implementation of innovative financial mechanisms. Electricity consumption across Central America is expected to increase by 6% annually over the period from 2005 to 2014.This growth in additional installed capacity is estimated to be approximately 2,500 MW across the region. Currently the market for energy efficiency is non-existent and therefore the REEEP has supported BUN-CA to establish suitable policies to create an energy efficiency marketplace within the commercial and industrial sectors.

The project has identified a model which can be shared with Central American countries to enable finance to reach energy efficiency markets. In 1990, Mexico created a trust fund, Fideicomiso para el Ahorro de Energia Electrica, (FIDE), to foster energy conservation. Among its activities, FIDE provides financial support to private developers to implement energy conservation. In addition, Nacional Financiera (NaFin), a Mexican development bank, has created a risk capital fund “Latin American Clean Energy Services Fund (FONDELEC)” dedicated to financing EE investments in SMEs in the industrial, commercial and service sectors. Mexico strongly supports Empresas de Servicios Energeticos (ESCOs) and the policies supporting the energy efficiency market within the Secretary of Energy’s Comision Nacional para el Ahorro de Energia (CONAE) and this provides a model for replication. The REEEP funded project worked with the ongoing UNDP/GEF regional energy efficiency project in Central America, in addition to a bilateral EE project for hotels in Costa Rica.

The project promoted energy efficiency investments by introducing in the Central American context two financing mechanisms: equipment leasing and the ESCO approach. It identified and screened four projects to implement financial models and it developed a handbook for energy efficiency business plans within the private

[354] cf Renewable Energy and Energy Efficiency Partnership, 2006, pp 80-81

sector. The project engaged financial institutions and local Chambers of Industry and Commerce within the target countries to establish and maintain energy efficiency markets. The main activities of the project included:

1)Design of at least two innovative financial mechanisms for energy efficiency (EE) investments – EE equipment leasing and ESCO approach – in addition to conventional finance, involving local commercial banks, project developers, chambers of industry and commerce, and industries and commercial entrepreneurs;

2)Identification and screening of at least four projects to carry out investments;

3)Design of a specific capacity building programme for investors, financial institutions and project developers, with the active participation of CONAE and FIDE;

4)Development of a Handbook to prepare business plans for EE investments in Central America in the private sector;

5) Organisation of a regional workshop to strengthen knowledge transfer and best practices on EE project financing. FIDE and commercial lending institutions from Mexico and participated as key speakers.

It was expected that the project will result in:

1) Entrepreneurs in the commercial and industrial sectors can reduce the energy bill of their business operations, without affecting the final quality of their products and services and

2) Strengthening of the transfer of knowledge between Mexican and Central American financial institutions.

BUN-CA carried out the regional initiative on capacity building which has trained 225 key stakeholders up to June 30, 2008. Of this, 128 investors, project developers and energy policy makers region-wide were trained due to the REEEP Project.

9.2.2.3 Government Procurement Roadmap[355]

The initiative was to develop a harmonisation roadmap for government procurement for energy efficient products through market and policy research. The main activities of the initiative included

1) Assess policy in three to five chosen Asia Pacific Economic Cooperation (APEC) economies including a review of existing purchasing policies, regulations, and practices, and evaluate policy barriers for procurement policy harmonization;

2) Review existing energy efficiency criteria (testing, labelling, and procurement), evaluate technical barriers, and prioritise product categories for harmonization;

[355] cf Renewable Energy and Energy Efficiency Partnership, 2006, pp 66-67

3) Organise an APEC international workshop on procurement policy harmonisation to bring together procurement officials and experts on energy efficiency standards, labels and product testing to explore harmonisation opportunities and detailed schemes among APEC economies; and

4) Develop a harmonisation roadmap for government procurement to allow direct follow-up of harmonisation activities.

The expected benefits of the project include:

1) Contribution to the facilitation of APEC energy efficiency market transformation and trade liberalisation through the development of a harmonisation roadmap;

2) Increased international cooperation to facilitate the development of harmonised energy efficiency standards and labels;

3) Promotion and dissemination of successful experience and good practice of government procurement policy for energy efficiency products.

The roadmap was developed by CSC and the team was involved in the development of the government procurement of EE products for China. The roadmap offers very useful information about the case study countries.

9.2.2.4 Central American Standards and Labelling Programme[356]

The programme was designed to accelerate the market transformation towards energy-efficient products in Central America by supporting the development of Standards and Labelling (S&L) programs at a regional level. Currently, the market for energy-efficient equipment in Central America is virtually nonexistent, with Government programs being few and national in scope. UNDP-GEF approved a regional efficiency program including an S&L component. The UNDP-GEF project is designed to reinforce these efforts through capacity-building and policy implementation support by providing the necessary groundwork for stakeholder awareness of policy options and components and for the transfer of experience from Mexican experts. It gives hands-on training in the technical basis of product certification and provides a framework for program development based on international experiences and the particular market barriers prevalent in the region.

The activities of the project included:

1) Inception workshop to bring together representatives from the participating countries and international experts in S&L program development and focusing on program development elements, barriers to market transformation in the region, financial and capacity building needs and international best practices and experience in the broader Latin American context;

[356] cf Renewable Energy and Energy Efficiency Partnership, 2006, pp 32-33

2) Training course and study tour in Mexico, taking advantage of the Mexican experience by including both a training course by Mexican technical experts for a Central American delegation and a study tour of Mexican laboratories equipped for testing of electric motors, refrigerators, light, and air conditioners and

3) Policy implementation support by international experts in the form of a reference document outlining international experiences, with an emphasis on Latin America.

The benefits expected from the project included:

1) Creation of a regional network of key stakeholders and technical staff;

2) Provision of training by Mexican experts, including demonstration of test procedures and discussion of certification and accreditation issues;

3)Preparation of reference materials by international experts outlining the trends of S&L program practices which may be applicable in Central America, considering the international experience of Mexico and other countries including those in South America;

4)Introduction of at least 50 government officers in 7 countries to components of S&L program development;

5)Provision of full knowledge of S&L international protocols to stakeholders and

6)Empowerment of national energy authorities regarding the energy efficiency market mechanisms associated with S&L.

According to BUN-CA, there has been a huge expansion of S&L in the region since the project was completed, considering that the baseline was no standards – currently there are several standards in Costa Rica, Nicaragua and El Salvador.

9.2.2.5 Renewable Energy Finance Facility for Brasil[357]

The initiative involved development of a dedicated private equity investment fund for renewable energy and energy efficiency focussed on opportunities in Brasil. To meet environmental and energy goals, Brasil needs to establish more small-scale renewable and energy efficiency projects, an objective supported by the REEEP and its co-funding partners, the Blue Moon Fund and local consulting companies. The REEEP thus provided seed funds to support the establishment of a dedicated private equity investment fund to the La Guardia Foundation to provide financing for clean energy in Brasil. The project identified potential sources of capital, promoted the involvement of national and local investors and financial institutions, and supported the adaptation of orthodox financial mechanisms and business structures. The project reduced

[357] cf Renewable Energy and Energy Efficiency Partnership, 2006, pp 28-29

issues of risk and contributed towards their mitigation through training, guarantees and bundling.

The project built on lessons already learned from a feasibility study carried out in Brasil in 2004-2005. The project team recognised that the main activities necessary to establish a renewable and energy efficiency fund in Brasil were the preparation of a project pipeline, the involvement of financial advisory services, the preparation of consistent legal documents, the raising of funds and the overall coordination of the project. These activities were cost shared with local fund managers experienced in renewables. Debt in local currency was available at attractive rates of interest for investors in renewable energy thanks to provisions made by the National Development Bank. The activities carried out by REEEP included

1) Preparation of the project pipeline;
2) Contracting financial advisory services;
3) Legal supervision for preparation of documents and registration with the Brasilian authorities;
4) Fund raising and related activities and
5) Project coordination.

The output was a first-of its-kind $70 million equity and guarantee facility to finance small hydropower, with a total leverage of $280 million. Based on average construction costs of small hydropower plants in Brasil, at least 200 MW of new, installed capacity of renewable energy generation could be built within the first three years of the fund. SHP Investment Fund operational since early 2006 (Energia PCH FIP Fund, managed by Santander Bank/Global Banking and Markets). Thirteen (13) projects under development in the states of Minas Gerais and Mato Grosso adding up to 193MW, according to LGF. Present equity is close to 270 million Brasilian Reais (about 110million US$). Besides contributing with about 20% of the number of SHP units under construction (13 out of 67), this project may contribute with other market development impacts related to the business approach: project bundling, gradual financial guarantee, EPC company, back up power contracting.

9.2.2.6 State-level Legal Framework for Renewable Energy in Mexico[358]

The purpose of the initiative was to propose the national model of legal framework to promote the use and exploitation of renewable energy resources in the states and municipalities of Mexico. The “National Model of Legal Framework to Promote the Use and Exploitation of Renewable Energy Resources in the States and Municipalities of Mexico” was expected to facilitate the process of government promotion of renewable energy. Furthermore, this legal framework was to allow achieving the

[358] cf Renewable Energy and Energy Efficiency Partnership, 2006, pp 78-79

objectives of development of projects with private, public and social investment in renewable energy to benefit rural and urban communities. The national model was envisaged to contribute to the creation of a culture and public policy of sustainable exploitation of natural resources. It was also expected to contribute to reducing poverty and mitigating green house gas emissions by releasing less polluting gases into the atmosphere. The model was intended to define a new social culture through which private rights related to renewable energy sources and their exploitation are regulated.

The proposed national model was intended to shape public, social and private participation relating to the use of renewable sources of energy. Various aspects relating to soil use, construction and final disposition or remainders were expected to be regulated with an emphasis on energy issues. The ways of public, social and private participation, referred to self supplying, small production, independent production and co-generation, was limited by Public Service of Energy Law. The principal activities carried out by the project were:

1) Analysis of local legal frameworks in Mexico and the world related to renewable energy sources;

2) Development of a draft national model that includes the institutional and regulatory mechanisms to promote utilisation of renewable energy;

3) Preparation of a multimedia edition of the national model in a didactic format that allows its use in the states of Mexico.

The expected impacts from these activities were:

1) Proposition of guidelines to establish State legislation and Municipality regulation for renewable energy exploitation;

2) Promotion of a public policy of exploitation and use of renewable energy sources among the States and Municipalities of Mexico mandated by the Federal Government;

3) Furthering of public, private and social investments to develop projects using solar, wind, hydro, biomass and geothermal as sources of electricity as provided for in the Federal Legal Framework;

4)Stimulation of the process of Federal and State Government promotion of renewable energy;

5) Increase in States' and Municipalities' understanding of legal issues relating to the use of solar, wind, hydro, biomass, and geothermal energy sources and

6) Establishment of a legal framework to diminish poverty in rural communities throughout Mexico by using and exploiting renewable energy sources.

9.2.2.7 Sustainable Energy Regulatory Capacity Building[359]

The initiative sought to apprise and train the regulators and policy makers in Andhra Pradesh (AP) state of India, about the international instruments like German Feed-in Tariff, Renewable Tax Credit (RTC) and Renewable Energy Obligation (REO). India's Electricity Act 2003 (EA 2003) is prompting state regulators to begin exploring methods for implementing the mandate given to them under Section 86(1) – "specify for purchase of electricity from such sources, a percentage of the total electricity consumption in the areas, from cogeneration and renewable sources of energy." The Andhra Pradesh Electricity Regulatory Commission (APERC) was attempting to identify policy frameworks and instruments for mainstreaming renewables based electricity within the state.

TERI, with funding from REEEP, analysed the barriers to renewable energy in Andhra Pradesh and identified the quantity of renewable resources within the state. The project reviewed successful instruments utilised in other REEEP partner countries, including Germany's Feed-in Tariff Law and the UK's Renewable Obligation Certificates. Analysis and applicability of the key dimensions of Renewable Portfolio Standards were also considered. The project worked closely with the REEEP core activity – Sustainable Energy Regulation Network (SERN). The main activities of the project included:

1) Investigation of the barriers to a renewables based electricity supply,
2) Analysis of policies that influence the renewables based electricity sector including the Electricity Act 2003,
3) Analysis of international instruments/policies and the underlying principles that drive them,
4) Development of a policy framework for mainstreaming the renewables based electricity,
5) Analysis of key dimensions of 'Renewable Portfolio Standards' taking into consideration the availability of renewable resource(s) in the state of Andhra Pradesh,
6) Preparation of a framework document and study material, including a case study on a renewable energy project in Andhra Pradesh,
7) Organisation of a conference focusing on 'Renewables and regulatory issues' covering the Indian and European experiences and key learning's and
8) Organisation of a training-cum-awareness workshop for regulators and policy makers in Andhra Pradesh

[359] cf Renewable Energy and Energy Efficiency Partnership, 2006, pp 18-19

The project produced a framework document, study material and case study which will be disseminated via training courses for regulators and policy makers in Andhra Pradesh. The policy and regulatory frameworks identified could be applicable to other Indian states and also to other REEEP partner countries looking to implement policies in support of renewable energy and energy efficient technologies. It is expected that the support provided by the initiative will lead to adoption of new policies and regulations in Andhra Pradesh that accelerate the market for renewable energy. Since adoption of the Electricity Act 2003 (EA 2003), state regulators have been exploring ways and means of implementing the mandate given to them under Section 86(1) with the potential of implementation of the recommendations being particularly high. However the APERC was yet to implement any regulatory order regarding the RETs in late 2008 when the assessment was carried out.

9.2.2.8 Energy Service Companies for Street Lighting[360]

The initiative was aimed at supporting the implementation of an innovative financing mechanism, in order to reduce by 30-40% the consumption of the street lighting network in the cities of Madhya Pradesh state of India. Street lighting represents a significant proportion of energy consumption in India, and the burden of providing the service falls on the electricity boards[361] of each state. In several municipalities, the electricity consumed is not metered, and this provides no incentive for municipalities to improve efficiency. Furthermore, utilities have to offer street lighting electricity at a cheap rate, resulting in financial losses which in turn prevent them from making investment in more sustainable lighting systems. The REEEP provided an implementation grant to Econoler International to support municipal corporations, and the energy service company, Central Discom, supported the development of a sustainable financing mechanism for the implementation of energy efficient street lighting projects in the state of Madhya Pradesh.

REEEP anticipated that a 30-40% reduction in energy consumption for street lighting in Madhya Pradesh was a realistic target figure. To achieve this reduction, the project promoted the engagement of national and local investors, financial institutions and capital markets in improving energy conservation, and thus cost savings in street lighting within the state. Similar projects in Indore and Ujjain have already reaped considerable benefits, and the strategy employed to obtain investment was to bundle projects together, providing more attractive investment portfolios with profits shared among investors. In Indore and Ujjain, a private energy service company (ESCO) took over provision and the cost of street lighting with considerable efficiency gains. The utility which provided the power and gained from the savings then reimbursed

[360] cf Renewable Energy and Energy Efficiency Partnership, 2006, pp 16-17

[361] State owned energy utilities that are responsible for transmission and distribution of electricity in Indian states.

the ESCO for the costs of the project over a period of 27 months. The contract used between the municipalities, the ESCO and the Madhya Pradesh State Electricity Board (MPSEB) was based on a shared savings model.

The REEEP funded project was expected to implement street lighting projects across Madhya Pradesh. It is hoped that the MPSEB and its Discoms will develop sufficient capacity from such projects to launch additional energy-saving projects in the future. REEEP expects that the capacity built on the development of financial methods for reducing power consumption for street lighting projects will spread from Madhya Pradesh to other states across India, and across REEEP partner countries. The main activities of the project related to three demonstration projects on energy efficiency in street-lighting through an ESCO approach and involved:

1) Preparation of the baseline data that can be used for the tendering purpose for ESCO projects;

2) Development of the tender documents for the benefits of the Municipal Corporation;

3) Launching of the tender;

4)Selection of a winning ESCO to implement the project and negotiate the contract between the ESCO, the Municipal Corporation and MPSEB;

5) Supervising of the project implementation and insure the fair application of the performance contracting concept by all parties and

6) Search for a carbon buyer and support the trade of the CERs.

