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Chapter 9

Renewable Energy in the Context of Sustainable Development

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Chapter 9: Renewable Energy in the Context of Sustainable Development

CONTENTS

EXECUTIVE SUMMARY

Development is a concept frequently associated with economic growth, still in many cases disregarding income distribution, physical limits from the environment and the external costs of impacts caused by some and borne by others. Climate change is one of these most relevant impacts, with externalities present at global level.

Sustainable Development (SD) is a relatively recent concept, aiming to consider such impacts. There are several definitions of SD, but probably the most important came up in 1987, with an influential report published by the United Nations, entitled “Our Common Future” (or “The Brundtland Report”). In this publication, sustainable development is a principle to be pursued, in order to meet the needs of the present without compromising the ability of future generations to meet their own needs. The report recognized that poverty is one of the main causes of environmental degradation and that equitable economic development is a key to addressing environmental problems.

Energy for sustainable development has three major pillars: (1) more efficient use of energy, especially at the point of end-use, (2) increased utilization of renewable energy, and (3) accelerated development and deployment of new and more efficient energy technologies. The questions of renewable and sustainable energy have their roots in two distinct issues: while renewability is a response to concerns about the depletion of primary energy sources (such as fossil fuels), sustainability is a response to environmental degradation of the planet and leaving a legacy to future generations of a reduced quality of life. Both issues now figure prominently on the political agendas of all levels of government and international relations.

Much of the discourses on SD have historically focused on economic and environmental dimensions of renewable energy technologies and their implementation. Social and institutional dimensions have not received the same degree of attention. With growing interest in the two-way relationship between SD and renewable energy, the latter two dimensions need to be given the same level of importance. The use of renewable energy technologies can significantly reduce GHG emissions and some technologies have ancillary or co-benefits that will reduce local pollution and improve health benefits.

The reverse relationship whereby development that is sustainable can create conditions in which mitigation through the use of renewables can be effectively pursued is equally important and needs to be highlighted in future development pathways. Most development pathways already focus on SD goals such as poverty alleviation, water and food security, access to energy, reliable infrastructure, etc. How to make these pathways more sustainable such that GHG emissions are reduced is critically important for permitting an increased role for renewable energy technologies.

Access to, and affordability of, modern forms of energy, especially electricity for all purposes and clean fuels for cooking, heating, lighting and transportation to the billions of people without them today and in the future is a major challenge in itself. Wide disparities within and among developing countries contribute to social instability and affect basic human development. Making the joint achievement of promoting access while simultaneously making a transition to a cleaner and secure energy future is a challenging task.

Energy services can play a variety of direct and indirect roles in helping to achieve the millennium development goals - MDGs. They can halve extreme poverty (e.g. providing more jobs), reduce hunger (through improved agriculture, for example), increase access to safe drinking water, allow lighting that permits home study, increase security, among others. Moreover, efficient use of energy sources and good management can help to achieve sustainable use of natural resources and reduce deforestation (UNDP, 2004).

Renewable energy technologies are ones that consume primary energy resources that are not subject to depletion. Renewable energy resources have also some problematic but often solvable technical and economic challenges, like not fully accessible, sometimes temporally and regionally variable and not cost competitive. In addition to the direct SD implications of renewable energy, it is important to assess their life-cycle impacts. The latter can significantly influence the selection choice among competing renewable technologies.

From the policy perspective, the main attractions of renewable energy are their security of supply, and the fact that they are environmentally relatively benign compared to fossil fuels. Most forms of renewable energy, such as hydro, wind, solar and biomass, are available within the borders of one country and are not subject to disruption by international political events. (Reword using Tom's paragraph)

9.1 Introduction

Development is a concept frequently associated with economic growth, still in many cases disregarding income distribution, physical limits from the environment and the external costs of impacts caused by some and borne by others. Climate change is one of these most relevant impacts, with externalities present at global level.

Sustainable Development (SD) is a relatively recent concept, aiming to consider such impacts. There are several definitions of SD, but probably the most important came up in 1987, with an influential report published by the United Nations, entitled “Our Common Future” (or “The Brundtland Report”). In this publication, sustainable development is a principle to be pursued, in order to meet the needs of the present without compromising the ability of future generations to meet their own needs. The report recognized that poverty is one of the main causes of environmental degradation and that equitable economic development is a key to addressing environmental problems. The report also emphasized the issue of the legacy that the present generation is leaving for future generations.

The concept of sustainable development (SD) has its roots in the idea of a sustainable society (Brown, 1981) and in the management of renewable and non-renewable resources. The World Commission on Environment and Development adopted the concept and launched sustainability into political, public and academic discourses. The concept was defined as “development that meets the needs of the present without compromising the ability of future generations to meet their own needs” (Bojo, Maler, and Unemo, 1992; WCED, 1987).

While there are many definitions of sustainable development, the international sustainability discourse is helping to establish some commonly held principles of sustainable development. These include, for instance, the welfare of future generations, the maintenance of essential biophysical life support systems, ecosystem wellbeing, more universal participation in development processes and decision-making, and the achievement of an acceptable standard of human well-being (WCED, 1987; Meadowcroft, 1997; Swart, Robinson, and Cohen, 2003; MA, 2005).

Since the early 1960´s, the SD concept has grown out of concerns about a declining quality of the environment coupled with increasing needs for resources as populations expand and living standards rise. Early initiatives focused more on individual attributes of the environment, including water quality, air quality, management of hazardous substances and cultural resources. Some of the outcomes from the initiatives included a complex array of regulations intended to manage and improve development, a movement toward recycling of consumable resources and an emphasis on renewable energy as a substitute for energy production that consumed resources (Frey and Linke, 2002). While the initiatives taken regionally had many positive effects, it soon became evident that there were global environmental issues that needed to be addressed as well.

A significant event to the SD movement was the United Nations Conference on Environment and Development (UNCED) held in Rio de Janeiro, Brazil, in 1992, when the United Nations Framework Convention on Climate Change (UNFCCC) was proposed, seeking to stabilize atmospheric concentrations of greenhouse gases at considered safe levels. In 1997, the 3rd Conference of the Parties (COP) to the UNFCCC resulted in the Kyoto Protocol, a multilateral environmental agreement (MEA) aiming to curb worldwide emissions.

The discussion of sustainable development in the IPCC process has evolved since the First Assessment Report which focused on the technology and cost-effectiveness of mitigation activities, to the Second Assessment Report (SAR) that included issues related to equity and to environmental (Hourcade et al., 2001) and social considerations (IPCC, 1996). The Third Assessment Report (TAR) further broadened the treatment of SD by addressing issues related to global sustainability and the Fourth Assessment (AR4) included chapters on SD in both WG II and III reports with a focus on a review of both climate-first and development-first literature. The SRREN report will also serve as a good starting point for the Fifth Assessment (AR5) report.

In light of this background, every chapter of this WGIII SRREN focuses to some extent on its links to sustainable development practices. Chapter 1 introduces the concept, Chapters 2 to 7 cover the environmental and other implications of bioenergy, direct solar energy, geothermal, hydropower, ocean and wind energy, and Chapters 8, 10, and 11 focus on integration, costs and benefits, and policy respectively.

This chapter focuses on aspects of sustainable development that are not covered in depth in the other chapters, and as an integrative chapter it compares and reports the SD impacts of multiple technologies. The impacts include environmental and socio-economic aspects for many of which only qualitative information is available. The chapter begins by highlighting the two-way relationship between SD and renewable energy in Section 9.1. The discussion focuses on the interaction between SD and renewable energy in Section 9.2, on impacts of renewables on the socio-environment aspects in Section 9.3, and on socio-economic aspects in Section 9.4. Section 9.5 describes the implications of sustainable development pathways on renewables and finally Section 9.6 focuses on selected policy implications.

9.1.1 The Two-way Relationship between Sustainable Development and Renewables

Economic and social development has always depended on energy services for comfort (e.g., space heating and cooling), convenience (e.g., food storage and cooking), mobility (e.g., motive power), and productivity (e.g., power for operating tools). Throughout most of human history, these services have been provided by renewable energy sources such as biomass, hydropower, wind, and passive solar energy because they were the only alternatives at hand; but over the past several centuries industrial economies and societies have transformed landscapes and the quality of life by exploiting non-renewable fossil energy sources or other non-traditional sources such as nuclear energy.