It was expected that the three projects will be implemented in targeted cities with an evaluated cost of € 1.5 million. Further development of the capacities in MPSEB to launch additional projects in Madhya Pradesh on the same basis in the future was expected to take place. It was also expected that there will also be increased awareness amongst other municipalities in Madhya Pradesh to implement projects according to the developed approach.

Although the tender was launched the contracts were not awarded since the main city, Bhopal, could not reach an agreement with any of the ESCOs. No progress was made on the CDM finance model as a result. There has been no real market development impact in the project area. There has been considerable interest in developing other projects, including through REEEP funding in AP and Punjab. Apart from a limited lamp changing activity in the pre-project pilot area, there has been no project implementation. South Asia ICLEI has taken an interest and is working with MP to develop projects in 14 municipalities.

9.2.2.9 Low-Carbon Energy in Urban Slums[362]

The project involved development of a financial model appropriate to the South African context that will enable the national replication of the ‘low income urban housing energy upgrade project’, currently being piloted in Kuyasa, Cape Town. This development process considered both CDM and TREC financing mechanisms, for which the energy upgrade project was eligible. South Africa’s Cape Town is a city where the introduction of renewable power in homes has potential to bring benefits in both energy saving and poverty reduction. An energy upgrade housing demonstration project in the Kuyasa district of Cape Town involved the installation of insulated ceilings, solar water heaters and energy efficient lighting in low income homes. The project has resulted in reduced costs, dramatically helping impoverished families save money.

Additionally, because the project resulted in energy savings it had the potential to qualify for carbon revenue under the Kyoto Protocol’s Clean Development Mechanism (CDM).The project was also the first to qualify for the WWF’s CDM Gold Standard – a REEEP supported initiative. It was expected that South Africa could benefit from a national expansion of the Cape Town project. However considerable barriers exist to such an expansion, prompting the South South North (SSN) to seek REEEP support. SSN identified the need for a financial model to be drawn up, based on the Kuyasa project, which could then be used to replicate the project nationwide.

SSN, developed an assessment of the Kuyasa energy upgrade, identifying potential investors and holding workshops for them to discuss and develop model options. The project documented lessons learned from the Kuyasa project and is drafting a financial model, including innovative financing mechanisms such as CDM, which can be rolled out nationally. In the long term the REEEP believes that its involvement will mean more financing for renewable energy and energy efficiency and those projects will become available for low-income communities across South Africa. The main activities that were implemented by the project included:

1) Publishing of an assessment of the context and nature of the Kuyasa energy upgrade project’s financial challenges;

2) Identification of potential stakeholders in the financial model (incl. financial, government, technology providers, development and community) through bilateral meetings;

3)Organisation of workshop(s) with potential stakeholders to discuss and develop model options;

4)Organisation of follow-up meetings with stakeholders to further their interest, contribution and buy-in;

[362] cf Renewable Energy and Energy Efficiency Partnership, 2006, pp 14-15

5) Documentation of lessons learnt from the financial close and implementation of the energy upgrade project in Kuyasa and

6) Organisation of workshop(s) to develop the draft financial model to a ‘final draft’ stage, and securing political buy-in and disseminating information.

The project was expected to assist in enabling the replication of the energy upgrade project in Kuyasa in additional low-income urban housing areas nationally, delivering the associated benefits throughout South Africa. It was also expected to provide significant lessons regarding:

1) The use of CDM and TRECs in the financing of projects of this nature internationally and

2) Financing renewable energy and energy efficiency projects in low-income urban communities in South Africa.

The project activities were eventually completed but the large energy upgrade project was not implemented and it appeared that there was not an adequate buy-in from the government to support the project.

9.2.2.10 South-South Exchange on Village Power[363]

The project involved the transfer Chinese and international best practices of village power to East Asia countries including Mongolia and North Korea through the establishment of a business model for PV village power in Mongolia. The Chinese government has installed over 100 village power systems, using solar and other renewable technologies that were funded by a range of financing methods including government grants. These village power systems have proved so successful in bringing power to remote areas that the model has been rolled out across China.

The REEEP funded the project in Mongolia to showcase the model as a solution to rural electrification. The project was to develop a business model for an installed village power system and will promote regional workshops to disseminate the experience and results of this project. In the long term, it was expected that the business model designed and practised in Mongolia will be rolled out to other areas, thereby encouraging the sustainable development of village power across the region. The main activities of the project included:

1) Cataloguing the village power experiences in China and Mongolia, in particular the financial models used;

2)Development of a business model based on an installed village power system in Mongolia;

3) Implementation of the business model produced and

[363] cf Renewable Energy and Energy Efficiency Partnership, 2006, pp 20-21

4) Implementation of a regional workshop to disseminate the experience and study results.

It was expected that the project will ensure the sustainable development of village power in the region and enlarge the village power business in China and Mongolia by identifying a successful financing mechanism and policy framework. Mongolia has been following the development of village power electrification in China, notably the Township Electrification Programme. The experience made in the implementation of the Township Electrification Programme as part of Chinese Brightness Programme has helped the Mongolian experts to avoid flaws in the design of their own village power programme.

9.2.2.11 Wind Energy Roadmap in China[364]

The initiative was to develop a National Roadmap for Wind Development in China with supporting documentation that provides a detailed planning framework to enable China to achieve its intermediate and long term strategic wind development and policy goals for 2010 and 2020. The potential for grid-connected wind power in China is enormous, with current estimates at 250 GW and an offshore potential of 750 GW. China has recently established goals for near term development of 4 GW by 2010 and longer term goals of 20 GW by 2020 in order to accelerate the pace of development for wind. The initiative was implemented in 2005-06 after the passage of the Chinese Renewable Energy Law, with the goals and intent in place to create the policy and regulatory structures which are in support of renewable energy. The REEEP funded the Centre for Renewable Energy Development (CRED) to establish a logical framework of objectives and goals for cooperation between the government, industry and financial stakeholders to support the achievement of national objectives.

The project prepared a National Implementation Roadmap for Wind Energy Development which will become part of the Multi-Year Technology and Industry Development Plan. The detailed planning framework also established specific targets that can be associated with the 11th Five-Year Plan. The project activities include:

1) National Implementation Roadmap for Wind Energy Development in China (including elements of a National Action Plan for Wind Development),

2) Development of a Multi-Year Technology and Industry Development Plan and

3) Detailed objectives and targets for the 11th Five Year Plan (2005-2010).

The expectations while implementing the project included:

1) Chinese government, industry, project developers, and the financial community will be positioned to act in concert to assure that China’s strategic development goals for wind development will be achieved,

[364] cf Renewable Energy and Energy Efficiency Partnership, 2006, pp 22-23

2) China will achieve 4 GW in 2010 and 20 GW in 2020 of installed wind capacity,

3) China will establish a viable industrial base for domestic manufacturing of large-scale wind turbines,

4) China will establish a domestic capacity for commercial wind farm project development,

5) The lessons from the project and the developed roadmap framework can be helpful to other countries to enlarge the global wind market.

The finalising of the roadmap coincided with the elaboration of the “Promotion of Wind Power Industry Development” document. Domestic market development gained significant momentum, especially after the release of a) China’s Mid and Long-term RE Development Plan until 2020 in September 2007 and b) China’s 11th Five-Year-Plan RE Development Plan 2006-2010 in March 2008. Through the involvement and participation of stakeholders representing key govt. institutions in a steering committee the elaboration of the roadmap greatly benefited in terms of comprehensiveness. Furthermore, primary concerns identified and expressed by the involved govt. officials were incorporated in the Roadmap. Thus leading to greater acceptance of the documents and is therefore subsequently used as a reference document.

9.2.2.12 Biomass Co-firing in China[365]

China’s Renewable Energy Law states that 10% of China’s energy needs should be met by renewables by 2020 - and biomass is expected to play a vital part in meeting this target. Furthermore, biomass can play a key role in reducing dependency on imported fuels and in providing employment and economic benefits to rural areas. Despite this policy environment, there has been limited progress to date in using biomass for commercial energy production. The initiative considered and made recommendations on the institutional framework, policies and regulations to promote biomass co-firing in China and to guarantee a sustainable biomass supply. China has abundant biomass resources as well as a power sector dominated by coal-fired power stations that are suitable for conversion to burn a mixture of biomass and coal. However, to date there are very few examples of utility scale coal-fired power stations that substitute a certain percentage of coal for biomass. The initiative was aiming to

1) Look at the potential for biomass co-firing in China by examining the biomass resource available and the location of power stations most suited to co-firing,

2) Carry out a thorough analysis of the potential barriers and risks to co-firing in China,

3) Develop several case studies to provide practical examples of the potential for co-firing,

[365] cf Renewable Energy and Energy Efficiency Partnership, 2006, pp 70-71

4) Identify the market mechanisms and institutional and legal frameworks necessary to enable the strategic development of biomass co-firing in China and to ensure a sustainable biomass supply and

5) Develop these mechanisms as a means to achieve renewable energy targets and reduce the global impact of GHG emissions from coal-fired electricity generation.

The main activities of the project included

1)Definition of the potential for biomass co-firing in China and analysis of the international scenario in the sector,

2) Identification of the critical factors for the successful development of a market for biomass co-firing in China,

3)Definition of barriers and risks associated with biomass co-firing and commercial biomass supply,

4) Identification of innovative mechanisms and financial instruments to mitigate commercial risks associated with biomass supply and

5) Development of several case studies and recommendations and dissemination.

The expected impacts from the project included:

1) Provision of a profile of the biomass energy sector in China,

2) Provision of recommendations for the policy framework and financial mechanisms for the successful promotion and uptake of biomass co-firing in China,

3) Strengthening of the network of national and regional policy makers in the field of biomass energy, and in particular those interested in co-firing and

4) Enabling the selected case study for co-firing to take the proposition forward and act as an example in the field of biomass co-firing in China

There has been increased market development. Biomass has become a valuable resource, i.e. the price per ton increased by more the 30% since the RE Law and the fixed feed-in-tariff became into effect on January 1, 2006. Co-firing projects are still not eligible for the preferential biomass feed-in-tariff as the biomass share in co-firing is in the range of 10-20% and below the minimum threshold of 80% required for the feed-in-tariff. There is a need for an M&V and valuation protocol to enable the Chinese government to consider favourable tariffs.

9.2.2.13 Low-Carbon Building Programme in China[366]

The objective of this initiative was to increase energy efficiency and reduce GHG emissions in the building sector of China. Based on the national energy efficiency strategy from the Chinese government, 60% of energy in the building sector is lost

[366] cf Renewable Energy and Energy Efficiency Partnership, 2006, pp 68-69

due to the outdated standards and design practices. In order to reduce energy consumption in buildings, the Chinese government was planning to adopt new standards based on international best practices of energy efficiency technologies and renewable energy use. This project conformed to the general context of the sustainable development strategy for energy consumption in the construction industry in China, which is dedicated to the investigation and research of Chinese low energy-consumption building, by using the references of advanced technology and experience in European countries in order to accelerate low energy-consumption building in China.

The main activities of the initiative included:

1) Review the major experience of energy use in Europe and estimate the energy savings achievable in China's building sector,
2) Review best practices of sustainable building programs in European countries,
3) Introduce European standards to China and
4) Develop policy recommendations for a sustainable building program in China to promote the incorporation of energy efficiency and renewable energy technologies into the building sector.

The expected benefits from the initiative included:

1) Summary of best practices of sustainable building programs in European countries,

2) Basic analysis of current low energy-consumption building in China,

3) National policy recommendations report to the Chinese Government with support from other key stakeholder communities,

4) Increase the awareness of concepts for sustainable building development for several key stakeholder groups,

5) Increase energy efficiency and reduce GHG emissions in new building construction in China.

The construction of low energy buildings has gained significant momentum in China. Triggered to some extend by the Olympic Games and the World Expo in Shanghai in 2010. This has led to an increased awareness among relevant stakeholder s representing the governments, industries and general public. The promotion of energy efficiency within the industry & economy and national targets are clearly stipulated in China's 11^{th} Five-Year Plan 2006-2010 including the building sector. In general, the market development has gained momentum since the initiative was implemented.

9.2.2.14 Low-Carbon Energy Financial Models in South Africa[367]

The initiative involved development of replicable models for financing energy and water efficiency projects within municipal water supply systems in South Africa. Over the past 10 years the South African government has pushed forward with an ambitious plan to bring water services to millions. Since 2003, the Alliance to Save Energy's "Watergy" programme has partnered with various municipalities in South Africa to take advantage of the tremendous energy efficiency opportunities available in municipal water supply and wastewater treatment facilities. The REEEP funded project was expected to build on the ongoing USAID funded Watergy project in seven South African cities by more fully incorporating project finance into the assistance provided to municipalities. The project was expected to develop financial models that allow municipalities to fund energy efficiency projects in water supply. Roundtable forums will be conducted to bring together financial partners, local government and the NGO sectors. Case studies were to be written and disseminated to South African cities and water utilities. The Watergy programme in South Africa was active in seven South African cities. Since energy for pumping water often comprises the largest share of expenses in the cash-strapped municipal budgets, identification of financial models to fund energy conservation was expected to have an enormous impact on cost savings.

The main activities of the initiative included:

1) Incorporation of project financing into USAID-funded Watergy projects in seven South African cities;
2) Development of Watergy financial models that address legal and financial barriers impeding the development of sustainable municipal water energy efficiency projects;
3) Compilation of a set of case studies of completed and on-going water energy efficiency projects and their financing (or opportunities for financing if not yet financed);
4) Organisation of a high-level policy roundtable to engage governments, business and financial sector support for viable municipal water and energy efficiency projects;
5) Development of official capacities of participating municipalities for policies, financing and technologies for water efficiency improvements.

The envisaged impacts were that the replicable financing models will provide a tool for cities, project implementers and financial institutions to facilitate project funding for improvements in the efficiency of municipal water supply systems. Models will be distributed to cities throughout Southern Africa via institutions such as the South

[367] cf Renewable Energy and Energy Efficiency Partnership, 2006, pp 12-13

African Local Government Association (SALGA), South African Association of Water Utilities (SAAWU), the national Department of Provincial and Local Government (DPLG), the South African Cities Network (SACN) and the City Water Managers Forum.

The Alliance to save Energy is working with five municipalities to develop water efficiency programmes based on the developed financial models. The Alliance is scaling up the project outcomes by continuing to disseminate the financial models and case studies, raising awareness on the opportunities available. The demonstration of the financial viability and cost-effectiveness of energy efficiency to South African municipal and utility energy managers is expected to help leverage additional energy efficiency projects in the country’s municipal sector.

9.2.2.15 City Level Low-Carbon Energy Strategies in South Africa[368]

The project targeted the promotion of low-carbon energy as a practical means of assisting socio-economic development within urban communities in South Africa, whilst restricting the growth of carbon emissions, through “making the case” for such practice and ensuring related awareness, knowledge and capacity is built at local and national government level. Pioneering city energy strategy work and ‘State of Energy’ assessments undertaken over the past years in South Africa have highlighted the critical role cities play in the national energy picture. The largest cities account for approximately 40% of total national energy consumption and are important focus areas for achieving national energy targets around low-carbon energy as well as being key players in national economic development and social welfare in support of the Millennium Development Goals.

In order to take the energy agenda further in cities, 5 of the more pioneering cities in South Africa have formed an ‘energy alliance’. These cities have energy strategies or plans, and all have implemented low-carbon energy demonstration or pilot projects. Now they are looking to large-scale implementation, and have come together under a REEEP project to provide mutual support and form a critical mass to facilitate a large-scale roll-out of RE and EE interventions. The low-carbon energy options covered by the project, and identified by cities to be the most important focus areas include solar water heaters, efficient building design, efficient lighting and transport modal shift from private-vehicles to public transport. The project aimed to promote large scale implementation of low-carbon energy projects in the 5 cities, through widespread adoption of low-carbon energy in energy strategies, capacity building of staff and, possibly most importantly, bringing this alliance of 5 cities in contact with players around the country that can support them with implementation.

The main activities of the project included:

[368] cf Renewable Energy and Energy Efficiency Partnership, 2006, pp 48-49

1) Synthesise baseline information on energy use and CO2 emissions in cities, including existing RE and EE applications;

2) Quantify potential for substantial RE and EE implementation;

3) Identify economic, social and environmental benefits of RE and EE implementation;

4) Support cities with ‘actions plans’ to large-scale implementation;

5) Coordinate amongst organisations identified to be important to implementation;

6) Target activities in poor urban communities for improving access to sustainable energy development;

7) Promote equity in development through activities promoting greater EE within mid-high income communities;

8) Assess legislative, policy, financial, institutional framework, barriers and their solutions relevant to RE and EE development in South African cities;

9) Compile guidance on the appropriate role of these cities in effective RE and EE implementation from a national perspective and

10) Develop and present suitable material on practical actions for key officials in these, and other South African cities.

The envisaged benefits out of these activities included:

1) Project implementation occurs through linking 5 large cities with suitable implementation organizations and financiers (example: Development Bank of Southern Africa);

2)Renewable energy and energy-efficient interventions in the form of solar water heaters and energy-efficient lighting to be implemented within 5 cities;

3)Renewable energy and energy-efficient building guidelines and by-laws developed within 5 cities;

4)Installation of energy-efficient lighting in all government buildings within 5 cities – programs have started;

5)Extending sustainable energy strategies/planning to other South African cities with several cities already want to engage in developing sustainable energy strategies/plans for their jurisdictions;

6)Greater support from national government to local authorities towards achieving RE and EE targets;

7) Informing national government of the potential role of cities in supporting RE and EE agenda and convincing national government that RE and EE will positively contribute to development targets.

It was noted that cities made a significant progress in sustainable energy strategies and implementation and the REEEP Project by a good sensitization has really contributed (influence) to this. City Authorities are discussing development of a City Energy Efficiency Accord and the Minister in charge of energy has launched the state of energy of the country which will take account the potential of low-carbon energy. The intention of cities to develop a large-scale implementation remains. It should be stressed; however there are some barriers to cross to a mass implementation in terms of organisational issues, billing channels, legal implications, standards etc.

9.2.2.16 Low-Carbon Energy Policy for Liberia[369]

The initiative involved increasing national awareness on low-carbon energy and to remove barriers to investment and market development through a national policy instrument. The project was expected to formulate an RE & EE policy framework to induce investment and market development in the RE & EE sectors of Liberia. The project further intends to provide policy support to develop the renewable energy sector of Liberia, thereby providing increased access to energy services to address the issue of poverty and to foster the Liberian long-term development agenda. The project outputs/outcomes were expected to have significant market development impact through the:

1) Creating the political commitment to develop the clean energy market in Liberia;

2) Nationwide public awareness of the economical, social and environmental benefits of low-carbon energy in Liberia;

3) Creating the appropriate climate for scale-up in low-carbon energy through local and foreign investment and

4) Acceleration of the low-carbon energy market in Liberia and

5) Building of local capacity to respond to an increase in the low-carbon energy market.

The main activities of the project were :

1) Identification and evaluation of existing energy policy documents;

2) Facilitation of RE policy dialogue through consultation meetings between relevant government ministries and agencies, civil society organisations/NGOs, development partners, the private sector, local government officials, energy experts, etc.;

3) Establishment of an institutional framework (RE & EE Committee) to serve as the vehicle for formulating the low-carbon energy policy and Action Plan;

4) Drafting of a national RE & EE Policy and Action Plan for Liberia;

[369] cf Renewable Energy and Energy Efficiency Partnership, 2006, pp 58-59

5) Convening of a forum to review, finalise and validate the draft RE & EE Policy and Action Plan;

6) Submission of the final RE & EE Policy and Action Plan to the Government of Liberia through the Ministry of Lands, Mines & Energy for approval.

The project was expected to produce a national policy instrument to build and increase the application of RE & EE in Liberia by promoting investment, market development and end-use technologies. Given the uneven economic advantage that conventional energy sources have over renewables, this project was expected to make the energy sector competitive by facilitating:

1) Government support through tax subsidies for low-carbon energy scale-up;

2) Private sector investment/lending in the low-carbon energy sector;

3) Increase investment in off-grid rural electrification through the deployment of renewable energy technologies;

4) Foster indigenous energy technologies that demonstrate clear cost advantage without jeopardising quality and

5) Training to build local capacity to deal with RE issues.

After the REEEP project, the implementation of its outputs has permitted the establishment of the Renewable Energy Agency. On another level, the Government, in partnership with NGOs, the private sector and relevant donors is planning to embark on the formulation of a rural energy master plan. The Government is also in the process of establishing a Rural Energy Fund (REFUND) to support investment and market development. The project outputs have influenced donors and foundations to intervene in the development of renewable energy and energy efficiency sector of Liberia:

1) CSET has signed a memorandum of understanding (MoU) with E+Co to conduct a feasibility study for energy enterprise development for rural women in Liberia;

2) Furthermore the World Bank , USAID, CSET, a local private solar power company, and Liberian Bank for Development and Investment are currently implementing the Lighting Africa Development Market Place Project and

3) The Global Environment Facility (GEF) has approved funding to supporting the development of small hydro power in Liberia.

9.2.2.17 Latin American Sustainable Energy Policy Forum[370]

The project aimed to catalyse reforms of policies and regulations in the energy sector among key countries of Latin America. Through a logical sequence of activities, the

[370] cf Renewable Energy and Energy Efficiency Partnership, 2006, pp 86-87

project was to identify the most viable reform opportunities and will assist policymakers and other stakeholders in the host countries to initiate critical reform efforts to improve market conditions for the development and use of renewable energy and energy efficiency technologies and systems. The project had two primary objectives:

1) Document the sustainable energy policy environment of multiple (ten or more) countries in Latin America. In doing so the project will make this information available in a knowledge-sharing format. This process will also facilitate the identification of key policy and regulatory hurdles that may be reformed to improve market conditions for sustainable energy systems;

2) Facilitate energy policy reforms in several key countries of Latin America such that the market conditions for sustainable energy projects are improved

The Organisation of American States (OAS) served as the coordinator of the programme, and worked with senior officials in participating countries as well as the regional energy organization, OLADE. The expected outputs for the project were the preparation of a detailed report that outlines the current status of renewable energy and energy efficiency policies and regulations in the participating countries. This report will enable the preparation of country-specific guidelines that highlight the critical reforms necessary to stimulate further growth of renewable energy and energy efficiency markets. Finally, the forum was to prepare recommendations for each country that outline possible pathways for implementing the recommended reforms. The main activities of the initiative included:

1) Actualise and electronically publish a comprehensive survey of RE/EE policies and regulations in each participating country of Latin America (at least ten countries);

2) Identify key gaps, reform measures, and stakeholders critical to bring about a significant change in the policy/regulatory environment;

3) Develop results-oriented recommendations and outline strategies for executing the critical reforms necessary in several countries.

The expected impacts of these activities included:

1) Development of an information network on sustainable energy policies and regulations in Latin America and

2) It is expected that through the engagement of approximately ten countries of the region in this forum process, three or more concrete policy and/or regulatory reform processes will result, thereby improving market conditions for sustainable energy in those countries.

Argentina, Peru, and the Dominican Republic, Guatemala and Mexico reflected their legal frame work and reforms regarding sustainable energy. The project intensified the information exchanges of policies, regulations, programs, projects experiences, learned lessons and highlights their status quo and further actions needs and is documented via final report. A report was prepared for the Sustainable Energy Policy Initiative (SEPI) to advance the development and implementation of effective sustainable energy policies and regulations in the Latin America and Caribbean (LAC) region, with focus on renewable energy and energy efficiency.

9.2.2.18 Amazonia Energy Initiative[371]

The project carried out the design and initiated the Amazonia Energy Initiative (AEI) aimed at increasing energy access for isolated communities in the Amazon region while promoting productive and efficient energy use. Amazonian rural traditional communities are either not served by electricity or rely on poor-quality unsustainable power generation systems, typically running on diesel. Aggressive targets of the Luz para Todos Programme (Brasil Government Programme aimed at providing universal access to electricity) require innovative financing, regulatory and institutional approaches. Winrock worked in cooperation with local partners, supported by the Ministries of Mines and Energy (MME) and Science and Technology (MCT), REEEP and USAID, in the design of the PRISMA Model and the Amazonia Energy Initiative is aiming to create an adequate framework for community-managed, independent power production using small-scale renewable energy systems. Productive and efficient energy use that supports the development of selected value chains is also promoted, contributing to local development and to the sustainability of the energy enterprise. A local NGO (PRISMA) was designed and is being tested to own and operate a power plant and selected productive uses to serve a typical remote Amazonian community. Nationally, a new regional market agent will be proposed/ designed to balance the relationship between the small independent power producers (PRISMAs) and the big players. The regional organisation will also guarantee that technical assistance, commercial and financial instruments and tools are available for wide replication of the PRISMA Model.

The main activities of the project included:

1) Convene/participate in stakeholder meetings to discuss improved and innovative financing and technical assistance schemes;

2) Institutionalise selected ongoing projects and establish as independent micro-power producers, managed locally and stimulating income generating energy use;

3) Gather lessons learned/field information from the institutionalisation process;

4) Provide inputs to the ongoing discussions headed by MME aligned with the GVEP action plan and priorities. REEEP has signed an MoU with GVEP to collaborate;

5) Jointly with MME and Renove (Renewable Energy NGOs Network), finalise the design of the Initiative components: the framework of a programme consisting of a

[371] cf Renewable Energy and Energy Efficiency Partnership, 2006, pp 82-83

collection of financing and public policy recommendations; a new market agent, bundling independent micro-power producers, facilitating commercial transactions and mitigating risks. The expected impacts included:

1) Implementation of Two projects (50kW each);

2) Ninety families receiving energy service;

3)Business Plan/Bylaws for Amazon Energy Market Agent developed;

4) Innovative financing mechanism for micro independent power producer designed;

5) For the two remote Amazonian communities where pilot interventions will be made, the AEI will contribute to a sustainable energy service provision and development of productive activities, ultimately contributing to their socio-economic development;

6) For the Brasilian energy sector, the AEI will deliver a mechanism that will help to mitigate the risk for investors interested in exploring the business of electrifying remote communities, therefore contributing to a faster achievement of the targets of the Luz para Todos Program.

The Prisma model has been implemented for the community of Cachoeira do Aruã, state of Pará. The model was evaluated; Lessons and further recommendations were reported via final report. The Cachoeira do Aruã Prisma Project installed a 50 kW micro hydroelectric plant, built a mini distribution system and established a community furniture shop, connecting 51 consumers to the grid, among which: 42 households, 2 churches, 1 community furniture shop, 1 community telecenter, 1 health clinic, 1 school, 1 club house, 1 water supply system and 1 community shed. The project has also installed public lighting in a large area of the community.

9.2.2.19 Carbon Finance for Low-Carbon Energy Projects in Southern Africa[372]

The project aimed to facilitate the financing of smaller low-carbon energy CDM projects in Southern Africa using the Gold Standard[373] (GS) as leverage. Substantial challenges exist for the commercialisation of smaller RE/EE projects, with financing often cited as a major barrier. This despite there being a significant demand for African Gold Standard carbon credits internationally. Part of the solution is to incorporate GS carbon finance when considering the financing structure of these projects to reduce risk. Another aspect is to build capacity and networks on the issue of carbon finance within the countries. SSN is working with the Gold Standard, and implement-

[372] cf Renewable Energy and Energy Efficiency Partnership, 2006, pp 50-51

[373] Gold Standard is a portfolio standard applicable to emission reductions from clean energy projects that are used for compliance under the Kyoto Protocol and also in the voluntary carbon market. Certification to the Gold Standard allows emission reductions to benefit from increased prices.

ing partners GED (Mozambique) and TaTEDO (Tanzania) towards this solution in the following ways:

1) Holding capacity building workshops in Mozambique and Tanzania to distribute the ‘Financing and Transaction Guide’ and to raise capacity and awareness around carbon financing. In addition these workshops served to build networks within the financial, government and project development sectors in the countries;

2) Achieving the financial closure of at least one Gold Standard RE/EE carbon case study project in each country. These projects will ensure credible emission reductions and boost access to reliable energy services for low-income households, thereby contributing to sustainable development and poverty reduction – a major objective of the Millennium Development Goals;

3) Holding two workshops following the financial close of the projects to disseminate the project learnings and build awareness of successful financing models.

The main activities of the project included

1) Carbon Financing and Transaction Guide developed and disseminated;

2) Two capacity building workshops held;

3) Network and capacity developed between local and international financial institutions, government, project developers and NGOs;

4) Financial closure of two RE/EE projects and

5) Two information dissemination workshops held.

The expected benefits included:

1) Publication and distribution of CDM Financing Guide and increase in number of projects in RE/EE using CDM financing in addition to other financing streams in the region;

2) Networking and capacity building of financial institutions, members of government and NGOs both locally and internationally in the two countries;

3) Financial closure of two RE/EE Gold Standard (GS) projects, one each in Mozambique and Tanzania and

4) Capacity, networks and awareness of carbon financing in Mozambique and Tanzania.

The project resulted in the GS and UNDP MDG Carbon Facility procedures aligned, and developing a do not harm assessment which is now applied to all project proposals. The project assisted financial institutions to get a better understanding of the potential and limitations of innovative financing mechanisms such as the carbon finance. By doing so, awareness was raised which in turn might promote a greater uptake of renewable energy and energy efficiency.

9.2.2.20 Low-Carbon Energy Policy Framework in Guatemala[374]

The initiative aimed to prepare a proposal to the Government of Guatemala for a long-term national energy policy, with emphasis on renewable energy, energy efficiency and environment to foster poverty reduction, economic competitiveness, environmental sustainability and mitigation to climate change. The main activities of the project implemented by Fundacion Solare are

1) Prepare a basic energy document and legal gap analysis;

2) Consult with key government ministries and institutions;

3) Facilitate a workshop with key government ministries and institutions;

4) Prepare the basic document and policy outline for national consultation;

5) Identify Stakeholders for consultation;

6) Organise workshops;

7) Update basic policy document incorporating validated stakeholder input and

8) Prepare final document of a long-term sustainable national energy policy framework delivered to the government of Guatemala.

Expected impacts of the project included

1) Increased national awareness regarding the need for a long-term national energy policy;

2) Generation of awareness on renewable energy, its upside from an environmental, economic and social point of view, and the national potential and climate change impact;

3) Increased information on the importance and economics of energy efficiency;

4) Production of a proposal to the Government of Guatemala of a sustainable long-term energy policy prepared with multi-stakeholder participation and

5) Involvement of indigenous populations with workshops in native languages.

The project was very timely, and to some extent benefited from external factors. There was an evident strong buy-in from stakeholders, possibly due to the participatory approach, from the design of the project to its implementation. Moreover, the project is fully integrated into on-going undertakings and makes the most of complementary activities. The implementing agency managed to maintain a good working relationship with the governmental institutions during the course of the project, albeit

[374] cf Renewable Energy and Energy Efficiency Partnership, 2006, pp 88-89

the change of government. It is not a natural role for a NGO to propose policies to national government. Therefore, the risk of the government not buying-in with the project outputs remains high.

9.2.2.21 Increasing Supply of Gold Standard CDM projects[375]

The project aimed to provide support and training in the Gold Standard for CDM[376] to increase the supply of quality energy efficiency and renewable energy projects accessing carbon markets. Capacity and awareness raising is required for CDM projects to ensure that there is a pipeline of Gold Standard CERs to supply the rapidly growing demand in both Kyoto compliance and particularly the retail market. The Gold Standard can help renewable energy (RE) and energy efficiency (EE) projects to benefit from the CDM. In particular the Gold Standard

1) Guarantees a significant contribution to sustainable development arising from the project activities;

2) Promises meaningful local participation;

3) Focuses on renewable energy and energy efficiency projects and

4) Has the potential to attract premium prices in the VER and CER markets.