In most respects, consumers of energy services are focused on whether those essential services are abundant, reliable, and affordable – not on where the energy comes from. In many industrial societies, in fact, energy is viewed not as a commodity but as an entitlement (Aronson, 1984), and governments are considered responsible for meeting this fundamental human need, along with health, education, opportunity for self development, food, shelter, and safety. When more energy services are considered essential for sustainable development, getting more energy can be a higher priority than carbon emissions or other indirect effects associated with choices among energy sources. In other words, whether the energy source is renewable or not is not always the most important issue under a development perspective.

Central issues for renewable energy in the modern context include all three of the dimensions of energy services for development:

- Abundance. Among currently available renewable energy technologies large-hydro has shown significant penetration in many regions. However, in many other regions where current renewable energy niches in either electricity production or transportation fuels are low, increasing them to significantly higher levels is a profound challenge to scalability because of the magnitude of the needs. Clearly, Brazil stands out as a sizeable economy built to a considerable degree on hydropower, plus significant attention to biofuels but realistic near-term trajectories toward that kind of energy mix for other large countries remain elusive. Meanwhile, some smaller countries and regions are becoming laboratories for pursuing more ambitious goals, such as Denmark's goal of increasing its share of wind power as an electricity source.

- Reliability. Many renewable energy sources are based on continual energy sources, such as water flow or plant growth, but some are based on intermittent energy sources, such as solar radiation or wind. Where the sources are intermittent, the only ways that they can meet continuing needs for energy services are by energy storage, improved grid integration and management, and/or by using other energy sources as supplements, each of which tends to increase costs and reduce net benefits.
- Affordability. Energy costs are a complex issue for renewable energy. At a local scale, in many cases renewable energy options offer a prospect of reduced energy costs. In applications such as rural lighting, solar lanterns that replace kerosene lamps are cost effective particularly where kerosene is subsidized. But for larger-scale energy needs for development, fossil energy sources – or intermediate sources dependent on them -- are considerably less expensive at present (except for select hydro and wind power sources). Achieving grid parity through rapid reduction in costs of renewable technologies is a oft-noted aim in many regions that are pursuing targeted goals for RE penetration.

Renewable energy applications are essential to deliver genuine results on Millennium Development Goals and all five World Summit on Sustainable Development 2002 (WSSD) components:

- water: sustaining communities and industry without waste or pollution;
- energy: generated from clean, renewable sources;
- health: ensuring clean water, air and sanitation;
- agriculture: renewable base with sustainable forms of irrigation;
- biodiversity: elimination of habitat destruction, such as energy poverty induced deforestation practices, or water depletion and contamination in fossil and nuclear power generation.

Making development more sustainable recognizes that there are many ways in which societies balance the economic, social, environmental, and institutional aspects, including climate change, dimensions of sustainable development. It also admits the possibility of conflict and trade-offs between measures that advance one aspect of sustainable development while harming another (Munasinghe, 2000). For a development path to be sustainable over a long period, however, wealth, resources, and opportunity must be shared so that all citizens have access to minimum standards of security, human rights, and social benefits, such as food, health, education, shelter, and opportunity for self-development (Reed, 1996).

The earlier chapters (mainly Chapters 2-7) provide an overview of the impacts of the implementation of many renewable technologies and practices that are being or may be deployed at various scales in the world. In this chapter, the information from the sectoral chapters is summarised and supplemented with findings from the sustainable development literature.

Synergies with local sustainable development goals, conditions for their successful implementation, and tradeoffs where the climate mitigation and local sustainable development may be at odds with each other are discussed. In addition, the implications of policy instruments on sustainable development goals are described in Section 9.5 and 9.6. As documented in the sectoral chapters, renewables options often have positive effects on aspects of sustainability, but may not always be sustainable with respect to all three dimensions of SD -- economic, environmental and social. In some cases the positive effects on sustainability are more indirect, because they are the results of side-effects of reducing GHG-emissions such as through the use of biofuels. Therefore, it is not always possible to assess the net outcome of the various effects.

The sustainable development benefits of renewable energy options will vary across sectors and regions. Tables 2 and 3 describe the positive and negative impacts of renewables, fossil fuels ands nuclear energy technologies on a variety of selected SD indicators. Appendix A provides more detailed information on the content in these tables. Generally, options that improve productivity of resource use, whether it is energy, water, or land, yield positive benefits across all three dimensions of sustainable development. More efficient and environmentally friendly use of bio energy can enhance productivity and promote social harmony and gender equity by reducing strain on humans and the natural environment. Other categories of options have a more uncertain impact and depend on the wider socioeconomic context within which the option is being implemented. A finite amount of land area is available for bioenergy crops, for instance, which limits the amount of fuel that can be produced and the carbon emissions that can be offset.

In the sectoral discussion below we focus on the three aspects of sustainable development – environmental, and economic and social (Section 9.3). Environmental impacts include those occurring in local areas on air, water, and land, including the loss of biodiversity, human health and the built environment. Virtually all forms of renewable energy supply demand land and/or water resources, and cause some level of environmental damage. The emission of greenhouse gases (GHG) is often directly related to the emissions of other pollutants, either airborne, e.g. particulates from burning biomass which causes local or indoor air pollution, or waterborne, e.g., from leaching of nitrates from fertilizer application in intensive bioenergy cropping.

Economic implications include costs and overall welfare. Sectoral costs of various mitigation policies have been widely studied and a range of cost estimates are reported for each sector at both the global and country-specific levels in the sectoral chapters and in Chapter 10. Yet mitigation costs are just one part of the broader economic impacts of SD. Other impacts include growth and distribution of income, employment and availability of jobs, government fiscal budgets, and competitiveness of the economy or sector within a globalizing market. The social dimension includes issues such as gender equality, governance, equitable income distribution, housing and education opportunity, health impacts, and corruption. Most renewable energy options will impact one or more of these issues, and both benefits and tradeoffs are likely.

In addition to the above renewable energy impacts on sustainable development, the implications of the pursuit of SD pathways on renewable energy are equally important. The pursuit of rural development in all countries for example has been accelerated through the process of electrification. In the modern era, renewable energy sources such as the use of solar lanterns as a substitute for kerosene-fuelled lamps offers a low-pollution technology with significant health benefits. Similarly the increased demand for water can be facilitated through the use of biogas-driven electric pumps.

Climate change is one of the most important global environmental challenge facing humanity with implications for food production, natural ecosystems, fresh water supply, and health. It is projected to lead to temperature increases as high as 6 degrees C by 2100 (IPCC and SRES, 2000) [TSU: reference will be corrected] and cause changes in regional and severity of precipitation patterns, sea level rise and flooding, regional temperature increases, and wind storms. Since all the renewable energy sources are directly connected to one or more of the above natural parameters, their energy output will be affected either through an impact on the infrastructure and energy source, or through a change in operating parameters. The impact of sea level rise on hydro power sources and biomass is probably the most studied among the renewable sources because of the impact on land and water is easier to estimate than the change in wind patterns and regimes.

While renewable energy sources may be affected by climate change impacts they can also be used as adaptation strategies. Micro grids using PV technologies for instance can serve as a means of electricity in cyclone shelters and after hurricanes and earthquakes.