The project adopted a learning-by-doing approach to promote Clean Development Mechanism (CDM) projects in Brasil, China and the Philippines by guiding project developers through the process of identifying and preparing a CDM project using Gold Standard and providing technical advice when needed. At the same time, the project also supported building capacity in organisations in Brasil, China and the Philippines to prepare such energy projects for the CDM, and transfer this knowledge to their regions and globally. The main activities of the initiative involved

1) Training on the identification and development of Gold Standard CDM projects – a training workshop/project clinic to be held for companies developing RE and EE projects to help them understand the Gold Standard methodology and benefits

2) Identification of suitable potential Gold Standard projects,

3) Support and coaching for project development – selected EE and RE projects will be chosen for development using the Gold Standard as a guideline,

4) Attracting carbon finance to the Gold Standard project portfolio by organising a “buyers’ forum” at Carbon Expos

[375] cf Renewable Energy and Energy Efficiency Partnership, 2006, pp 74-75

[376] A protocol established by the NGO community to attract carbon finance towards low-carbon energy technologies of renewable energy and energy efficiency.

5)Global outreach and knowledge transfer – information on the Gold Standard projects will be disseminated to raise the profile of good quality RE and EE projects under the CDM and the benefits to project developers in terms of increased financing

It was expected that the project will result in

1) Training and dissemination on the Gold Standard to enable more RE and EE projects to benefit from the CDM,

2) Training for project developers on the Gold Standard for CDM to increase their capacity to advance Gold Standard CDM projects,

3) For at least three real EE and RE projects Gold Standard PDDs to be finalised and projects brought closer to securing CDM financing.

However the project implemented by IT Power and WWF was unsuccessful and did not meet REEEP’s expectations. The training programmes were conducted and support provided however it was not evident whether the three carbon finance projects were implemented and received enhanced carbon finance through the Gold Standard.

9.2.2.22 International Sustainable Energy Assessment[377]

The initiative was aimed at identifying and analysing the impact of international energy agreements on energy efficiency, energy conservation, and renewable energy technologies; the project also sought to increase international understanding of optimal ways to configure and utilise international energy agreements to achieve the goal of a sustainable global energy future.

The project activities involved

1) Identification of all bilateral and multilateral energy agreements currently in force; and completion of a detailed implementation and impact analysis for the entire set of identified agreements,

2) Creation of an online, searchable and freely accessible database of all international energy agreements currently in force and

3) Publishing of a series of professional and scholarly papers, monographs, books and law review articles setting forth the current state of international energy agreements, with particular emphasis given to their impact on energy efficiency, energy conservation and renewable energy.

The expected benefits from the project included increase in international understanding of methods to utilise and configure international energy agreements to achieve the goal of a sustainable energy future. The online, searchable and freely accessible

[377] cf Renewable Energy and Energy Efficiency Partnership, 2006, pp 26-27

database of bilateral and multilateral international energy agreements currently in force and to a limited extent, expired agreements will allow governments to determine the best routes towards the development of sustainable energy legislation and regulations. The knowledge that has since been built is very valuable and the collection of legal documents in the portal has been used in the United States. In 2006, the then Chairman of the Senate Foreign Relations Committee, U.S. Senator Dick Lugar, utilised this project to help inform and support legislation directed at facilitating bilateral and multilateral treaties on low-carbon energy.

9.2.2.23 Implementation and Impact Phase of the ISEA[378]

The project which was the second phase and in the previous stage of this initiative, ISEA identified, acquired and analysed a large number of international agreements dealing with or substantially relevant to energy. Users throughout the world will be able to access the full-text and analysis of all the agreements found in the ISEA database. This project constitutes a necessary next step to the previous ISEA project. The first and primary objective of the second project was to supply the unmet global need for a comprehensive, systematic & empirical - as distinct from an impressionistic - treaty implementation database. Using questionnaires, interviews and other information gathering techniques, this database, constructed in consultation with REIL and other key entities, will contain analysis and evaluation of whether and how important international energy treaties in the ISEA database are being implemented on the ground by governments and civil societies. This programme is a necessary next step to our original ISEA project because it examines the on-the-ground impact of ‘on-the-books’ legal instruments. It will greatly augment REIL and REEEP efforts to use law as an instrument to promote and support the development of the market for renewable energy globally. Second, the project was to expand the ISEA database to include international energy agreements from Brasil, Mexico, Russia and South Africa; and integrate this information with the treaties encompassed by the ISEA database. Third, the project was to create an innovative global open-network evaluation system enabling selected experts around the world to contribute to this treaty implementation database.

Treaties on the books are almost useless unless they are implemented. Unfortunately, there is no comprehensive, systematic & empirical energy treaty implementation database, informing stakeholders as to which treaties are being implemented, and what mechanisms work best. This project was designed to meet this need.

The main activities of the project included:

1) Acquisition of detailed implementation data for the covered treaties;

[378] cf Renewable Energy and Energy Efficiency Partnership, 2006, pp 104-105

2) Creation of metrics for evaluating treaty implementation;

3) Identification and analysis of social and economic impacts resulting from the implementation of these treaties;

4) Expansion of the present database to include all international energy agreements entered into by Brasil, Mexico, Russia and South Africa, along with implementation and impact analysis for these agreements;

5) Creation of an online system enabling selected stakeholders throughout the world to contribute agreements - and information on those agreements - to ISEA. This type of web-based system is designed to enable geographically dispersed users to easily add and edit content and

6) Development of synergies with such key entities as IUCN and UNTS.

The expected benefits of the project include:

1) Increase the understanding of decision-makers, regulators and other stakeholders about how to better construct and implement international agreements that support development and deployment of RE & EE;

2) Broaden the understanding of international treaties and how they are implemented;

3) Expand the scope and informational depth of the ISEA database and

4) Substantially enhance REEEP‘s efforts to suggest ways of using law to facilitate the market for renewable energy globally.

Extensive usage of the resource by other organisations has been found since establishment and upto late 2009. The resource is referenced, and also used to develop projects.

9.2.2.24 Low-Carbon Energy Regulation Methodologies in Mexico[379]

This initiative established new regulatory procedures and codes to support renewable energy development. The main activities of the project included

1) Hire consultants to transfer international experience in order to assist Comisión Reguladora de Energía (CRE);

2) Develop a methodology to assess the value of services such as voltage and frequency regulation or reactive power, that renewable energy generators and the grid offer to each other;

3) Develop a methodology to assess the capacity contribution of renewable energy and combined heat and power technologies to the grid and

[379] cf Renewable Energy and Energy Efficiency Partnership, 2006, pp 84-85

4) Develop a net-metering regulation procedure.

The expected impacts of the project include:
1) The Comisión Reguladora de Energía, an administrative agency of the Energy Ministry, shall have technical and operational autonomy pursuant to Ley de la Comisión Reguladora de Energía;
2) Promotion of the efficient development of generation, export and import of electricity by individuals;
3) Promotion of the efficient development of transmission, transformation, and delivery of electricity between entities that supply electric public service, and between those entities and the permit holders for generation, export and import of electricity and
4) Development of Mexico’s wind industry and increased number of power plant permits granted and completed.

The project helped create wind power and photovoltaic markets. At the end of 2011, CRE states that Mexico will have more than 2000 MW of wind capacity installed in the south of the country and 200 private projects of solar renewable energy; 250 kW of installed capacity. By the implementation of this project, the CRE was able to develop new regulatory instruments that addressed some barriers for investors to develop REES projects. CRE specialists received training that helped them to improve the regulatory instruments. Small-Scale Solar Power Interconnection Model Contract, Small Producer Power Purchase Agreement. This project contributed to the development of a directory of policy and regulatory experience for feed-in tariffs and net metering by compiling a database of international and regional experiences. This was used to enhance the reform of clean energy initiatives in Mexico. This project contributed to the development of policy and incentive measures for RE and EE, by examining best practices from across the globe and adapting this to the needs of Mexico in the form of interconnection agreements for solar energy, small scale generation using alternative energy and distributed generation in general.

9.2.2.25 Innovative Financing to Accelerate Solar Water Heating[380]

The project objective was to build knowledge and advance models for innovative financial mechanisms to boost solar water heating. The REEEP recognises the important contribution solar water heating (SWH) can make towards reduced energy consumption and the subsequent reduction of CO_2 emissions. Unfortunately, the market development for solar water heating across Latin America varies widely and is much lower than what could be achievable in many locations. In Brasil, market penetration of SWH is far below that in colder countries such as Austria, Germany, and Denmark which receive less solar radiation and which must employ more

[380] cf Renewable Energy and Energy Efficiency Partnership, 2006, pp 30-31

expensive solar water heating systems than Brasil, due to freezing conditions. Similarly, across most of the Caribbean, SWH reaches just a small percentage of the population. However, the possibility for the technology’s widespread use is clearly demonstrated by Barbados’ experience, where the penetration rate for residential solar water heating exceeds 40%, one of the highest penetration levels in the world.

With REEEP’s support, Green Markets International (GMI) developed and advanced innovative business and financial mechanisms to help to boost SWH markets, including fee-for-service operations, carbon finance, performance contracting, and renewable energy certificate trading. In Brasil, the Vitae Civilis Institute is working cooperatively with Abrava, the association representing Brasil’s solar water heating manufacturers, to create model business plans for SWH fee-for-service and performance contract operations. In the Caribbean, Caribbean Solar Technologies of Anguilla and GMI, are working to expand knowledge about fee-for-service operations and other innovative SWH finance possibilities throughout the residential and commercial sectors.

The main activities carried out by the project included;

1) Development of model business plans for Brasilian SWH fee-for-service and performance contract operations;

2) Development of model business plan for Caribbean SWH fee-for-service operations;

3) Exploration and integration of carbon finance role in above business models;

4) Working with Brasilian and Caribbean stakeholders to help evaluate viability and adapt business plans for their situation;

5) Building knowledge about possibilities for carbon finance in Caribbean utility SWH programmes;

6) Exploration of possibilities for international REC trading to boost developing-country SWH activities;

7) Sharing information above with a network of stakeholders, including in other REEEP priority countries, such as China, India, and South Africa.

The envisaged benefits of the project were that solar water heating manufacturers and electric utility companies will have model business plans from which to develop and launch new operations. They will also have a much greater understanding of replicable innovative financing models, such as fee-for-service and performance contract arrangements, as well as the tools needed to design and implement such programmes.

The project encouraged and helped inform the establishment of CBE Solar in Sao Paulo which has completed 3 commercial scale SWH installations for pool and shower heating, with more activities planned. The project helped to expand knowledge about the SWH fee-for-service business model in the Caribbean, where a SWH fee-for-service program is being planned in US Virgin Islands. The project helped build knowledge about carbon finance to help expand SWH projects and markets, helping to advance carbon market participation for SWH business activities in South Africa other positive impacts could result over time. The project was nominated by the World Watch Institute for a World Clean Energy award in 2007; Visitation to the project's webpage has remained strong; links to project outputs receive hundreds of hits each month.

9.2.2.26 Low-carbon energy Decision Support tools[381]

The initiative targeted empowering an estimated 300,000 planners, professionals and decision-makers by 2012 to make better energy decisions as a result of the knowledge transferred and by the subsequent use of the improved decision-making tools. The 'RETScreen' decision support tool, available free-of-charge, is now being used by more than 90,000 people in 216 countries and is quickly becoming the de facto international standard for clean energy project pre-feasibility analysis. RETScreen has already had a major impact on how pre-feasibility studies are done, with users saving more than $1 billion to date through the use of the software. With co-funding by the REEEP and the National Aeronautics & Space Administration's (NASA) Langley Research Center, engineers at NRCan's Canmet Energy Technology Centre – Varennes developed a new version of the RETScreen International Clean Energy Project Analysis Software. In RETScreen Version 4, the software's capabilities have been expanded from renewable energy to include energy efficiency applications. REEEP support was to be used to translate the software into 21 languages that cover roughly two-thirds of the world's population. During the development stage, RETScreen was expected to use cases from REEEP priority countries to test the models. CETC was to focus efforts on REEEP priority countries during dissemination.

The main activities of the project included:

1) Translation of software into 21 languages, including most key business/government languages of REEEP priority countries: Angola & Brasil (Portuguese);China (Simplified Chinese); India (English, Hindi, Bengali &Telugu); Kazakhstan & Russia (Russian);Mexico (Spanish); and Nigeria & South Africa (English);

2) Testing & debugging of software, including beta testing with cases from selected REEEP priority countries;

3) V4 software release, outreach and dissemination via RETScreen Website, CD-ROM, email notices and press releases, with targeted dissemination in REEEP priority countries in collaboration with REEEP.

[381] cf Renewable Energy and Energy Efficiency Partnership, 2006, pp 106-107

The expected impacts include:

1) RETScreen software for low-carbon energy technologies available in 21 languages;

2) RETScreen software free-of-charge on RETScreen website and CD-ROM;

3) Targeted testing, outreach and dissemination of software in REEEP priority countries;

4) Increased and improved access to energy efficient technologies, awareness & capacity building, and facilitation of implementation of energy projects that reduce GHG emissions.

RETScreen is an excellent policy development and programs tool and Version 4 will broaden its applications. Currently there are about 180,000 users of the RETScreen software in 222 countries. The users include professionals from organisations involved in policy and programs, e.g. the Indian Renewable Energy Development Agency (IREDA). RETScreen translated in additional languages with support from REEEP will make the software available to professionals in many such organisations in the future. Impacts from RETScreen use have been estimated to be 1000 MW and $1,800 million respectively. It was further estimated that even if funding for RETScreen were discontinued immediately, it would result in installation of 2.9 GW clean energy projects in the world by 2012 due to software momentum; continued funding would result in installation of 24 GW worldwide. Software available in 30 languages in 222 countries with 1000 new users per week.

9.2.2.27 Low-Carbon Energy Services in Developing Countries[382]

The project aimed at presenting objective information on low-carbon energy technologies to policy makers in REEEP focal countries, together with international donors. An added objective was to influence policy makers in IEA member governments. The project also aimed to publish recommended practice guides and conduct workshops in developing countries to support agencies to develop and implement sustainable renewable energy services, including addressing the targets of the Millennium Development Goals.

REEEP co-financing funded the expansion of ongoing work to include small hydro and wind technologies, as Renewable Energy Services for Developing Countries, and two workshops in South Africa and India were held in addition to those at World Bank and in China and Laos in 2005/6. Feedback to IEA member governments on potential policy changes and new directions towards sustainable energy is ongoing. Expected impacts of the project included

[382] cf Renewable Energy and Energy Efficiency Partnership, 2006, pp 42-43

1) Recommended Practice Guides (RPGs) for implementation of energy services (electricity, or services using electricity, e.g. water supply, health care, communications or productive uses);

2) RPGs available to policy makers and planners;

3) increased capability to identify sustainable renewable energy services and

4) expanded networks of stakeholders and experts.

Largely due to this initiative IEA is now preparing a new Implementing Agreement on “Rural Energisation” which takes into account all energy technologies. A workshop on sustainable rural energisation was held in Paris during May 2008. Delegates from twelve emerging economies were invited and eleven were represented at the conference. In addition to the organisers and representatives from nine Implementing Agreements, other attendees included energy experts from the German Development Bank (KfW), the Renewable Energy & Energy Efficiency Partnership (REEEP) and the OECD. The guide was highlighted in the presentation of PVPS Task 9 in the above workshop. The project has effectively widened the scope of the ongoing Task 9 of the PVPS. Thus, with a relatively low level of funding, the REEEP project has been able to create a long-lasting impact, showing that even a small project could create a big impact using this approach, i.e. broadening the scope of an on-going big research program.

9.2.2.28 Establishment of a Low-carbon energy fund for Asia[383]

The initiative involved establishment of a €50 million investment fund that will provide services and investment capital to enterprises and projects that generate renewable energy, enhance energy efficiency and offer energy services in the Asian region. REEEP provided seed funding to Emerging Power Partners (EPP) for the establishment of a €50 million investment fund – the Second Private Energy Markets Fund (PEMF2) Asia Sustainable Energy Fund – to provide services and investment capital to enterprises and projects that generate renewable energy, enhance energy efficiency and offer energy services in the Asian region.

The activities of the fund was planned to be handled through a Fund Management Company (FMC) operating out of Bangkok in Thailand. The investment fund, which was expected to build on the experiences of the PEMF1 fund, was to inherit existing contact networks, experience and a pipeline of deals. There were also plans for a third fund to be set up once PEMF2 has been successfully concluded. One of the foci of the fund was the promotion, financing and implementation of clean energy projects which enable switching to cleaner fuels and power generation from indigenous sources of energy. The initiative also identified new opportunities for innovative approaches to funding through the then nascent carbon market and other Kyoto

[383] cf Renewable Energy and Energy Efficiency Partnership, 2006, pp 24-25

mechanisms, potential investors in these new fields, and it brought together investors and projects.

The activities that were envisaged under the low-carbon energy initiative included preparation of the Private Placement Memorandum, investment road show, and use of placement agent to raise €50 million. The Fund Management Company would seek to

1) Seek, screen, and structure investment proposals

2) Complete approved transactions

3) Assist/advise the investee companies to enhance performance prior to and after the financial closing and

4) Monitor investment performance and provide management input on the board level.

The expectation was that when fully invested, PEMF2 will mobilise equity financing for 10-15 renewable energy projects with a total cost of €200-400 million, and an estimated capacity of 150-500 MW. When implemented, the funds could deliver reductions in CO_2 of between 20-30 million tonnes.

Eventually after almost a year of efforts, the Company - Emerging Power Partners (EPP) who was implementing the PEMF2 decided not to pursue the establishment of the Fund and withdrew from the effort. The fund was thus not closed and hence investments have not been made as envisaged at the proposal stage. The collapse of the PEMF2 fund brings out into the open, the inconsistency between the perceived market opportunity in emerging economies and the risk-return expectations of prospective investors. Given the fairly nascent regulatory regimes in such geographies, the macroeconomic risk perception, the specificity of project assets created etc., investors seek higher returns and lower risk, than can be borne by the project portfolio.

9.2.2.29 Small-scale low-carbon energy investments in South Asia[384]

The project supported an expansion of investment portfolio and incorporation of additional financing mechanisms into the Small-scale Sustainable Infrastructure Development Fund (S3IDF) model that facilitates local finance and enterprise development for small low-carbon energy projects with large pro-poor impacts, global and local environmental benefits, and the continued dissemination of the model’s successes and lessons. In South Asia, poor households lack the energy infrastructure necessary for poverty alleviation (e.g., lighting, productivity increases via energy-dependent investments such as pumping, agro-processing).These RE & EE investments face financing and other constraints, which are addressed in a cost-effective,

[384] cf Renewable Energy and Energy Efficiency Partnership, 2006, pp 62-63

financially and environmentally sustainable manner by S3IDF’s “Social-Merchant-Bank” approach through additional/new structures/initiatives. S3IDF’s “Social-Merchant-Bank” approach provides integrated financial, technical and business development assistance. Its innovative financing is leveraged by inducing local financial institutions’ participation in viable pro-poor projects that were non-bankable under “business-as-usual” practices. S3IDF has established partner-ships/collaborations with local banks and technology suppliers.

S3IDF’s investment-cycle activities for developing its portfolio and pipeline of small, pro-poor RE & EE investment transactions include: deal identification, feasibility analysis, financial engineering (transaction and ownership/operations business structuring), assisting during implementation and operation, and M&E lessons dissemination. S3IDF’s work under the REEEP supported initiative was expected to

1) Expand S3IDF’s market-shed;

2) Expand the mix of financing and risk mitigation ownership/operation structures (e.g., BOT for small schemes, sub-franchise licensing, ESCOs and other special structures) in the context of specific transactions (e.g., projects of distributed generation and energy efficiency);

3) Introduce policy initiatives (e.g., sub-franchise agreements) for specific new investments;

4) Tackle related issues mentioned for larger and longer gestation projects, which need such structuring and risk mitigation approaches; 5) Continue and broaden dissemination of lessons from S3IDF’s evolving successful experience in solving financing challenges for small, pro-poor REES projects.

The expected impacts of the initiative were:

1) Further demonstration and dissemination of new/innovative financing and related risk mitigation ownership arrangements, (e.g., BOT) for “collateral-poor” and/or inexperienced owner/operators in low-carbon energy projects;

2) Implementation of 15-20 additional poverty alleviating and environmental benefits transactions with local financing (increased local financial-institution involvement) and expansion of the portfolio’s market-shed;

3) Replicable – but new to the portfolio – innovative financing/deal structuring arrangements and associated business models owning/operating pro-poor REES investments;

4) Increased understanding of the poor’s willingness-to-pay for energy services;

5) Additional M&E and dissemination of lessons and

6) New/additional international financial resource mobilization for REES investments from socially, ethically and/or environmentally concerned individuals (including GHG offsets).

The S3IDF initiative has helped create RE and EE finance facilities in underserved markets, while encouraging the participation of local financial institutions. On aggregation, such initiatives have the potential to help address climate change at the global level and promote energy security at the national level. The sub-projects launched by S3IDF are an extension of the Fund’s activities from the recent past, and seek to build on the experience gained with implementing small scale projects employing proven technologies. The necessity of setting up supply chains and “shops” was not visualized initially and is a clear learning that has come about from the exercise. S3IDF has applied REEEP financial assistance to enlarging its portfolio of projects while initiating new types of projects, forging new alliances and exploring new channel partnerships. The broad spectrum of projects suggests that the Fund has chosen to demonstrate the grass-roots approach and the hands-on intervention to mainstream financial institutions and development banks. Of the seventeen ‘showcase’ projects (‘sub-projects’), ten involve hire-purchase or leasing of solar PV powered CFL and LED lanterns and lighting systems. The Fund has encouraged the growth of RE and EE enterprises, namely the commercial assembly of solar PV light fixtures and accessories, construction of energy efficient cook stoves for agro-processing, set up of solar powered kiosks, and the accompanying supply chains for each. The Fund has also been actively promoting the replacement of kerosene lamps by solar PV lighting systems.

9.2.2.30 Financing to link low-carbon energy services and income generation[385]

The initiative aimed to promote innovations to increase access of energy services to rural poor through a multiple approach focused on income generation, innovative financing mechanisms and service delivery mechanisms. Secondly, the project aims to ensure that more energy services-based income-generating products, new credit mechanisms and creative marketing methods are infused into the targeted markets. SELCO is working with SEWA Bank in Gujarat and various financial institutions in the state of Karnataka to create a sustainable linkage between energy services and income generation. For energy services to be successfully diffused in the under-served areas of India, economic linkages need to be established. To create effective linkages, appropriate financial programmes need to be implemented, thus the importance of having financial institutions as partners. The uniqueness will be in the linkages between energy services, financing and income generation. The projects would bring about the need of financing that is either savings- or earnings-based.

[385] cf Renewable Energy and Energy Efficiency Partnership, 2006, pp 64-65

The aim is to prove that in order to reduce poverty, income-generating activities need to be created, and to create such activities, energy services are essential.

The main activities of the initiative included:

1) Analysing the various target segments of SEWA Bank;

2) Identifying the appropriate energy service for the selected target segments of SEWA Bank and the financial institutions in Karnataka;

3) Demonstrations of the particular energy service to the targeted segments and potential entrepreneurs from the selected segments and

4) Working with the respective financial institutions to create the appropriate financing mechanism for the end-user and entrepreneur. The expected impacts of the initiative included:

1) Very strong link between energy services and income generation;

2) Flexible financing makes energy services affordable;

3) Increase income and/or increase quality of life for the end-user and increased local employment and

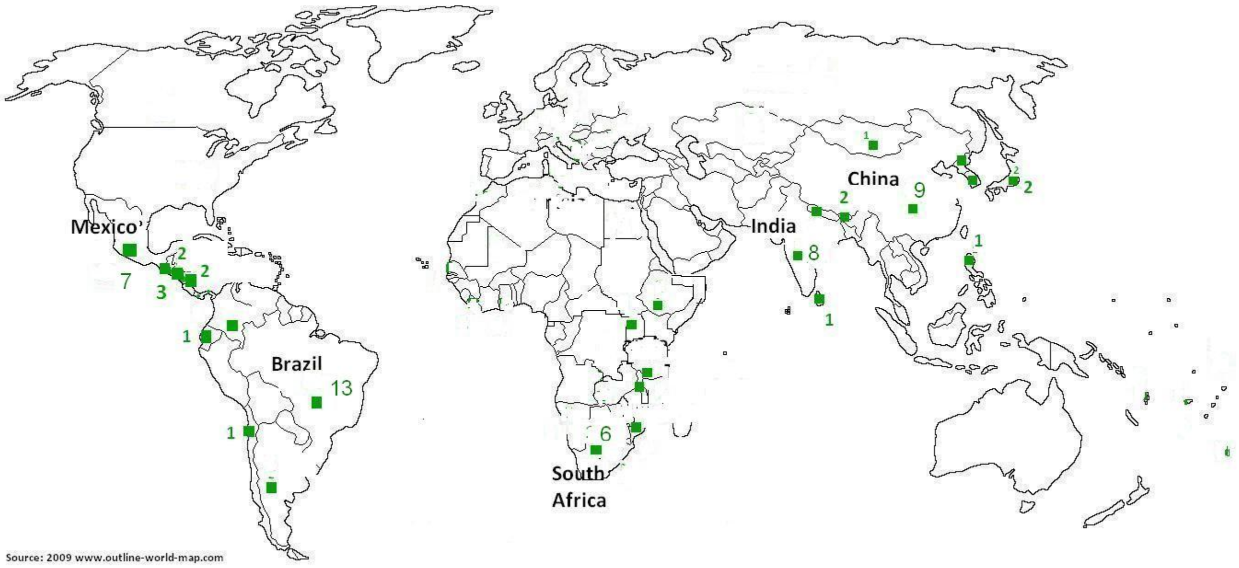
4) Establish a link between poverty and lack of energy services.

SELCO has undertaken nine ‘sub-projects’ with REEEP assistance and through co-financing from the likes of SEWA Bank in Gujarat and trusts, financial institutions and Non-governmental organizations (NGO) in parts of Karnataka and Tamil Nadu. Primarily focusing on solar PV applications for income generation, the company has also explored technology options in fuel-efficient cook stoves and thermo-electric generators for hybrid cooking-lighting solutions. The SELCO project addresses the donor objective of increasing renewable energy uptake (7.8 kWp and growing) and helps substitute kerosene lamps and candles with low carbon technology packages. The project also serves to identify efficient cook stoves to reduce firewood consumption, collectively, displacing approximately 90 t CO_2e per annum. By expanding the working relationship with SEWA Bank and by partnering with Basix India, the SELCO project has also promoted the engagement of local financial institutions.

9.2.3 Analysis

The 30 low-carbon energy initiatives being analysed cover the 21 developing countries which are shown in fig 27. It may be noted that some of the projects cover more than one country. Some of the projects have a global coverage, however with focus on a number of specific countries.

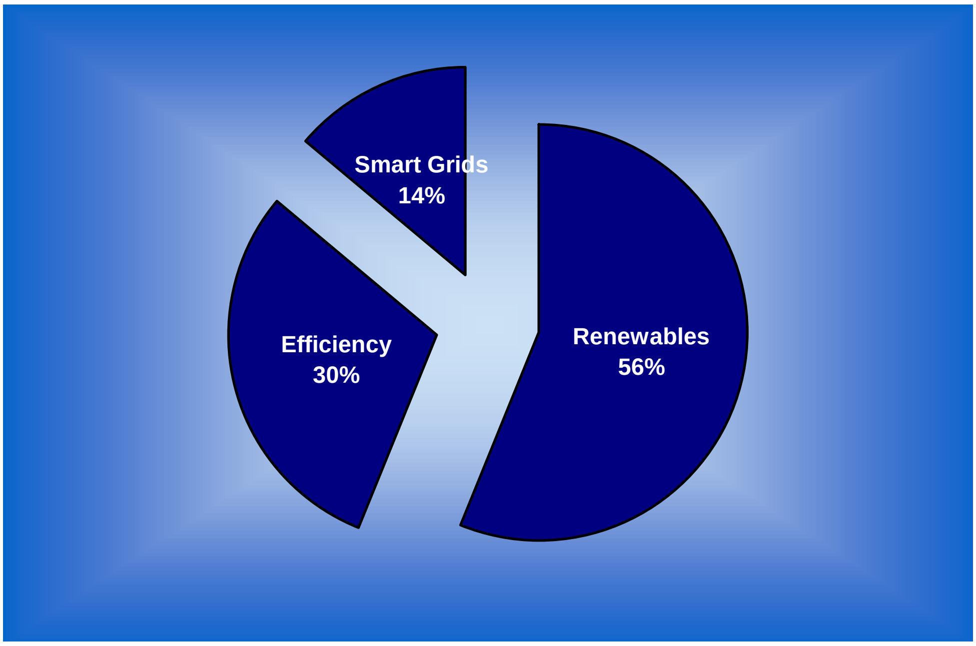
Fig 27: Geographical Distribution of Low-carbon Energy Initiatives



It can be seen from the geographical distribution in fig 25 that there is an increased number of initiatives that are concentrated in the large developing countries such as Brasil, China, India, Mexico and South Africa.

The share of different low carbon energy technologies across the 30 low-carbon energy technology initiatives is shown in fig 28. As is evident the portfolio is dominated by renewable energy and energy efficiency technologies followed by smart-grid technologies. Low-carbon energy technologies such as clean coal, carbon capture and storage and nuclear are energy are not covered in the portfolio. Such a share of technologies is in line with REEEP's mission to support the development of clean energy markets through the facilitation of renewable energy and energy efficiency technologies.

Fig 28: Low-carbon energy technologies in the portfolio



The list of the 30 initiatives showing the developing country, low-carbon energy technology and the energy innovation institution is shown in table 34.

Table 34: Low-Carbon Energy Initiatives being Analysed

Sl No	Initiative	Developing Country	Low-carbon energy technol-ogy	Energy Innovation Institution
1	Brasilian Energy Effi-ciency Fund	Brasil	Energy Efficiency	Econoler International
2	Central American Electrical Energy Efficiency Programme	Mexico	Smart Grids	BUN-CA
3	Government Procure-ment Roadmap	China	Energy Efficiency	China Standard Certification
4	Central American Standards and labeling Programme	Costa-rica, El-salvador, Guatemala, Honduras, Nicaragua, Panama	Smart Grids	CLASP
5	Renewable Energy Finance Facility	Brasil	Renewable energy	Fiorello H la Guardia Foundation

Sl No	Initiative	Developing Country	Low-carbon energy technology	Energy Innovation Institution
6	State level legal Framework for renewable energy	Mexico	Renewable Energy	CONCyTEG
7	Sustainable Energy Regulatory Capacity Building	India	Renewable Energy	TERI
8	Energy Service Companies for Street Lighting	India	Energy Efficiency	Econoler International
9	Low-carbon energy in Urban Slums	South Africa	Renewable energy, Energy Efficiency	SouthSouth-North
10	South-South Exchange on Village Power	Mongolia, China	Renewable Energy	Beijing Jike Energy New Technology Development Company
11	Wind Energy Roadmap in China	China	Renewable Energy	Centre for Renewable Energy Development
12	Biomass co-firing in China	China	Renewable Energy	ESD
13	Low-carbon Building Programme in China	China	Renewable Energy, Energy Efficiency	China national engineering Research Centre for Human settlements
14	Low-carbon energy financial models in south Africa	South Africa	Smart grids	Alliance to save Energy
15	City-level low-carbon energy strategies	South Africa	Smart grids	Sustainable Energy Africa
16	Low-carbon energy policy for Liberia	Liberia	Renewable Energy and Energy Efficiency	CSET