9.1.2 Energy Indicators of Sustainable Development

To make implementation more sustainable, indicators can help to monitor progress towards sustainable development, and identify where improvements need to be made. There are many different ways to classify indicators of sustainable development (Sathaye et al., 2007). In 1995 United Nations Department of Economic and Social Affairs (UNDESA) began working to produce an overall set of indicators for sustainable development and concluded with a package of 58 indicators, of which only 3 energy related: annual energy consumption per capita, intensity of energy use and share of consumption of renewable energy resources. At the 2002 WSSD, the International Atomic Energy Agency (IAEA) presented a partnership initiative, in cooperation with UNDESA, the International Energy Agency (IEA), the Statistical Office of the European Communities (Eurostat) and the European Environment Agency (EEA), defining a set of 30 energy indicators and corresponding guidelines and methodologies to be used worldwide by countries in tracking their progress toward nationally defined sustainable energy development goals. These are based on seven themes that include equity, health, use and production patterns, security, air, water and land themes. Most of the social and environmental trends can be clearly identified as being desirable or undesirable, but it is not possible to provide a black-and-white evaluation of the economic ones. The development of sustainability criteria requires the analysis of local conditions and, for the formulation of what is to be considered sustainable, the involvement of local stakeholders. According to the field of activities, different organizations have developed sustainability criteria and tools, e.g. International Labour Organization (ILO) for acceptable labor conditions, the WWF for ecological aspects, the Worldbank for financial results; the OECD and the UN for development policymaking and information (Lewandowski and Faaij, 2006).

Measurement and reporting of indicators is thus a critical aspect of the implementation of sound renewable energy technologies. Measurement not only gauges but also spurs the implementation of sustainable development and can have a pervasive effect on decision-making (Meadows, 1998; Bossel, 1999). In the subsequent sections, we make use of some of the relevant indicators provided by the IAEA in reporting the relative sustainable development synergies and tradeoffs of various renewable energy options.

9.1.3 Barriers and Opportunities

There are several key barriers that prevent the more rapid introduction of renewable energy technologies into the energy market. These include (1) high first cost of renewable technologies, (2) lack of accounting of externalities of conventional generation, (3) lack of data and information about resources, (4) challenge of integrating renewable energy technologies into the electricity grid, (5) susbsidies for conventional supplies, and (6) lack of storage facilities. These barriers are already noted and discussed in previous chapters. In addition, there are several SD barriers that limit the introduction and scale of RE technologies. These include (1) access to land resources, (2) population displacement, (3) water pollution, (4) ecosystem and biodiversity, (5) human health, (6) built environment and (7) inadequate capacity to build and monitor performance of renewables.

These barriers have limited the introduction or expansion of RE technologies in many countries (Appendix A). Land use for bioenergy may compete with food supply, and geothermal generation can lead to land subsidence. Displacement of population from large-hydro reservoirs is limiting the expansion of this source of power. Water usage for crops and fertilizer nitrate pollution from bioenergy sources has been documented as an important issue (see Section 9.3.4). Indoor pollution from biomass use, nuisance effects from wind mills, and toxic waste from manufacturing PV, potential infrastructure damage due to inundation act as additional barriers to RE expansion. There are also strong concerns such as gender equity in rural areas in developing countries, which have largely been ignored to date but may act as a barrier in the future. As in the case of non-SD barriers there are many ways to overcome or minimize the SD barriers as well.

Ultimately capacity building is a key barrier to the rapid transfer of technologies across and within countries. Lack of capacity to set RE policies and design and implement programs delays and sometimes negates implementation of renewable technologies. Within countries, lack of maintenance in rural areas prevents adoption or limits the scale up of commercially available technologies.

9.2 Interactions between sustainable development and renewable energies

9.2.1 Sustainable Development Links to Renewable Energy Options

Some of the most relevant SD goals are described in Appendix A: poverty reduction; water security; sanitation; food security; energy security; energy access; energy affordability; infrastructure; governance; land use and rural development. Compared to conventional fossil fuels, nuclear energy and large hydros – which have overall highly concentrated and capital-intensive production, transformation and distribution chains - renewables have an important role in rural development. Relatively simple systems such as solar panels, improved cookstoves or micro hydro plants can provide the necessary lighting, heat or electricity to pump water, prepare food, refrigerate vaccines and medicines, and allow education during the night period. Local pollution and health benefits are improved.

There is a need to substitute human energy for modern energy systems that will reduce drudgery and increase wellbeing. Energy poverty is a perennial problem in many developing countries. Modern energy systems are generally considered as a key input for socio-economic development and reduction of poverty (Barnett, 1999). The availability of energy services affect women and men differently (Clancy, Operaocha, and Ulrike, 2004). Women tend to shoulder the disproportionate burden of the current fuel crisis. Women expend long hours on laborious household chores due to the lack of efficient energy systems. Cooking with firewood, cow dung, agricultural residue, twigs or old plastic buckets make up desperate choices in the absence of efficient and clean sources of energy. Women and their children tend to suffer ill health as a result of cooking in confined spaces and resulting from the adverse effects of polluting fuels. The opportunity costs of trekking long distances in the search of fuelwood and spending long hours on food processing is often done at the expense of leisure or income generating activities.

Renewable energy technologies such as wind pumps can enhance agricultural practice and increase food security thus improving the socio-economic status of women and men, but particularly women who constitute the bulk of the active agricultural labour force in developing countries. Renewable technologies and effective energy interventions in rural areas can help widen energy access in agricultural activities since the bulk of agricultural production is energy-dependent. One reason for the inability of agriculture to lift rural populations out of the poverty trap is lack of access to efficient forms of energy since energy power is essential in every aspect of the food chain and agricultural development (water pumping, irrigation, cultivation of seedbeds, post-harvesting food processing, etc.). However whilst the potential value of renewable to reduce current drudgery particularly amongst social groups such as women is well known – the real benefits accrued from using renewable are not evenly distributed. Biogas systems have in some cases increased women’s load because of the daily need for water and dung addition which often needs to be headloaded. (Denton, 2002). Attempts need to be made to address such constraints including those faced with the use of solar cookers in some parts of Africa (Gitonga, 1999). For women to benefit even more from renewable energy technologies, more efforts need to be made on a pricing level to allow women to expand their energy choice and thus have the purchasing power to cater for a range of energy services that meet their needs.

In some cases, there are also impacts associated with these technologies and they– as shown in Appendix A – also may have limited number of years of use if grid electricity arrives at a cheaper price in the future. These multiple benefits of the increased use of renewable energy technologies, which in general are coupled with efficient end use devices, are environmental protection; reduction of indoor pollution; promotion of energy security through decentralization and source diversification; job creation and income generating activities through the use of local resources; improving the quality of waste management systems (like landfills for gas); reduction on the dependence of oil imports; relieving pressure on the balance of payments.

The 2002 WSSD´s Johannesburg Plan of Implementation reflects a growing interest in renewables and addresses as well the problems of social exclusion and poverty eradication. A large number of people in the rural areas in developing countries have no access to commercial energy due to the lack of purchasing power or for other reasons. In order to survive, these people depend on non-commercial sources of energy, mainly fuelwood, manure and agricultural waste that can be obtained at a negligible monetary cost. In many of these countries, non-commercial energy corresponds to a significant share of the total primary energy consumption.

9.2.2 Past and present roles of renewable energy for development

Developing countries have in their energy matrices a very significant share of biomass, of which a fair part may be notoriously neither renewable nor “sustainable” since it comes from deforestation. About 2 billion people in the world rely on fuelwood and other primitive solid fuels for their basic needs. If each person were to use kerosene, 50 kg a year would be necessary, which would represent 100 Mtoe of oil or about 3 per cent of the world’s consumption of this fuel (Goldemberg, 2002). Clearly, this does not represent a resource limitation.

An intrinsic characteristic of a dual society in developing countries is the fact that the elite and the poor differ fundamentally in their energy uses. The elite try to mimic the lifestyle prevailing in industrialized countries and have similar luxury-oriented energy standards. In contrast, the poor are more concerned on obtaining enough energy for cooking and for other essential activities. For the poor, development means satisfying basic human needs, including access to employment, food, health services, education, housing, running water, sewage treatment, etc. The lack of access to these services by most people is a fertile ground for political unrest and hopelessness that leads to emigration to industrialized countries in search of a better future.