Sl No	Initiative	Developing Country	Low-carbon energy technol-ogy	Energy Innovation Institution
17	Latin American Sustain-able Energy Policy Forum	Brasil, Mexico, Chile, Gautema-la, Argentina, Colombia, Ecuador, El Salvador, Nicaragua	Renewable Energy, Energy Efficiency	Organisation of American States
18	Amazonia Energy Initiative	Brasil	Renewable energy	Winrock Brasil
19	Carbon Finance for low-carbon energy projects in Southern Africa	Tanzania and Mozambique	Renewable Energy, Energy Efficiency	SouthSouth-North
20	Low-carbon energy policy framework for Gautemala	Gautemala	Renewable Energy	Fundacion Solar
21	Increasing the supply of Gold Standard CDM Projects	Brasil, China, Philippines	Renewable Energy	IT Power
22	International Sustainable Energy Assessment	China, India	Renewable Energy and Energy Efficiency	University of Colorado
23	Implementation and Impact Phase of the International Sustainable Energy Assessment	Brasil, South Africa	Renewable Energy and Energy Efficiency	University of Colorado
24	Low-carbon energy regulation methodologies in Mexico	Mexico	Renewable Energy	Comision Regulatora de Energia Mexico
25	Innovative Financing to Accelerate Solar Water Heating	Brasil	Renewable Energy	Green Markets International
26	Low-carbon energy decision support tools	Brasil, China, India, Mexico, South Africa	Energy Efficiency	Canmet Energy Technology Centre
27	Low-carbon Energy services in Developing Countries	Brasil, China, India, Mexico, South Africa	Renewable Energy	IT Power

Sl No	Initiative	Developing Country	Low-carbon energy technol-ogy	Energy Innovation Institution
28	Establishment of a low-carbon energy fund for Asia	Thailand, India, China	Renewable Energy	Emerging Power Partners
29	Small-scale low-carbon energy investments in South Asia	India, Bhutan, Nepal	Renewable Energy and Energy Efficiency	The Small-scale Sustainable Infrastructure Development Fund
30	Financing to link low-carbon energy services and income generation	India, sri Lanka and Bhutan	Renewable Energy	SELCO Solar

A total of 26 energy innovation institutions were involved in implementing the 30 low-carbon energy innovations detailed in table 31 above. The 26 energy innovation institutions are spread on over 11 countries and 54 % of the organisations are from developing countries and the remaining 46% from developed countries. 42% of organisations are non-governmental organisations followed by 27% private sector; these were followed by government institutions and academia. The geographical distribution of these 26 Energy Innovation Institutions is shown in fig 29:

Fig 29: Geographical Distribution of Energy Innovation Institutions analysed

The above 26 energy innovation institutions were evaluated using the indicators of the EII index as shown in table 35 below:

Table 35: Analysis of Energy Innovation Institutions

Sl No	Energy Innovation Institution	Management and Expertise[386]	Technical Journal Articles[387]	Level of Funding[388]
1	Econoler International	50+20 = 70	250/60 = 4.16	3,712,000€/60
2	Biomass Users Network for Central America (BUN-CA)	35+15 = 50	45/13 = 3.46	1,718,317€/13
3	China Standard Certification	35+15 = 50	15/20 = 0.75	500,000€/20
4	Collaborative Standards and Labels Programme	40+10 = 50	3/3 = 1	=6823721€/3

386 The first score denotes the expertise of the innovation team based on their track-record achievements and qualifications. The second score indicates the management systems and how it has affected the institutions performance.

387 The technical articles data was not available for some the organisations analysed and data gaps were addressed by using data for similar sized organisations from the same or similar countries.

388 The financial data was not available for some of the organisations surveyed and the data gaps were addressed by using data from organisations with similar financial turnover in the same country or similar countries.

Sl No	Energy Innovation Institution	Management and Expertise[386]	Technical Journal Articles[387]	Level of Funding[388]
5	Fiorello H La Guardia Foundation	45+15 = 60	14/12 = 1.16	900,000€/12
6	Consejo de Ciencia y Tecnología del Estado de Guanajuato (CONCyTEG)	40+15 = 55	2/18 = 0.11	962,922€/18
7	The Energy and Resources Institute	55+20 = 75	200/499 = 0.4	12,274,235€/499
8	SouthSouthNorth	40+15 = 55	25/10 = 2.5	530,234€/10
9	Beijing Jike Energy New Technology Development Company	35+10 = 45	3/8 = 0.33	5,653,000€/15
10	Centre for Renewable Energy Development	40+15 = 55	33/14 = 2.35	310,000€/14
11	Energy for Sustainable Development	50+25 = 75	15/45 = 0.33	2,856,700€/45
12	China National Engineering Research Centre for Human Settlements	50+15 = 65	2/15 = 0.13	346,780€/15
13	Alliance to Save Energy	50+25 = 75	10/7 = 1.42	12,000,000€/184
14	Sustainable Energy Africa	45+20 = 65	37/12 = 3.08	664,843€/12
15	Centre for Sustainable Energy Technology (CSET)	35+10 = 45	2/4 = 0.5	66,540€/4
16	Organisation of American States	35+25 = 60	4/945 = 0.0042	63,470,000€/945
17	Winrock Brasil	50+20 = 70	3/722 = 0.0041	32,344,400€/722
18	Fundacion Solar	30+15 = 45	4/7 = 0.57	986,060€/17
19	IT Power	50+15 = 65	20/25 = 0.8	1,348,700€/25
20	University of Colorado Law School	55+20 = 75	25/8 = 3.08	765,000€/8
21	Comision Regulatoria de Energia Mexico	40+25 = 65	7/45 = 0.15	2,313,458€/45
22	Green Markets International	35+15 = 50	6/2 = 3	135,530€/2

Sl No	Energy Innovation Institution	Management and Expertise[386]	Technical Journal Articles[387]	Level of Funding[388]
23	Canmet Energy Technology Centre	55+20 = 75	100/110 = 0.9	7,406,000€/110
24	Emerging Power Partners	40+20 = 60	3/8 = 0.375	1,240,000€/8
25	The Small-scale Sustainable Infrastructure Development Fund	35+15 = 50	10/7 = 1.42	463,468€/7
26	SELCO Solar	40+20 = 60	4/26 = 0.15	964,806€/26

The criteria: expertise of organisations was scored based on the track-record, achievements and qualifications of the researchers and experts who are employed full-time employed. The management systems were scored on the basis of the evidence of how the managements have been effective in providing an environment of innovation and collaboration. It was examined how the organisation has performed under the current management in terms of its growth, innovation strategy and market[389] strategies. These have been scored based on an analysis of the experience. Track-record, projects and initiatives, bio-data of research managers and researchers, clients and the performance and achievements of the organisation as a whole.

While applying the criteria: technical journal articles, it was noted that several organisations which work in developing countries in the low-carbon energy sector do not accord priority to publishing articles in technical journals. While research and academic institutions accord considerable priority to publications in reputed technical journals, most government, private and non-governmental sector energy innovation institutions do not publish papers in technical journals. However these organisations publish a number of professional reports, papers and publications which are influencing low-carbon energy transition but are not peer-reviewed and published in a technical journal. A number of large energy innovation institutions also publish their own reports and papers. So the number of technical journals/researcher criteria has been modified to include all the publications, papers and reports that have been published by the Organisation. However it may be noted that information about professional reports, own publications and papers are not centrally available and there is a wide range of quality of these reports. The information about publications was not available for some of the organisations surveyed here but it was possible to obtain comparable data from other organisations implementing REEEP projects. The

[389] Geographical and technology markets

data from comparable institutions from the same country or similar countries were used as substitutes.

Level of funding for each researcher is also a criterion which can be skewed by the nature of the institution and the labour environment in which the energy innovation institution operates. For not-for-profit organisations the income and the expenditures are generally the same and it is easy to use this criteria. However for for-profit energy innovation organisations the income and the expenditures vary as a result of considerations of profit and loss. Therefore for private sector organisations the expenditure is taken to arrive at the funding per researcher criteria than the income. Similarly energy innovation institutions working on countries with strict labour laws and high social security costs tend to minimize the number of researchers or experts directly employed and tend to sub-contract or outsource the research to external organisations and consultants. These practices may also affect the effective application of this metric. Information on funding was not available for some of the organisations that are being analysed but it was possible to collect funding data on a number of other organisations which have implemented REEEP projects. Funding information from institutions of similar size from the same country or comparable countries was used as substitutes.

All the scores for each of the sub-criteria were normalised on a 100-point scale and the final scores were obtained by totaling the scores for each of the indicator. The Energy Institution Index was obtained by normalising the total scores on a 100-point scale and is shown in table 36 below.

Table 36: Energy Innovation Institution Index

Sl No	Energy Innovation Institution	Management and Expertise	Technical Journal Articles	Level of Funding	Energy Innovation Institution Index
1	Econoler International	79.17	100	53.85	92.31
2	Biomass Users Network for Central America (BUN-CA)	29.17	96.15	88.46	84.62
3	China Standard Certification	25.00	53.85	19.23	11.54
4	Collaborative Standards and labels Programme	25.00	65.38	96.15	73.08
5	Fiorello H La Guardia Foundation	54.17	65.38	76.92	76.92

Sl No	Energy Innovation Institution	Manage-ment and Expertise	Technical Journal Articles	Level of Funding	Energy Innovation Institution Index
6	Consejo de Ciencia y Tecnología del Estado de Guanajuato (CONCyTEG)	54.17	11.54	38.46	19.23
7	The Energy and Resources Institute	100	38.46	15.38	46.15
8	SouthSouthNorth	37.50	80.77	34.62	42.31
9	Beijing Jike Energy New Technology Development Compa-ny	4.17	30.77	100	38.46
10	Centre for Renewable Energy Development	37.50	76.92	7.69	26.92
11	Energy for Sustainable Development	100	26.92	57.69	65.38
12	China National Engineering Research Centre for Human Settlements	70.83	15.38	11.54	7.69
13	Alliance to Save Energy	100	69.23	61.54	88.46
14	Sustainable Energy Africa	70.83	88.46	46.15	80.77
15	Centre for Sustainable Energy Technology (CSET)	4.17	42.31	3.85	3.85
16	Organisation of American States	54.17	7.69	69.23	34.62
17	Winrock Brasil	79.17	3.85	26.92	23.08
18	Fundacion Solar	4.17	50	50	15.38
19	IT Power	70.83	57.69	42.31	57.69
20	University of Colorado Law School	100	92.31	84.62	100
21	Comision Regulatoria	70.83	23.08	30.77	30.77

Sl No	Energy Innovation Institution	Manage-ment and Expertise	Technical Journal Articles	Level of Funding	Energy Innovation Institution Index
	de Energia Mexico				
22	Green Markets International	25.00	84.62	76.92	73.08
23	Canmet Energy Technology Centre	100	61.54	73.08	96.15
24	Emerging Power Partners	54.17	34.62	92.31	61.54
25	The Small-scale Sustainable Infrastruc-ture Development Fund	25.00	73.08	65.38	53.85
26	SELCO Solar	54.17	19.23	80.77	50

The following observations can be made from the Energy Innovation Institution Index analysis for the 26 organisations from around the globe.

- It is seen that the EII index is applicable irrespective of the size of the organisa-tion and the location. Very diverse set of organisations figure in all the quartiles of the institutions analysed.
- It is seen that organisations from developed countries and organisations from the larger developing countries have high EII index scores. Generally organisations from smaller developing countries seem to have lower values of EII index scores reflecting the lower levels of publications, and financial turnover.
- Research and innovation institutions active in a large number of developing countries have generally scored high in the EII index scores. Other organisations which have policy, regulatory and political orientations have scored relatively low in the EII index scores.
- Organisations from developing countries tend to score relatively lower in the criteria of level of funding as the cost of living in these countries are relatively low and so are the salaries paid to researchers and experts.
- In a similar way organisations that are involved in applied research and imple-mentation of low-carbon energy system projects and initiatives have an undue advantage in the criteria on level of funding because the cost of the low-carbon energy equipment tends to inflate the funding per researcher;

- Organisations in developing countries also tend to have high staffing patterns compared to organisations in developed countries, which results in the denominator for the criteria being higher for both the criteria of technical journal articles and financing. Several staff also work as associates and work part time in the developed countries which also inflates the scores for both the criteria for developed country institutions.

Combining the three sub-indices for energy innovation institution, technology and developing country for all the 30 low-carbon energy technology initiatives we get the DeCLEI index applied to all the 30 low-carbon energy technology innovations. The results are shown in table 37 as follows:

Table 37: Application of DeCLEI Index to Low-carbon Energy Initiatives

Sl No	Initiative	Developing Country Sub-index	Energy Technology Sub-index	Energy Innovation Institution Sub-index	DeCLEI Index
1	Brasilian Energy Efficiency Fund	67.90	83.33	92.31	86.67
2	Central American Electrical Energy Efficiency Programme	81.48	16.66	84.62	30.00
3	Government Procurement Roadmap	88.89	83.33	19.23	40.00
4	Central American Standards and Labeling Programme	38.89	16.66	84.62	10.00
5	Renewable Energy Finance Facility	67.90	83.33	76.92	76.67
6	State level legal Framework for renewable energy	81.48	83.33	7.69	20.00
7	Sustainable Energy Regulatory Capacity Building	67.90	83.33	46.15	50.00
8	Energy Service Companies for Street Lighting	67.90	83.33	92.31	86.67
9	Low-carbon energy in Urban Slums	98.77	83.33	53.85	80

Sl No	Initiative	Developing Country Sub-index	Energy Technology Sub-index	Energy Innovation Institution Sub-index	DeCLEI Index
10	South-South Exchange on Village Power	77.16	83.33	61.54	63.33
11	Wind Energy Roadmap in China	88.89	83.33	34.62	56.67
12	Biomass co-firing in China	88.89	83.33	69.23	90.00
13	Low-carbon Building Programme in China	88.89	83.33	11.54	33.33
14	Low-carbon energy financial models in south Africa	98.77	16.66	88.46	53.33
15	City-level low-carbon energy strategies	98.77	16.66	80.77	46.67
16	Low-carbon energy policy for Liberia	41.02	83.33	3.85	3.33
17	Latin American Sustainable Energy Policy Forum	50.31	83.33	38.46	16.67
18	Amazonia Energy Initiative	67.90	83.33	26.92	23.33
19	Carbon Finance for low-carbon energy projects in Southern Africa	18.52	83.33	53.85	13.33
20	Low-carbon energy policy framework for Gautemala	25.93	83.33	23.08	6.67
21	Increasing the supply of Gold Standard CDM Projects	64.20	83.33	61.54	60.00
22	International Sustainable Energy Assessment	78.40	83.33	100	96.67

Sl No	Initiative	Developing Country Sub-index	Energy Technology Sub-index	Energy Innovation Institution Sub-index	DeCLEI Index
23	Implementation and Impact Phase of the International Sustainable Energy Assessment	83.34	83.33	100	100
24	Low-carbon energy regulation methodologies in Mexico	81.48	83.33	30.77	43.37
25	Innovative Financing to Accelerate Solar Water Heating	67.90	83.33	76.92	66.67
26	Low-carbon energy decision support tools	80.99	83.33	96.15	93.33
27	Low-carbon Energy services in Developing Countries	80.99	83.33	61.54	70.00
28	Establishment of a low-carbon energy fund for Asia	78.60	83.33	65.38	73.33
29	Small-scale low-carbon energy investments in South Asia	39.51	83.33	57.69	26.67
30	Financing to link low-carbon energy services and income generation	51.85	83.33	50	36.67

While determining low-carbon energy innovation index for a group of countries the average score for all the countries in the group was taken as the index score. For two countries – Bhutan and Liberia, data was not available to calculate the low-carbon energy innovation index scores and therefore average scores of countries in the same region[390] was used.

[390] For Bhutan average scores for South Asian countries and for Liberia average scores for African countries were used instead.

10 Observations and Conclusions: Can Low Carbon Energy Innovation be Measured?

10.1 Observations

Based on the application of DeCLEI to 30 low-carbon energy interventions spread over 21 developing countries and to 26 energy innovation institutions from 11 countries, the following observations can be made:

- Low carbon energy initiatives that have scored high in the application of DeCLEI have focussed on energy technologies with Low-Carbon Energy technology index and also countries that have high low-carbon energy potential.
- While the high scores in the Energy Innovation Institutions did have some influence in the relative positions of the initiatives but did not have fundamental influence on the final score of initiatives;
- It was also seen that initiatives that were implemented in countries with lower low-carbon energy potential generally scored low, irrespective of the scores of the energy innovation institution.

The results from the application of DeCLEI were also compared with the final results of the initiatives supported by REEEP and the final impact assessment reports of these completed initiatives. The descriptions of these initiatives are given in section 9.2.2. These comparisons are shown in table 38.

Table 38: Comparison of DeCLEI scores and final achievements

Sl No	Initiative	DeCLEI Index	Final Achievements
1	Brasilian Energy Efficiency Fund	86.67	In 2008 Petrobras created a joint venture EBL Companhia de Eficiência Energética S.A. and implemented energy efficiency projects covering 33 buildings of Oi group
2	Central American Electrical Energy Efficiency Programme	30.00	The project trained 128 stakeholders including investors, developers and policy-makers. No clear impacts on energy consumption reduction or technology/know-how transfer.
3	Government Procurement Roadmap	40.00	The Procurement roadmap was developed for China and presented Southeast Asian cases. Not much evidence of the procurement roadmap’s impacts.

Sl No	Initiative	DeCLEI Index	Final Achievements
4	Central American Standards and Labeling Programme	10.00	Standards established in Costa Rica, Nicaragua and El Salvador[391] Not much evidence of the impact of the standards.
5	Renewable Energy Finance Facility	76.67	US$ 70 million equity and guarantee facility to finance small hydro power and about 200 MW of new hydro capacity expected to be built.
6	State level legal Framework for renewable energy	20.00	The state level policy framework was developed in the state of Guanajato. However the impacts limited by the absence of a supporting national policy framework.
7	Sustainable Energy Regulatory Capacity Building	50.00	A regulatory framework document, study material and a case study developed and trainings held for the Andhra Pradesh Energy Regulatory Commission in India. APERC expected to implement a regulatory order.
8	Energy Service Companies for Street Lighting	86.67	Tender documents developed for the innovative model in Bhopal and the value of the tender at €1.5 million.
9	Low-carbon energy in Urban Slums	80	The project developed an innovative financial model combining carbon finance and certificate trading for urban slum in Cape Town with replication potential within South Africa and internationally.
10	South-South Exchange on Village Power	63.33	The transfer of experience from the Chinese township electrification programme helped Mongolia to design its national programmes.
11	Wind Energy Roadmap in China	56.67	Prepared a national Implementation Roadmap for Wind Energy Development which fed into policy and implementation targets such as China's 11th 5 year plan of 2006-2010
12	Biomass co-firing in China	90.00	The project developed a framework for biomass co-firing in China for renewable electricity. There has been increased use of biomass in electricity projects in China since.
13	Low-carbon Building	33.33	The project made recommendations on low-

391 The three countries have relatively low LCEI indices – El Salvador is 22.22, Nicaragua is 38.227 and Costa Rica is 53.09

Sl No	Initiative	DeCLEI Index	Final Achievements
	Programme in China		carbon building practices and there has been good momentum in construction of low energy buildings in China.
14	Low-carbon energy financial models in South Africa	53.33	The project developed the financial case for water utility energy efficiency in South Africa the results of which are being replicated in five municipalities.
15	City-level low-carbon energy strategies	46.67	The project helped sensitized several South African cities to pursue sustainable energy strategies.
16	Low-carbon energy policy for Liberia	3.33	The REEEP project resulted in establishing a renewable energy agency. Several other donor initiatives on the anvil in Liberia.
17	Latin American Sustain-able Energy Policy Forum	16.67	The project facilitated information exchanges and a report was prepared to advance the development and implementation of sustaina-ble energy policies in Argentina, Peru, Domini-can Republic and Guatemala[392].
18	Amazonia Energy Initiative	23.33	The PRISMA model implemented in communi-ty of Cachoeira do Aruã with income generat-ed from wood products.
19	Carbon Finance for low-carbon energy projects in Southern Africa	13.33	Project carried out training efforts in Mozam-bique and Tanzania and created more aware-ness. Not much results on implementation.
20	Low-carbon energy policy framework for Guatemala	6.67	Project was timely and had good coordination with the government. However Guatemala has a low LCEI[393].
21	Increasing the supply of Gold Standard CDM Projects	60.00	The project carried out training and dissemina-tion and increased the awareness on gold standard and increased capacity.
22	International Sustainable Energy Assessment	96.67	Created an on-line searchable database of all international energy agreements between key emerging countries China, India and the US. The projects outputs used by US Senate

[392] Three of the four countries covered by the project have low LCEI indices. Guatemala has a LCEI index of 25.93, Peru 39.51, Dominican Republic 38.27 and Argentina 77.78

[393] Guatemala has an LCEI Index of 25.93.

Sl No	Initiative	DeCLEI Index	Final Achievements
			Foreign Relations Committee for US policy making.
23	Implementation and Impact Phase of the International Sustainable Energy Assessment	100	Database expanded to include Brasil. Mexico, Russia and South Africa. The projects outputs used by US Senate Foreign Relations Committee for US policy making on international energy partnerships.
24	Low-carbon energy regulation methodologies in Mexico	43.33	Project created specific regulatory instruments for wind and Photovoltaics in Mexico. The PV and wind markets benefited from the regulations.
25	Innovative Financing to Accelerate Solar Water Heating	66.67	Created SWH fee for service business model awareness in Brasil and Caribbean. One operation using the model established in Brasil.
26	Low-carbon energy decision support tools	93.33	The version 4 for RETScreen the output is now being used in over 220 countries and by over 200,000 users making it the most popular clean energy software in the world.
27	Low-carbon Energy services in Developing Countries	70	The project expanded the scope of an IEA technology agreement cooperating with developing countries to cover other renewable energy technologies and emphasise rural energy.
28	Establishment of a low-carbon energy fund for Asia	73.33	The fund was to establish a € 50 million fund as a follower to an earlier fund. After a year of efforts the company decided not to pursue the establishment of the fund and withdrew. The fund was thus not established.
29	Small-scale low-carbon energy investments in South Asia	26.67	The fund supported 17 small projects 10 of which deal with solar lanterns replacing kerosene lamps.
30	Financing to link low-carbon energy services and income generation	36.67	Supported 9 sub-projects with co-financing from a women’s micro-credit bank.

Based on the application of DeCLEI to the 30 low-carbon energy innovation initiatives and comparing the DeCLEI scores to the final independent impact assessments of the projects, the following observations can be made:

- The highest rated low-carbon energy initiatives which had a DeCLEI Index score of more than 75 were the set of most successful projects based on independent assessments. All these 8 projects produced significant and in most cases tangible impacts to create low carbon energy policies, finance facilities, business models or tools that generally targeted countries with high LCEI scores;
- The lowest rated low-carbon energy initiatives which had a DeCLEI index score of less that 25 were generally projects that were either not quite successful in achieving their impacts or were implemented in countries with a low LCEI score. These 7 projects either produced project outputs which did not result in the desired outcomes or impacts or the impacts were created in countries with low potential for scale-up or global demonstration. The impacts envisaged by these projects were in the realm of policies, business and finance models;
- For the projects which received average DeCLEI index scores[394], it was seen that there is a good correlation between the final impact of the project and the DeCLEI index scores. In general where the DeCLEI scores were high[395], it was seen that the impacts produced by the projects were high. And such project activities included roadmaps, financial and business models, technology/know-how transfer and funds. It was also seen that where the DeCLEI scores were relatively lower the impacts created were either small or limited or the country where the initiative had geographically focussed had lower LCEI scores.
- There were also some exceptions in the 30 initiatives which did not conform and correlate with DeCLEI scores. Detailed examination revealed that there were 3 initiatives or 10% of the initiatives that did not entirely conform well to the DeCLEI scores vis-à-vis their impacts. These three initiatives are listed below:
    1. Wind Energy Roadmap in China which had an average DeCLEI score of 56.67 but was eventually one of the most successful projects by REEEP where the roadmap created policy conditions and targets which resulted in China being a global leader in wind energy;
    2. Amazonia Energy Initiative in Brasil which had a low DeCLEI score of 23.33 but which was considered a successful project as it piloted and established the feasibility of a concept on income generation from rural electrification;

[394] Between 25 and 75 DeCLEI Index scores
[395] Higher than 50 in general

3. Establishment of a low-carbon energy fund for Asia had a high DeCLEI score of 73.33 but the initiative was not pursued by the finance company after an effort which lasted one-year and the fund was never established.

- A closer examination of the above three initiatives that were not consistent with DeCLEI scores indicate that in two of the cases, the initiative was implemented by an organisation which scored low in the EII Index. Both organisations were reputed local organisations and did not score high on the criteria relating to technical journals and funding. The reasons such as large numbers of staff and lower levels of funding and publication by organisations in developing countries seem to have affected the EII rating of these two organisations and consequently the Low-carbon Energy Innovation Initiatives.

- The third project certainly had the right geographical focus, focus on high potential technologies of renewable energy and energy efficiency and a strong institution with a previous track-record. However the institution took a management decision not to pursue the initiative to establish a fund and the initiative was discontinued. Therefore there were no impacts and the initiative was deemed a failure. This raises another issue which affects all initiatives in general and new ventures such as establishment of a new fund in particular which is the issue of risk and risk management. Some of the initiatives which are rated high will certainly have high risks due to the nature of the activity and will affect the eventual outcome. However risk and its mitigation or management is not an issue covered by the thesis and the issue is not further researched here. However financiers of Low-Carbon energy initiatives such as REEEP will need to put in place effective systems for risk evaluation and mitigation of the initiatives it supports.

10.2 Updates and the final thesis

The following statements can be made with respect to the hypothesis after completion of the research efforts:

- Extensive research was carried out into low-carbon energy technologies with an emphasis on renewable energy and energy efficiency technologies but also covering other low carbon energy technologies such as advanced nuclear energy, clean coal, carbon capture and storage and smart-grid technologies. Research was carried out into the scientific and technical aspects of these technologies, their prospects and diffusion;

- Research was also carried out into the barriers for low-carbon energy technology diffusion and the lessons from barrier removal. These were helpful in characterising the determinants of successful low-carbon energy innovations;

- Detailed research was also carried out into technology innovation processes and the existing approaches to measure technology innovation. This research was helpful in defining the building blocks for measuring low-carbon energy innovation in developing countries.

- Research was also carried out into low-carbon energy institutions and the leading energy innovation initiatives globally to better understand the key aspects of energy innovation at the institutional level and at the initiative level. This research was helpful in identifying the key determinants of successful institutions and initiatives for low-carbon energy innovation.
- The developing country sub-Index was developed to assess the low-carbon energy potential and the innovation systems in the countries. The developing country sub- index was determined for 81 developing countries for which the data was available.
- The Low-Carbon Energy Technology Indices were developed for technologies such as renewable energy, advanced nuclear energy, advanced clean coal, carbon capture and storage, energy efficiency and smart-grids. This is expected to indicate the low-carbon energy potential of the technology against the baseline options;
- The Energy Innovation Institution (EII) Index uses metrics such as management and expertise, technical articles and funding to assess the capability of the energy innovation institution to carry out the low-carbon energy innovation initiative.
- A set of 30 Low-carbon energy innovation initiatives supported by REEEP and 26 Energy Innovation Organisations were identified to carry out research to validate the hypothesis and the measurement methodology and indices developed to evaluate the hypothesis. Data for the analysis was collected from the proposals, progress reports, evaluation reports, independent assessment reports of the initiatives available with REEEP.

The hypothesis defined at the inception of the reserach was that:

Low-carbon energy innovations in developing countries can be assessed on the basis of the innovation systems and the low-carbon energy technology potential in the developing country where the innovation is proposed, the low-carbon nature of the energy technology involved and the capacity of the Energy Innovation Institution involved.

As a result of the analytical work carried out as part of the research it was found that the hypothesis was valid for 90% of the 30 low-carbon energy innovations that was researched on. A close examination also revealed that 2 out of the 3 energy innovation initiative which did not conform to the hypothesis did suffer from limitations associated with comparing energy innovation institutions across the developed countries and developing countries.

Detailed examination of the metrics of the scores on the sub-criteria of the Energy Innovation Index was carried out by scrutinising the scores of the criteria on management and expertise, technical journal articles per researcher and financing per researcher. The total scores before normalisation were analysed after grouping the organisations into two Institutions from developing countries and institutions from developed countries. It was found that there were 12 energy innovation institutions from developed countries and 14 organisations from developing countries. It was also seen that the energy innovation institutions from developed countries occupied eight out of the top ten positions in energy innovation institutions. It was also seen that the average score of the 12 energy innovation institutions from developed countries were 51% higher than the 14 developing country counterparts. This variation in the ratings is a result of several factors some of the prominent ones being:

- The level of technical articles published by developed country energy innovation institutions and researchers is relatively high in comparison with counterparts in developing countries;
- The cost required to operate and manage a research or development institution and the average salaries are significantly higher in developed countries than in developing countries;
- Developing country energy innovation institutions tend to have larger numbers of average full-time staff compared to developed country organisations and many energy innovation institutions in developed countries maintain part-time and associate staff members who contribute to specific initiatives.

In view of the above factors which skew the Energy Innovation Institution Index towards developed country organisations, there maybe a need to either adjust and normalise the scores of one of such groups with the other or each of the groups to be considered separately.

The first of the above option may be accomplished by assigning different weights to energy innovation institutions from developing and developed countries to make them comparable.

The second option is to compare the energy innovation initiatives implemented or proposed to be implemented by developed country and developing country institutions separately. Since this research and the thesis work deals with low-carbon energy innovations in developing countries such an approach will be more appropriate for the research. An analysis of energy innovation institutions from developing countries was carried out and the results are shown in table 39.

Table 39: Developing Country Energy Innovation Institution Index

Sl No	Energy Innovation Institution	Management and Expertise	Technical Journal Articles	Level of Funding	Developing Country Energy Innovation Institution Index
1	Biomass users Network for Central America (BUN-CA)	29.17	96.15	88.46	100
2	China Standard Certification	29.17	53.85	19.23	21.43
3	Consejo de Ciencia y Tecnología del Estado de Guanajuato (CONCyTEG)	41.67	11.54	38.46	35.71
4	The Energy and Resources Institute	100	38.46	15.38	78.57
5	SouthSouthNorth	41.67	80.77	34.62	71.43
6	Beijing Jike Energy New Technology Development Company	4.17	30.77	100	64.72
7	Centre for Renewable Energy Development	41.67	76.92	7.69	50.00
8	China National Engineering Research Centre for Human Settlements	70.83	15.38	11.54	14.29
9	Sustainable Energy Africa	70.83	88.46	46.15	92.86
10	Centre for Sustainable Energy Technology (CSET)	4.17	46.15	3.85	7.14
11	Winrock Brasil	79.17	3.85	26.92	42.86
12	Fundacion Solar	4.17	50	50	28.57
13	Comision Regulatoria de Energia Mexico	70.83	23.08	30.77	57.14
14	SELCO Solar	54.17	19.23	80.77	85.71

The above results when applied to determine the DeCLEI would also result in validating the results for all of the initiatives covered. It is therefore proposed that the application of DeCLEI be targeted at evaluating low-carbon energy innovations in developing countries to be implemented by developing country based energy innovation institutions. It is also proposed that the hypothesis be modified to insert the words “Developing Country” to qualify the energy innovation institutions to arrive at the final thesis as follows:

Low-carbon energy innovations in developing countries can be assessed on the basis of the innovation systems and the low-carbon energy technology potential in the developing country where the innovation is proposed, the low-carbon nature of the energy technology involved and the capacity of the ***Developing Country*** *Energy Innovation Institution involved.*

10.3 Conclusions and Recommendations

The research which was carried out at the Institute of Electricity Economics and Energy Innovation at the Graz University of Technology during the period 2006-2011 was concluded with the following results:

- The research has identified that there are three key elements which are important in prioritising low carbon energy innovations in developing countries – the countries where the initiative will be implemented; the technology (s) that are part of the initiative and the institution which implements the low-carbon energy initiative;
- Based on an extensive research into low-carbon energy technologies, prospects, barriers and deployment; study of programmes and institutional frameworks in the energy sector several metrics were identified that could be used to measure technologies and institutions;
- Research was also carried out into energy technology innovation, innovation systems at the country levels and a detailed study was carried out into existing approaches globally to measure technology innovation;
- Based on this extensive research a hypothesis was developed as: “Low-carbon energy innovations in developing countries can be assessed on the basis of the innovation systems and the low-carbon energy technology potential in the developing country where the innovation is proposed, the low-carbon nature of the energy technology involved and the capacity of the Energy Innovation Institution involved.”
- Based on the hypothesis, a new quantitative approach to measuring low carbon energy innovation in developing countries was developed titled Developing

Country Low-Carbon Energy Innovation (DeCLEI) Index. Three sub-indices of DeCLEI titled Low-Carbon Energy Innovation (LCEI) Index, Low-Carbon Energy Technology (LCET) Index and Energy Innovation Institution (EII) Index to measure countries, technologies and institutions respectively.