A large part of the energy for agriculture, transportation and domestic activities in poorer developing countries comes from the muscular effort of human beings and from draught animals. Other sources include biomass in the form of fuelwood, animal and agricultural waste. Fuelwood is actually the dominant source of energy in rural areas, especially for cooking. In rural areas, women and children usually pick up wood sticks as fuel to cook instead of buying wood. A basic level is the fulfilment of basic human needs, which may vary with climate, culture, region, period of time, age and gender. There is not a single level of basic needs, but a hierarchy of them. There are needs that have to be supplied for survival, such as a minimum of food, of dwelling and protection against fatal illnesses. The satisfaction of a greater level of needs such as basic education makes ‘productive survival’ possible. Even higher levels of needs such as trips and leisure emerge when people try to improve their quality of life beyond ‘productive survival’. Obviously, the needs perceived as basic vary according to the conditions of life in any society.

Negative aspects include environmental impacts, such as resources depletion, inputs usage (e.g. water), contaminating emissions (to air, water, soils), toxic wastes and risks of accidents. Another topic is the competition with food for land, a controversial issue due to its relation to biodiversity protection, to the distribution of goods and different aspects of international trade. Also to mention are geopolitical disputes and international security (case of weapon proliferation). Impact assessment implies consideration to life cycle approaches that are described in Section 9.3, where different boundaries and functional units may consider indirect impacts. Cost analyses also differ, according to the considered parameters (such as discount rate or indirect costs).

9.2.3 Human settlement and energy access

Historically, access to energy sources has had a significant effect on human settlement patterns. For instance, the world's population map reflects the importance of the seas for ocean transport, along with the importance of rivers for both transport and local hydropower for milling and industrial production. In the fossil fuel era, areas accessible to coal and oil sources (and to the wealth that they enabled) had comparative advantages for regional and urban growth, and in some cases this feeds opposition to major changes in energy sources.

A different dimension of this issue, however, is access to energy services in places where people already live, rather than where they may choose to locate. In this regard, the current issues tend to divide between concerns about energy access in rural settlements and in urban settlements:

- Rural settlements. Rural electrification to promote development (and reduce pressures for rural to urban migration) has been a development priority for many decades. In most cases, the preferred approach has been to combine local renewable resource endowments (such as solar radiation or biomass) with institutional innovations. For instance, a notable early success was the successful deployment of solar cells in rural villages in the Dominican Republic in the 1980s, led by Richard Hanson and Enersol Associates (Hanson, 1988; Waddle and Perlack, 1992). Some initiatives such as the UNEP Global Clean Energy Network and the Global Village Energy Partnership reinforced the need for sustained attention to rural energy (World Bank, 1996). For cooking and heating, systems such as improved stoves are ways of utilizing solid biomass with more efficiency and less pollution (MacCarty et al., 2008).

- Urban settlements. In many urban areas in developing countries, the major energy access issues are (a) the lack of reliability of electricity supply and (b) air pollution associated with local industrial, transportation, and energy production, which affect rich and poor alike. But even where it is generally available, the poor often lack ready, affordable access to electricity, as urban electricity supply institutions emphasize supplies to relatively large customers who can pay. In many cases, especially the poor use traditional renewable energy sources such as wood or charcoal for cooking and heating and passive solar energy for food preservation as the only affordable options, but urban wood and charcoal consumption often poses threats to the sustainability of regional biomass energy supply capacities when it is obtained at the expenses of deforestation (Naughton-Treves, Kammen, and Chapmand, 2007; Girard, 2002).

Box 9.1. The importance of access to energy

Access to modern forms of energy, especially electricity for all purposes and clean fuels for cooking, heating and lighting to the 2 billion people without them -- and the additional 3 billion people projected to increase world population by 2020 -- is a major challenge in itself. Wide disparities within and among developing countries contribute to social instability and affects basic human development. Making the joint achievement of promoting access while simultaneously making a transition to a cleaner and secure energy future is a challenging task. Key policy areas to be addressed include the impact of energy reform programmes (including private sector investment) on the poor, the excessive focus on upstream investment and large-scale fossil energy supply projects, the lack of appropriate institutional structures to support international energy and development programmes, research and development not being sufficiently relevant to policy, and the lack of funding to support major infrastructure investments. Energy sector reform, particularly in the electricity sector, has become a priority of the multilateral institutions involved in energy and development, and is having a profound impact on access (**Johansson** and Turkenburg, 2004; **Spalding-Fecher**, Winkler, and Mwakasonda, 2005).

Energy services can play a variety of direct and indirect roles in helping to achieve the millennium development goals (MDGs), in order to halve extreme poverty; to reduce hunger and improve access to safe drinking water; to reduce child and maternal mortality and to reduce diseases; to achieve universal primary education and to promote gender equality and empowerment of women and to ensure environmental sustainability. Access to energy services facilitates economic development – micro-enterprise, livelihood activities beyond daylight hours, locally-owned businesses, which will create employment – and assists in bridging the “digital divide”. Energy services can improve access to pumped drinking water – clean water and cooked food reduce hunger (95 % of food needs cooking). Energy is a key component of a functioning health system, for example, operating theatres, refrigeration of vaccines and other medicines, lighting, sterile equipment and transport to health clinics. Energy services reduce the time spent by women and children (especially girls) on basic survival activities (gathering firewood, fetching water, cooking, etc.). Lighting permits home study, increases security and enables the use of educational media and communications in schools (including information and communication technologies, or ICTs). Improved energy services help to reduce emissions, protecting the local and global environment. Moreover, efficient use of energy sources and good management can help to achieve sustainable use of natural resources and reduce deforestation (Goldemberg, 2002).

9.2.4 The scale of action and prospects for closing the development gap

Where renewable energy can be developed and implemented at a relatively small scale and accessible technological level, it may offer potentials for relatively rapid improvement in social and economic well-being through sound government policies. Compared with large-scale electricity generation or liquid fuel production, for example, renewable energy sources can open up opportunities for local innovation (e.g., (Kamkwamba and Mealer, 2009)) and enable local technology production and business development/job creation (e.g., (Lovins, 2002); + refs to China’s growth in solar energy). Moreover, renewable energy technology deployment can deliver improvements quickly when it is coupled with effective local institutions. For instance, the 2009 Zayed Future Energy Prize was awarded to Dipal Chandra Barua, Director of Grameen Shakti, for that institution’s successes in bringing solar PV electricity and biogas to rural populations in

Bangladesh, linked with local micro-credit programs (www.gshakti.org). [TSU: info on websites needs to be provided in footnotes]

A cautionary note, however, is that local energy resource-technology actions can in some cases have cumulative effects at larger scales that some stakeholders consider undesirable, such as effects of local bioenergy developments on biosphere protection

9.2.5 Energy security as an aspect of sustainable development

Where reliability of energy services is important to sustainable development, which is nearly always the case, economic and social threats to that reliability particularly from external sources – including threats of sudden spikes in energy prices – are an important concern. Many developing regions, for example, still recall the effects of the oil crisis of the 1970s on their development, their well-being, and even their landscapes as biomass cover disappeared for tens of kilometres around cities, and more recent reports suggest that developing countries have become more vulnerable to external shocks than at that time (World Bank, 2008). One of the most attractive features of increasing the use of local renewable energy sources, especially if local populations either control or share in the control of the use of those sources, is that it decreases risks that external factors may introduce disruptive supply shortages or price increases, often very suddenly.

9.3 Social, Environmental and Economic Impacts: Global and Regional Assessment [TSU: this has been changed from the original title 'Environmental impacts: global and regional assessment' and needs to be approved by IPCC Plenary]

9.3.1 Introduction: An overview of social, environmental and economic impacts

Development and exploitation of renewable energy has become increasingly important in the past three decades. In recent years, greenhouse gas abatement policies and the need for climate change mitigation and meeting increasing energy requirements have led to a rise in the development of renewable energy sources. In this section, we report on the social, environmental, and economic impacts of renewable energy sources. The following Table 1 provides a qualitative summary of the information available on the use of resources and the impact of different renewable technologies on the social and environmental impacts. For comparison purposes, conventional fossil fuel and nuclear technologies are also included. The subsequent Table 2 provides a similar summary of the social and economic impacts. The material presented in Table 1 is described in more detail in subsequent Sub-sections 9.3.2 to 9.3.7 in which environmental impacts of renewable energy sources on land, water, air, ecosystems and biodiversity, human health and built environment are discussed.

Since the economic impacts are also covered in earlier chapters and in the cost chapter (Chapter 10), this chapter does not provide their detailed description. The information in both Tables 1 and 2 is derived from the larger table in Appendix A.

9.3.1.1 Environmental and Social Impacts (Table 1)

Renewable energy technologies are relatively cleaner in terms of GHG emissions and environmental pollution than fossil energy sources. Apart from hydropower, windpower (White, 2007) and bioenergy (Blanco-Canqui and Lal, 2009; Liska et al., 2009; Luo, van der Voet, and Huppes, 2009), literature on the impacts of other renewables such as direct solar, geothermal and ocean energy sources on environment is rather limited.

Both positive and adverse environmental and social impacts exist for each of the RE technologies. There are options to mitigate their adverse impacts, making such technologies sustainable and preferable in comparison with conventional energy sources.

RE technologies have many ***similar*** positive environmental and social impacts that make them attractive compared to their fossil and nuclear counterparts. However, the adverse environmental and social issues that affect their deployment and limit development opportunities are more ***technology-specific*** and in some cases ***site specific.*** There are mitigative options for the adverse impacts and their implementation can improve and in many cases ensure sustainability of the technologies. Details of the most significant environmental and social impact topics, positive and negative, are shown in Table 1.

Land use and population*:* Renewable energy technologies offer a way to improve the use of degraded or desert lands that otherwise may have few productive uses. In addition, small RE power plant sites can coexist with minimal side effects on farming, forestry, and other land uses. RE offer decentralized options, reducing the impacts on land use from ducts and transmission lines.

There are several adverse impacts and conflicts with RE land use especially on lands that are being currently used for food crop production. In addition, there are risks such as land subsidence or soil contamination near geothermal plants, population displacement through the setting up of hydro reservoirs and competition with fishing in oceans.

Air and Water: Most RE technologies have little or no direct local and global atmospheric emissions, which serves as a strong mitigation mandate. Exceptions include release of methane from hydro reservoirs and biomass burning, in crops or in poorly controlled industrial processes. Even so, such releases are less toxic compared to those from poorly controlled fossil fuel combustion or even with nuclear material accidents. Small bioenergy, solar PV, hydro and other RE plants serve as a valuable resource for local (rural) ground water extraction and supply of basic energy services to communities. Wind farms offer a way to amortize strong winds.

Similar to fossil fuel sources, however, many types of RE technologies can adversely affect water sources. The need for cooling RE power plants in water-short arid areas, risk of water contamination through geothermal generation, thermal pollution, water quality degradation and health impacts from hydro reservoirs, swell/waves and tidal/ocean currents are established examples of water impacts.

Ecosystem and Biodiversity: RE plants offer limited benefit to ecosystem and biodiversity – if not considered global warming. Shaded solar reflectors may improve micro-climate and ocean energy sources may increase biodiversity in some locations. On the other hand, loss of biodiversity and disruption of ecosystem structure is a major concern mainly for bioenergy and hydropower. Impacts due to monoculture originating from bioenergy sources, loss of biodiversity and obstacle to fish migration through hydro units, ecological modification of barrages, bird and bat fatalities due to wind farms are classic examples of such problems. Recent projects utilizing modern technologies, following adequate guidelines and providing due environmental compensation have mitigated significantly these adverse effects.

Human Health: Human health can benefit through low and less toxic emissions from renewable energy sources. Steady and clean water supply from reservoirs serve as recreational and entertaining facilities, as well as for fishing and irrigation. By the same token, uncontrolled bioenergy combustion can increase indoor and outdoor air pollution, manufacturing and disposal of PV modules can generate toxic waste, hydro reservoirs can spread vector borne diseases and noise at wind farms can be a nuisance.

Built Environment: Not unlike fossil and nuclear plants, RE infrastructure provides socio-economic benefits to local communities through creation of jobs and facilitation of local development. Ocean energy provides additional benefit through protection of coastal erosion. Changes in bioenergy plant landscape, induced local seismicity near geothermal plants, risks from dam bursts or wind tower breakdown, as well as changing conditions at ocean discharge sites are illustrations of concerns about the built environment.

Bioenergy has a high potential for reducing greenhouse gas emissions, what helps benefiting ecosystem and biodiversity and overall human well-being due to reduced global warming and extreme weather events. There are many adverse impacts and conflicts with land uses (especially lands that are being currently used for food crop production), extensive water requirement, potential for introducing invasive species, loss of biodiversity from extensive monocultures and some health impacts associated to local air pollution or contamination with agrochemicals.

Mitigative measures include: adequate land use planning (ecozoning) associated to ecosystems conservation/restoration, crop intensification increasing productivity, large scale development and uses of second generation biofuel and expanding feedstock cultivation to marginal and idle lands; improving water application efficiency and development of less water hungry feedstock varieties can reduce water demand.

Solar energy is being used for soil disinfection. Replacing fossil fuels, it can contribute to avoid considerable amount of greenhouse gas emissions and to improve air quality. Its uses in desalinization process in coastal areas and ground water pumping in remote rural areas can contribute to fresh water supply. Large solar thermal plants require significant land areas. Minimal quantities of air pollution can occur during manufacturing, maintenance and demolition phases. Some health hazards can occur from the materials used for PV modules and as well as from handling of the batteries. As in other types of thermal plants, CSP power require significant amount of water for cooling purposes.

Regular recycling of PV modules can limit concerns about electronic waste; land usage concerns can be minimized by relying on otherwise-unused land, already-disturbed land, or by integrating solar energy with buildings. Dry cooling technology can be used to limit water needs for CSP power plants.

Geothermal plants occupy small area. Emissions from such plants are seldom none to negligible. They are clean in terms of health impacts. Hot mineral water is used for spa and has health benefits. Adverse impacts include: land subsidence and related damages to infrastructure, occasional release of pollutants to water and air and health hazards from hydrogen sulphide. Local public consultations, following up environmental regulations and environmental impact assessment as well as designing/implementing remedial measures can mitigate environmental and social impacts.

Hydropower projects generate benefits through energy generation, providing irrigation water, supplying water for domestic uses, mitigating flood hazards and recreational benefits. Dams in desert areas also allow the creation of fisheries. It is also relatively cleaner than fossil fuels regarding greenhouse gas emissions. For hydropower especially the large ones environmental concerns often focus on the loss of biological diversity due to inundation, loss of natural fish and other species habitats, infrastructure loss, altered hydrological regimes, downstream erosion and sedimentation in the reservoir, whereas social concerns include population displacement and altered recreational opportunities. In many cases, fish habitat can restored by constructing fish ladders or elevators, careful site selection and programs of specimens capture/relocation can reduce loss of ecosystem and biological diversity. Direct involvement of affected human populations in the project planning process can help reduce social concerns. Sustainability guidelines for dams have improved over time and compliance to these is better accepted nowadays by environmental protection groups.

Ocean energy is mostly safe for the air quality. For ocean energy, potential impacts vary by technology, but include ecological modification, impacts on fish and marine mammals, sediment re-distribution in the coast, pollution hazards, visual effects and competition with other possible uses of the ocean. Ocean energy developments may benefit to some degree from earlier experience with other forms of RE (e.g., being proactive in monitoring and early mitigation of potential effects) and integrated marine spatial planning is being introduced to address competition and environmental effects.

Wind energy turbines occupy less space and can co-exist with ecosystems. It requires very and small quantity of water and has the least impact on water resources. The technology does not produce any emissions during operation. Important environmental concerns include bird and bat fatalities, social concerns include visibility, noise impacts, nuisance effects, and impacts radar signals. Bird and bat fatalities can be reduced by deploying improved designed turbines, solid tubular towers etc. Large scale offshore projects reduce significantly such impacts and allow exploring vast potentials in a very sustainable way.