- It is possible to apply the LECI index to evaluate developing country low-carbon energy innovation potential and rank developing countries. This was carried out for 81 countries and results presented. Similarly the LCET Index was calculated for six low-carbon energy technologies – renewable energy, nuclear energy, clean coal, carbon capture and storage, energy efficiency and smart grids. The LCET index results were also presented.
- The DeCLEI was applied to 30 selected low-carbon energy initiatives covering renewable energy, energy efficiency and smart grid technologies in 21 developing countries. The DeCLEI index was calculated for all the 30 Low-carbon energy initiatives, the 26 energy innovation institutions and the 21 developing countries where these innovations were implemented;
- The results of the DeCLEI index was compared with the external independent assessments of the 30 researched energy innovation institutions and it was found that the DeCLEI scores were consistent with the final impacts of the energy initiatives and there was a high level of correlation with 90% of the results being consistent;
- More research into the 10% non-conformities revealed that the energy innovation institutions located in developed countries and developed countries cannot be uniformly compared using the EII Index due to the factors such as cost-of-living and salary levels, employment practices and publication rates.
- The DeCLEI application was therefore limited to energy innovation institutions from developing countries and it was found that the results were valid for all the initiatives covered. Based on these results the hypothesis was modified to limit application to developing country institutions and as: “Low-carbon energy innovations in developing countries can be assessed on the basis of the innovation systems and the low-carbon energy technology potential in the developing country where the innovation is proposed, the low-carbon nature of the energy technology involved and the capacity of the Developing Country Energy Innovation Institution involved.”
- The research therefore has resulted in a valid hypothesis to measure low-carbon energy initiatives in developing countries implemented by developing country institutions. The testing of the hypothesis has also resulted in a quantitative framework consisting of the DeCLEI index and its three sub-indices which can be used to evaluate proposals for low-carbon energy initiatives;

- The DeCLEI Index can be a helpful tool for use in evaluation of applications for financial support in developing countries for low-carbon energy innovation. This is expected to be a useful tool for international energy technology partnerships[396] that have been proposed and the technology and mitigation finance mechanisms that are envisaged to be part of a future climate change architecture which will succeed the Kyoto Protocol.
- The DeCLEI Index can also be used by development agencies, the UN system and the World Bank and the Regional Development Banks (RDBs)[397] to prioritise their funding to support the best possible initiatives for low-carbon energy innovation in developing countries. In this way initiatives such as the Climate Investment Funds (CIF) available to the World Bank and RDBs could benefit from the application of DeCLEI;
- The DeCLEI Index can be used by REEEP for selection of projects from a large number of proposals it receives. However the application of DeCLEI to REEEP programmes are limited due to the donors limiting choice of countries to a few similar groups[398] and REEEP's focus on two low-carbon energy technologies[399] with same LCET Indices.
- However it is possible to use the EII sub-index within the REEEP selection process to improve the project selection. This is expected to result in selection of better energy innovation institutions. However integration of the EII sub-index into REEEP's systems will require collection of additional information on publications, employment and financial turnover of the institutions.
- DeCLEI provides a transparent and objective framework to pre-determine which low-carbon energy initiatives in developing countries will have higher impacts. In the current environment where the availability of resources from governments and other stakeholders are considered to be significantly short of the demand for low-carbon energy initiatives in developing countries, DeCLEI may provide a way to direct the available funding to the best possible opportunities.

[396] Such as the Carbon Capture and Storage technology partnership and various global technology roadmaps being developed by IEA and the Major Economies Forum(MEF)
[397] African Development Bank, Asian Development Bank, Inter-American Development Bank etc.
[398] Such as Emerging Economis, Sub-saharan African LDCs or Pacific Island Countries
[399] Renewable Energy and Energu Efficienct both of which share the LCET index of 83.33

Literature Survey

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Energy Information Administration – www.eia.doe.gov

Global Bioenergy Partnership – www.globalbioenergy.org

Global Environmental Facility – www.gefweb.org

Global Network for Energy for Sustainable Development – www.gnesd.org

Global Village Energy Partnership – www.gvepinternational.org

International Energy Agency – www.iea.org

International Monetary Fund - www.imf.org/external/index.htm

IPCC Emission Factor Database - http://www.ipcc-nggip.iges.or.jp/EFDB/main.php

Mediterranean Renewable Energy Partnership – www.medrep.info

Odyssee – www.odyssee-indicators.org

OECD –www.oecd.org

Reegle – www.reegle.info

Renewable Energy and Energy Efficiency Partnership – www.reeep.org

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TT: Clear – Technology Transfer Clearinghouse- http://unfccc.int/ttclear/jsp/index.jsp

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Abbreviations

Abbreviation	Expansion
ABWR	Advanced Boiling Water Reactor
AC	Alternating Current
ACP-EU	Africa, Caribbean and the Pacific – European Union
ADB	Asian Development Bank
AEI	Amazonia Energy Initiative
AfDB	African Development Bank
AMI	Advanced Metering Infrastructure
AP	Andhra Pradesh
APEC	Asia-Pacific Economic Cooperation
APERC	Andhra Pradesh Electricity Regulatory Commission
APWR	Advanced Pressurised Water Reactor
ASHRAE	American Society of Heating, Refrigeration and Air-conditioning Engineers
ASTAE	Asia Alternative Energy Unit
ARCO	Archibugi and Coco
BAP	Bali Action Plan
BEE	Bureau of Energy Efficiency, India
BIS	Bureau of Indian Standards
BOT	Build-Operate-Transfer
BRICS	Brazil, Russia, India, China and South Africa
BUN-CA	Biomass Users Network of Central America
CCS	Carbon Capture and Storage
CDM	Clean Development Mechanism
CDP	Carbon Disclosure Project
CEC	California Energy Commission
CERs	Certified Emission Reductions
CFL	Compact Fluorescent Lamps
CHP	Combined Heat and Power
CIP	Competitive Industrial Performance

Abbreviation	Expansion
CLASP	Collaborative Labelling and Appliance Standards Programme
CONAE	Comision Nacional para el Ahorro de Energia
CPUC-ED	California Public Utility Commission’s Energy Division
CRE	Comison Reguladora de Energia
CRED	Centre for Renewable Energy Development
CSET	Centre for Sustainable Energy Technologies
CTF	Clean Technology Fund
DC	Direct Current
DeCLEI	Developing Country Low-Carbon Energy Innovation Index
DEFRA	Department of Food Rural Agriculture and Environment
DESA	Department of Economic and Social Affaires
DFA	Distribution Feeder Automation
DoE	United States Department of Energy
DPLG	Department of Provincial and Local Government, South Africa
DSM	Demand Side Management
EAF	Electric Arc Furnace
EBRD	European Bank for Reconstruction and Development
E+Co	Energy Investment Company
EE	Energy Efficiency
EEC	Energy Efficiency Coalition
EEG	Erneuebare Energien Gesetz
EII	Energy Innovation Institution Index
EPC	Engineering, Procurement and Construction
EPI	Environmental Performance Index
EPP	Emerging Power Partners
EPR	European Pressurised Water Reactor
ESBWR	Economic Simplified Boiling Water Reactor
ESCOs	Energy Service Companies
ESMAP	Energy Sector Management Programme
EUEI	European Union Energy Initiative
EV	Electric Vehicle

Abbreviation	Expansion
EVO	Efficiency Valuation Organisation
FDI	Foreign Direct Investment
FIDE	Fideicomiso para el Ahorro de Energia Electrica
FLISR	Fault Location Isolation and Service Restoration
FMC	Funds Management Company
FONDELEC	Latin American Clean Energy Services Fund
G-8	Group of Eight
GBEP	Global Bio-Energy Partnership
GDP	Gross Domestic Product
GEEREF	Global Energy Efficiency and Renewable Energy Fund
GED	Grupo de Accao em Energias Renouvaveis a Desenvolvimento
GEF	Global Environment Facility
GFR	Gas-cooled Fast Reactor
GHG	Green House Gas
GII	Global Innovation Index
GMI	Green Markets International
GNESD	Global Network for Energy for Sustainable Development
GS	Gold Standard
GTZ	Deutsche Gesellschaft für Technische Zusammenarbeit
GVEP	Global Village Energy Partnership
GWEC	Global Wind Energy Council
HCI	Human Capital Index
HDI	Human Development Index
HVAC	Heating Ventilation and Air-conditioning
HVDC	High Voltage Direct Current
IAEA	International Atomic Energy Agency
IBRD	International Bank for Reconstruction and Development
IC	Internal Combustion
ICSID	International Centre for Settlement of Investment Disputes
ICT	Information and Communication Technologies
ICLEI	International Council of Local Environmental Initiatives

Abbreviation	Expansion
IDA	International Development Agency
IDAE	Instituto para la Diversificacion y Ahorro de la Energia
IDB	Inter-American Development Bank
IEA	International Energy Agency
IEE	Institute of Electricity Economics and Energy Innovation
IFC	International Finance Corporation
IGCC	Integrated Gasification Combined Cycle
IMF	International Monetary Fund
IPCC	Inter-Governmental Panel on Climate Change
IPMVP	International Performance Measurement and Verification Protocol
IPR	Intellectual Property Rights
IREC	Interstate Renewable Energy Council
IREDA	Indian Renewable Energy Development Agency
IRENA	International Renewable Energy Agency
ISEA	International Sustainable Energy Assessment
ISO	International Organisation for Standardisation
ISP	Internet Service Provider
IT	Information Technology
IVVC	Integrated Volt-VAR Control
IUCN	International Union for Conservation of Nature
JREC	Johannesburg Renewable Energy Coalition
KEI	Knowledge Economy Index
KfW	Kreditanstalt für Wiederaufbau
LAC	Latin America and the Caribbean
LBNL	Lawrence Berkeley National Laboratories
LCEI	Low-carbon Energy Innovation Index
LCET	Low-carbon Energy Technology
LDCs	Least Developed Countries
LED	Light Emitting Diodes
LFA	Logical Frame Approach
LFR	Lead-cooled Fast Reactor

Abbreviation	Expansion
LNG	Liquefied Natural Gas
LPG	Liquefied Petroleum Gas
LULUCF	Land-use, Land-use Change and Forestry
LWRs	Light Water Reactors
M&V	Measurement and Verification
MDM	Meter Data Management
MEA	Monoethanolamine
MEDREP	Mediterranean Renewable Energy Partnership
METI	Ministry for Economy Trade and Industry, Japan
MIGA	Multilateral Investment Guarantee Agency
MME	Ministry of Mines and Energy
MNRE	Ministry for New and Renewable Sources of Energy
MoU	Memorandum of Understanding
MP	Madhya Pradesh
MPSEB	Madhya Pradesh State Electricity Board
MRV	Measurement, Reporting and Verification
MSC	Most Significant Change
MSR	Molten Salt Reactor
NaFin	Nacional Financiera
NASA	National Aeronautics and Space Administration
NBAL	The National Accreditation Board for Testing and Calibration Laboratories, India
NDRC	National Development and Reform Commission, China
NGO	Non-Governmental Organisation
NIS	National Innovation Systems
NOx	Oxides of Nitorgen such as NO, NO_2, N_2O_2 etc.
NRCan	Natural Resources Canada
NREL	National Renewable Energy Labs
OAS	Organisation of American States
OECD	Organisation for Economic Cooperation and Development
OLADE	Organisacion Latinoamericana de Energia
OM	Outcome mapping

Abbreviation	Expansion
PDDs	Project Design Documents
PEMF2	Private Energy Markets Fund-II
PEV	Plug-in Electric Vehicle
PFE	Swedish Programme for Improving Energy Efficiency
PHEV	Plug-in Hybrid Electric Vehicle
PMIS	Programme Management Information System
PPPs	Public-Private-Partnerships
PV	Photovoltaics
PVPS	Photovoltaic Power Systems
PWRs	Pressurised Water Reactors
R&D	Research and Development
RBM	Results Based Monitoring
RE	Renewable Energy
REEEP	Renewable Energy and Energy Efficiency Partnership
REFUND	Rural Energy Fund, Liberia
REO	Renewable Energy Obligation
REIL	Renewable Energy and International Law
RETScreen	Renewable Energy Technologies Screening Software
Ren21	Renewable Energy Policy Network for the 21st Century
RPGs	Recommended Practice Guides
RTC	Renewable Tax Credit
S&L	Standards and Labelling
S3IDF	Small-scale Sustainable Infrastructure Development Fund
SAAWU	South African Association of Water Utilities
SACN	South African Cities Network
SALGA	South African Local Government Association
SCADA	Supervisory Control and Data Acquisition
SCWR	Supercritical Water Cooled Reactor
SEI	Sustainable Energy Ireland
SELCO	Solar Electric Light Company
SEPI	Sustainable Energy Policy Initiative

Abbreviation	Expansion
SERN	Sustainable Energy Regulators Network
SEWA	Self-Employed Women’s Association
SFR	Sodium-cooled fast Reactor
SHP	Small Hydro Power
SIDS	Small Island Developing States
SLC	Smart Load Control
Sl. No.	Serial Number
SMES	Superconducting Magnetic Energy Storage
SMEs	Small and Medium Enterprises
SOx	Oxides of Sulfur such as SO_2, SO_3 etc
SPV	Solar Purpose Vehicle
SSI	Sustainable Society Index
SSN	South South North
S3IDF	Small Scale Sustainable Infrastructure Fund
SUV	Sport Utility Vehicle
SWH	Solar Water Heating
TAI	Technology Achievement Index
TaTEDO	Tanzania Traditional Energy Development Organisation
TERI	The Energy and Resources Institute
TNAs	Technology Needs Assessments
TREC	Tradable Renewable Energy Certificates
TRIPS	Trade Related Intellectual Property Rights
TT:Clear	Technology Transfer Information Clearing House
TUG	Graz University of Technology
UAE	United Arab Emirates
UN	United Nations
UNCTAD	UN Commission on Trade and Development
UN-DESA	United Nations Department of Economic and Social Affaires
UNDP	United Nations Development Programme
UNEP	United Nations Environment Programme
UNFCCC	United Nations Framework Convention on Climate Change

Abbreviation	Expansion
UNICI	UNCTAD Innovation Capability Index
UNIDO	United Nations Industrial Development Organisation
UNTS	United Nations Treaty Series
USAID	United States Agency for International Development
US	United States
USCC	Ultra Super-Critical Coal
USEPA	United States Environmental Protection Agency
USPTO	US Patents and Trademark Office
V2G	Vehicle-to-Grid
VAR	Reactive Power
VHTR	Very High Temperature Reactor
WBCSD	World Business Council on Sustainable Development
WCI	World Coal Institute
WEC	World Energy Council
WEF	World Economic Forum
VERs	Verified Emission Reductions
WB	World Bank
WSSD	World Summit on Sustainable Development
WTO	World Trade Organisation
WWF	World-Wide Fund for Nature

Units

$	Dollar
%	Per cent
¢	Cents
°C	Degree Celsius
€	Euro
bar	100 kilo pascals
DM	Deutsche Mark
g/kWh	Grams per kilowatt-hour
J	Joules
kg	Kilogram
kW	Kilowatt
l	litres
m^2	Square meter
m^3	Cubic Meters
MPa	Mega Pascals
Mt	Mega tonnes
MWp	Mega Watt-peak
mtoe	million tonnes of oil equivalent
ppm	parts per million
t	Tonnes
tCO_2e	Tonnes of carbon dioxide equivalent
toe	tonnes of oil equivalent
V	volt
W	watts
W/m^2	Watts per meter square
Wh	watt-hour
$Wh/M^2/day$	Watt-hour per square meter per day
Wp	Watt-peak

y	Year

List of illustrations

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