Table 9.1. Environmental and Social Benefits (+) and Concerns (-) Associated with Renewable and Conventional Energy Sources

From/ on		Bioenergy	Direct Solar	Geothermal	Hydropower	Ocean Energy	Wind Energy	Nuclear	Fossil Fuels
Land Use and Population	+	positively intensified land uses (e.g. degraded land)	decentralized energy allowing better land use (e.g. degraded or desert)	decentralized energy allowing better land use	stored water for irrigation and other uses (fisheries, domestic use, recreation)	decentralized energy allowing better land use	decentralized electricity co-existing with farming, forestry, etc.	Low land use from power plants	some fuels (LPG, kerosene) allow decentralized energy avoiding deforestation
	-	competition with food supply; threats to small landowners	land use (mostly urban) for large installations	risks of land subsidence and/or soil contamination	population displacement / impacts on cultural heritage	competition for areas (e.g., fishing and navigation)	competition for areas, landscape alterations	accidents may affect large areas; mining; decommissioning sites	land occupation and degradation (e.g. mining),
Air and Water	+	decentralized electricity for water extraction and supply; lower GHG emissions	no direct atmospheric emissions; water pumping from PV electricity	no direct atmospheric emissions	low GHG emissions in most cases; impounded water can be used for irrigation, fisheries and domestic uses	no direct atmospheric emissions	no direct emissions; improved water pumping, amortization of strong winds	no direct atmospheric emissions under normal operation	
	-	water usage for crops; fertilizers nitrate pollution; risk of fires; GHG emissions from land clearing	(limited) life cycle pollution; water for cooling CSP plants in arid areas	water usage by power plants in arid areas; risk of water contamination	risks of water quality degradation and associated health impacts; potential high methane emissions in some cases	swell/waves & tidal/ocean currents: possible effects on pollution	nuisances from noise	risks of leakages and accidents releasing toxic material	significant atmospheric emissions (GHG, other pollutants); risks of water spills, leakages, accidents, fires
Ecosystem and Biodiversity	+	possible integration between crops and with bio-corridors/ conservation units	no harm and some benefits (reflectors shade improving micro-climate)	-	-	increase of biodiversity for some constructions	-	no or little impact under normal operation	-
	-	Biodiversity loss; impacts from monoculture, burning practices and habitat land clearing and landscape diversity; invasive species; use of agrochemicals	risks from large scale projects (disruption of ecosystem structure); CSP may affect birds	water contamination effects	loss of biodiversity from inundation, new hydrological regimes; obstacle to fish migration and introduction of alien species	ecological modification from barrages	bird and bat fatalities, impacts from noise	short to long-term effects in case of contamination	loss of biodiversity from pollution and spills; change of vegetation and wildlife in mining and waste-fields
Human Health	+	lower and less toxic air pollutant emissions improving human health	virtually no pollution	cleaner air and improved public health; hot water for spa resorts	virtually no air pollution; water supply from reservoirs can contribute to improved health	virtually no pollution	virtually no pollution	virtually no pollution	-
	-	indoor pollution from traditional biomass burning; health effects from crop burning practices (e.g. sugarcane)	toxic waste from manufacturing and disposal of PV modules	some risks of contaminations	risk of spreading vector borne diseases in tropical areas; odor in isolated cases	-	nuisance effects (e.g., noise)	very significant impacts from potential accidents	effects from pollution (occupational, local, regional, global); significant impacts from potential accidents
Built Environment	+	high level of socio-economic benefits from new infrastructure (e.g. jobs, local development.)	socio-economic benefits from new infrastructure	socio-economic benefits from new infrastructure	socio-economic benefits from new infrastructure	socio-economic benefits from new infrastructure; wave power protects coast from erosion	socio-economic benefits from new infrastructure; (some) turbines attractiveness e	socio-economic benefits from new infrastructure	socio-economic benefits from new infrastructure
	-	changes in landscape, negative visual aspects		induced local seismicity (EGS hydrofracturing); impact on scenic quality and use of natural areas	existing infrastructure damage due to inundation; risks from dam bursts; impacts from induced occupation	changing conditions at discharge sites (OTEC/osmotic power); irreversibility (tidal barrages)	impacts of wind turbines on radar systems; visibility of wind turbines	changes in landscape; necessary escape routes	large mining and processing structures; risks of accidents; impacts from induced occupation

9.3.1.2 Economic and Social Impacts (Table 2)

Investment Costs: Investment costs for all renewable technologies are uniformly higher than those for fossil power plants while they are comparable to those of nuclear plants (Appendix A). With addition of carbon capture and storage investment cost of fossil fuel units becomes comparable to those of renewable energy sources (IEA /OECD/NEA, 2010). Investment costs of wind energy and large hydro plants are in the same range and are typically lower than those for bioenergy, central solar plants, and geothermal units. There is significant future investment potential for direct solar and large and small hydropower. At the same time there are re-emerging investment opportunities for nuclear power due to its heavy promotion to combat climate change.

While the high first cost of RE plants may offer investors a possibility for larger returns, they also pose a barrier to their rapid deployment (Table 2). Achieving grid parity is an important goal that will affect the long term penetration of RE technologies. Barriers such as limited application in new bioenergy plant design of lessons learned from earlier units, subsidized solar systems falling into disrepair, no commercial markets yet for ocean plants, and high investment for offshore wind technologies will limit the rapid deployment of such plants.

Energy Generation/Supply Costs: The levelized cost of electricity supply from the list of RE and other technologies varies but is in the same range for both types of technologies from \$50 to \$120 per kWh (Appendix A). The costs are somewhat lower for hydrothermal and nuclear plants; the latter because of subsidies to the investment costs of these units. Costs tend to be higher for central solar and offshore wind technologies from \$100 to \$240 per kWh. PV plants incur the highest costs among this group of technologies.

The cost of new transmission and upgrades to the distribution system will be important factors when integrating increasing amounts of renewable electricity. Transmission improvements can bring new resources into the electricity system, provide geographical diversity in the generation base, and allow improved access to regional wholesale electricity markets. The structure of renewable portfolio standards, tax policies (production and/or investment tax credits), and other policy initiatives directed at renewable electricity (NAP, 2010).

Future potential for several RE technology sources appears to be very promising. Further improvements in power generation technologies, supply systems of biomass and production of perennial cropping systems can bring the costs of power generation from biomass down to attractive cost levels in many regions. Solar plants are becoming more competitive as costs are declining; 2030 costs are projected to be 60% lower. Further, operational costs of geothermal sources vary considerably from one project to another due to size, quality of the geothermal fluids, etc., but still they are far more predictable in comparison with power plants of traditional fossil fuel energy. In the evaluation of life-cycle costs, hydro often has the best performance, with annual operating costs being a fraction of the capital investment and the energy pay-back ratio being extremely favorable because of the longevity of the power plant components. The significant risks of high cost of accidents in nuclear plants and fossil fuel extraction outweigh the RE risks that tend to be more diverse and not as punitive.

Income and Livelihood: For RE technologies since the energy for operation of the technology is derived from natural sources there is very limited use of direct manpower for O&M purposes. Bioenergy is one exception where regular biomass sources need to be harvested and placed in a conversion unit. Design and construction of most RE facilities thus yields short-term income and livelihood opportunities. The use of small off-grid power sources (solar, hydro or biomass for example) offers an opportunity for rural users to make more productive use of their night time hours, which can enhance income and also provide higher comfort level and better livelihood.

Another benefit is derived from tax payments; land rents and use of local services that can help vitalize the economy of rural areas. This benefit is also plausible from conventional power plants.

Employment: RE sources typically constitute a significant source of employment that is higher than offered by conventional technologies (Appendix A). The number of job opportunities ranges from 0.17 job-years/GWh for wind technologies up to 0.27 for hydro units. Solar PV is an exception because of its high cost and it needs 0.87 job-years/GWh (**Wei,** Patadia, and Kammen 2010). These values include construction, installation and manufacturing and O&M and fuel extraction and processing jobs. These values are significantly higher than those reported for fossil (0.11 job-years/GWh) and nuclear (0.14 job-years/GWh) technologies. Energy efficiency too shows much higher values at 0.38. In addition, certain energy sources, hydro and ocean power for example, can become a source of eco-tourism and attraction in its own right, providing jobs in tourism and services.

Gender Equity: Among RE technologies, bioenergy (particularly its use in rural areas) is the one that most affects gender equity. Improved biomass systems such as efficient cook stoves enhance lifestyles and lighten domestic workload and reduce the time women spend in collecting fuel wood and other biomass sources. At the same time, development of biofuels may present equity- and gender-related risks concerning issues such as labour conditions on plantations, access to land, constraints faced by smallholders and the disadvantaged position of women. Similarly, small direct solar and hydro units can enhance lifestyles and decentralized energy use can provide more gender friendly jobs. In comparison, fossil fuel sources that substitute for household biomass use effectively promote gender neutrality. Exception is primitive use of coal that can cause significant indoor air pollution that affects mainly women, children and the elderly.

Table 9.2. Economic and Social Benefits (+) and Concerns (-) Associated with Renewable and Conventional Energy Sources

From/ on		Bioenergy	Direct Solar	Geothermal	Hydropower	Ocean Energy	Wind Energy	Nuclear	Fossil Fuels
Income and Livelihood	+	Increase in income in ag-forestry sector Production of biofuel feedstock offers income generating opportunities in developing countries	Rural off-grid solar offers income and livelihood opportunities Construction of all facilities yields short-term income and livelihood opportunities	Construction of facilities yields short-term income and livelihood opportunities	Small hydro schemes provide long-term support for both income and livelihood of remote rural areas, especially hilly regions.	Construction of facilities yields short-term income and livelihood opportunities	Tax payments, land rents, and use of local services can help revitalize the economy of rural communities	Construction of facilities yields income and livelihood opportunities	Construction of facilities yields income and livelihood opportunities
	-							High accidental risk potential	Negative impact on livelihood in selected areas.
Energy Generation /Supply Cost	+	Costs of new transmission and upgrades to distribution system can be important factors when integrating renewable electricity since locations of its resources need not match those of conventional fossil resources.					Can be competitive with fossil generation; wind energy is produced with near-zero marginal cost	Competitive but subsidized	Competitive but subsidized in many locations; Fluctuating prices of oil supply
		Significant potential to reduce costs of biomass supply, production of perennial cropping, and power plants	Becoming more competitive as costs are declining; 2030 costs projected to be 60% lower	Variation in O&M costs due to size and quality of geothermal fluids, however, predictable compared with fossil fuel plants	Often the best life-cycle costs; low O&M costs; extremely favourable energy payback ratio because of longevity of plant components				
	-	High prices of bioenergy products act as a constraint	Current supply costs still very high			Capex costs determined from prototypes but don't reflect market costs	High cost of off-shore wind technologies	Risks of significant costs for accident treatment	Risks of high cost for offshore drilling and coal mining accidents
Investment	+	Potential for large and small scale investment	Large investment potential	Large investment potential in Asia (Indonesia)	Considerable investment potential for still expanding large and small hydro projects		The installed capital cost of on-shore wind projects dropped until 2004 while turbine size grew significantly	Re-emerging investment opportunities due to heavy promotion to slow climate change	Largely established and mature generation and supply technologies
	-	Limited application in new plant design of lessons learned	High first cost barriers; issues with subsidized systems falling into disrepair	Capital intensive due to exploration and drilling costs	High first cost a barrier plus long design and construction lead times	Difficult to accurately assess investment viability due to no commercial markets	High investment for off-shore wind plants	Uncertain investment needs for long-term disposal of nuclear wastes	Investment risk due to uncertainty in remaining oil and gas reserves
Employment	+	Increased job opportunities, particularly in rural areas.	Jobs created in rural and urban areas.	Local workforce can get better employment opportunities.		Ocean power station can become a source of eco-tourism providing jobs	Worldwide, direct employment in the wind industry is estimated at approximately 500,000		-
	-								
Gender Equity	+	Efficient cookstoves can enhance lifestyles and lighten domestic workload. Large biomass can provide jobs on a gender friendly basis. Decreased fuelwood use reduces the collection time for women .	Improved systems enhance lifestyles. Decentralized energy has potential to provide more gender friendly jobs.		Small hydro is partially relevant for women.				Usually gender neutral; kerosene/LPG substitutes for biomass may promote gender neutrality.
	-	Biofuel feedstock production may present equity- and gender-related risks such as labour conditions on plantations, access to land, constraints on smallholders and disadvantaged position of women.							Primitive use of coal can cause domestic health impacts, affecting mainly women, children and the elderly.

9.3.2 Land

Land uses and associated impacts are important for any renewable energy technologies. Bioenergy from crops is an important source of renewable energy and large-scale land uses are occurring in many areas of the world. Although bioenergy production from perennial biomass crops has many potential benefits, land conversion to grow these crops may reduce, displace, and certainly change other important products and services of the existing land such as food production and biodiversity services (Lovett et al., 2009; van der Velde, Bouraoui, and Aloe, 2009; Searchinger et al., 2008).

Generally large land areas are not required to produce solar energy for small scale domestic uses. Solar energy systems, with the exception of very large solar thermal electric plants, whether it is a hot water system or photovoltaic system, do not occupy any dedicated urban land as they are either placed on roofs or they incorporate/replace existing building cladding systems (Geun and Steemers, 2008). Geothermal power plants occupy relatively small land. The ocean thermal energy conversion (OTEC) technology requires small surface area; if located in a platform, only land is required for the cable and connecting to the station. Dams and reservoirs for hydropower generation especially the large ones require substantial land areas. Despite the benefits –energy generation, irrigation, flood control, water supplies for domestic consumptions, fisheries and recreational benefits, dams are also associated with loss of forests, agricultural land, and grasslands in upstream watershed areas due to inundation of the reservoir area (Tefera and Sterk, 2008). The wind power plants, compared to several other types of power production, occupy less space, as farming, ranching, forestry and other types of activities can co-exist with them (see chapter 7.6.3.1). In many cases, wind power plants can be located in un-used spaces (mountain passes, elevated plateaus, etc.). The leasing of land for wind turbines can benefit landowners in the form of increased income and land values. But in some cases, wind power development may create conflicts among the land owners and other people living in the neighbourhood. For off-shore installations, limited conflicts could arise with navigation, but usually only shallow waters are used for the wind power generation off-shore.

Population displacement is an important issue associated with land uses for hydropower production. Dams play a role in alteration of traditional resource management practices and often cause displacement of population and impoverishment of people due to livelihood losses (Tefera and Sterk, 2008). The displaced people usually move to available areas within the watershed and take up agricultural activities on steep slopes and flood-prone areas. The process of migration and agricultural activities on new lands, in combination with normal population growth, can cause significant and harmful land use changes and exacerbate the rate of environmental degradation within the watershed area (Tefera and Sterk, 2008).

Not only will the land use competition between bioenergy crops and food crops affect the prices and expand croplands, but it will likely result in an overall decrease in the average yield of crops as well (Gillingham, Smith, and Sands, 2007). Both types of crops will be grown first in the most profitable and higher quality lands to obtain the highest yield. With growing demand of food and energy, the expansion will take place to lower quality lands. This may have implications in terms of increasing land and crop prices as well as reduction of yields due to utilization of lower quality lands (Gillingham, Smith, and Sands, 2007). This particular kind of impact does not occur for other renewable technologies unless they occupy large agricultural lands.

Solar energy is being used for soil disinfection. Steam soil disinfection is a highly efficient method and a safe alternative to use of chemicals. The method uses steam generated directly from solar energy by means of parabolic trough collectors (PTC) to disinfect contaminated soil. It has a short processing time and it does not leave toxic residues behind (Camilo et al., 2007).

Extraction of geothermal fluids can reduce the pressure in underground reservoirs and can cause land subsidence. In the Wairākei (New Zealand), the centre of the subsidence bowl is sinking at a rate of almost half a metre every year which is the largest subsidence on record (Stewart, 2007). As the ground sinks it also moves sideways and tilts towards the centre. This puts a strain on bores and pipelines, may damage buildings and roads, and can alter surface drainage patterns. Local earthquakes can be expected in the areas of steam/water extraction (Giardini, 2009).

There are options for reducing the impacts of large scale land uses for bio-energy and hydropower generation or in other words facilitating sustainable development: (1) intensive use of land for energy will improve agriculture and technology transfer will occur for conventional agricultural activities; (2) wide scale development and uses of second generation bio-fuels would reduce pressure on lands for feedstock production; (3) perennial biomass crops could be planted on more marginal and idle lands. Although most of the trials have so far been conducted on experimental sites, the economics simply dictate that, if bioenergy crops are in demand, they will expand to as much land as needed, and also try to obtain the highest yields possible. However, there should be a balance between food and biofuel production. One response to the potential competition between energy and food crops is to target degraded as well as grazing lands rather than prime, cropland for bioenergy production, while prime, higher quality croplands are left for food production. A possible benefit of this could be that cultivating energy crops on degraded lands would restore soil organic matter and nutrient content, stabilize erosion, balance moisture conditions, and thus contribute to overall improvement of the land; and (4) for hydropower, carefully selected sites can reduce impacts on forest lands as well as reduce the risk of population displacement. Resettlement is a mitigation measure now being practiced widely during dam/reservoir construction.

9.3.3 Air

The renewable energy technologies have a potential of reducing greenhouse gas emissions and improving air quality. The ***bioenergy*** resources make them a greenhouse-gas-free source of energy that could contribute to a more environmentally-friendly and sustainable energy system. Biomass fuels can be used in high efficiency combustion systems as a substitute for fossil fuels and can result in improving air quality and decreasing greenhouse gas emissions into the atmosphere (Fan, Freedman, and Gao, 2007). When measure over the entire production chain, the production of some biofuels, such as sugar-base ethanol, results in significant reductions in carbon dioxide emissions compare to conventional gasoline. However, in practice some bioenergy chains may cause relatively high nitrous oxide emissions from soil and need a lot of auxiliary energy for refining which can weaken the GHG balance considerably. Further, some bioenergy chains cause in initial phase large GHG emissions through land clearing for bioenergy crops (Searchinger et al., 2008; Achten et al., 2007; Pacca and Moreira, 2009). This concern can be addressed by cultivating perennial crops in marginal, degraded or abandoned lands with reduced tillage and leaving behind crop residues (Jessup, 2009; Lal, 2009; Tilman et al., 2009).

Besides CO2, using bioenergy leads to smaller emissions of SO2 compared with the use of coal. Biomass such as municipal organic waste contains small quantity of sulphur and SO2 which can be released into the atmosphere through the combustion process for biogas manufacturing. Note that emissions of SO2, CO, and NOx from biogas are considered trivial (Fan, Freedman, and Gao, 2007) thus resulting in cleaner air and health benefits such as reduced respiratory complaints (Sims, 2004). In the future, biomass can provide a source of hydrogen for fuel cells, heat for environmentally sound, small scale, distributed generation systems, and gaseous biofuels for micro-turbines.

Solar energy can contribute to avoid considerable amount of GHG emissions. Unlike conventional fossil fuels which produce large amounts of GHG gases, solar energy produces almost zero emissions (Kalogirou, 2008).

Hydropower is considered a green technology, as it has very few greenhouse gas emissions compared with other large-scale fossil energy options (US EPA, 2007). According to US Environmental Protection Agency, hydropower's air emissions are negligible because no fuels are burned. However, if a large amount of vegetation exists alongside the riverbed when a dam is built, this vegetation can decay in the created reservoir, causing the build-up and release of methane gas – a potent greenhouse gas during the first years after impoundment (US EPA, 2007). Despite this however, hydropower is still considered a green and clean technology and can be a significant contributor to address air pollution and climate change as it offsets greenhouse gas emissions and air pollutants from fossil fuel power plants (Government of Canada).

Uses of solar energy can significantly improve indoor air qualities (Palanivelraja and Manirathinem, 2009). However, minimal quantities of air pollution could possibly occur from the manufacture, normal maintenance operations, and demolition of solar energy systems. The great majority of the components of solar energy systems are recyclable, thus posing minor burden on the environment (Kalogirou, 2008). Generation of hydropower allows for the power demand to be met without producing heated water, air emissions, ash, or radioactive waste (Kaygusuz, 2009). Hydropower does not produce air pollutants that cause acid rain and smog and polluting or toxic waste by-products (US EPA, 2007).

Generally, emissions from the ***geothermal*** power plants are none (binary cycle plants) to negligible as compared to fossil fuel powered plants. However, some geothermal plants can discharge pollutants (arsenic, hydrogen sulphide, methane, ammonia, radon, etc.) to the atmosphere that need special attention. Mostly, the pollutant gases are denser than air and can collect in pits, depressions or confined spaces. They pose potential hazards for working at geothermal stations or bore fields and human settlements. In the USA, official requirements for the removal of hydrogen sulphide from geothermal emissions are already established (US DOE, 2009), and it should be monitored at any geothermal plant. The carbon dioxide emission of conventional geothermal power plants is not negligible too (see Chapter 4).

The ***ocean*** energy production is mostly safe for the air quality; in fact, it eventually makes the air cleaner due to possibility to decrease the fossil fuel energy production. For OTEC technology, no solid wastes and no emissions of conventional air pollutants are reported (Cohen et al., 1982).

The ***wind*** energy production, once again, is one of the most environment-friendly technologies, except for making the wind farm equipment. The wind energy plant itself does not produce any emissions to the air. Some studies point out to possibility of influencing the local climate (wind regime, turbulence, etc.) behind the turbines, but these effects are not significant (Lu, McElroy, and Kiviluoma, 2009).

9.3.4 Water

All renewable energy development processes require water and therefore, they have implications in terms of quantity and quality. The ***bioenergy*** crop production is highly dependent on water and water demand in future would increase for this purpose (Stone et al., 2010; Varis, 2007). It has been estimated that somewhere between 3900 and 12,000 km^3 per year will be needed for production of biomass– a figure that already excludes those food crop residues that could also be used (Lundqvist et al., 2007). If 15 percent of this water were to be contributed by irrigation, the demand for blue water would rise by another 1200-3500 km^3 per year. ***Solar*** energy technology requires water during production process of hardware and some water may be required time to time for cleaning of them after installations. Parabolic trough and central tower systems using conventional steam plant to generate electricity require the use of cooling water. This could place a significant strain on water resources in arid areas (Tsoutsos, Frantzeskaki, and Gekas, 2005). ***Hydropower*** generation requires impoundment of water of large quantity and such action can cause impacts in downstream areas depending on the ecological water requirement of the downstream stretch of the channel and water requirements for other economic sectors. Desalination technology has been used in many large cities all across the world to satisfy growing water needs and this industry continues to grow especially in arid regions with limited water availability. ***Solar*** energy can be combined with desalination technology to generate a sustainable source of freshwater as well as a source of energy (Ettouney and Rizzuti, 2007). For small scale applications, Meah, (Meah, Fletcher, and Ula, 2008), found ground water pumping using solar PV systems cost effective in the drought hit rural Wyoming State, USA.

Solar energy has been proven effective for water treatment methods such as chlorination and bacterial disinfection. Small amount of electricity is generated from solar cells for drinking water chlorination (Appleyard, 2008). Moreover, solar energy can effectively be used in to disinfect biologically contaminated water. Using the thermal power of solar energy and heating water to a disinfecting temperature level as well as exposing the water to ultraviolet radiation result in inactivation of micro-organisms and elimination of coliform-group bacteria (Saitoh and El-Ghetany, 2001).

During production of bioenergy feedstock, the quality of surface water and groundwater is being impacted through nitrate pollution from the applied fertilizers in the bioenergy crop fields (Lovett et al., 2009). Except for the normal use, in the ***solar*** thermal system, there may be the risk of accidental water pollution through leaks of heat transfer fluid (Tsoutsos, Frantzeskaki, and Gekas, 2005). Construction of hydropower dams and reservoirs especially the large ones can effect the quality of water positively in the impounded area. Reservoirs generally act as traps for nutrients and sediments, since these matters tend to settle down when water is discharged into the reservoir area. As a result, reservoirs are reliable and provide higher quality water supply sources for irrigation and domestic and industrial use. On the other hand, sedimentation depletes capacity of a reservoir and increases flood risks at the upstream (Chapter 5). Additionally, reservoirs provide for fisheries because of the storage of high amount of nutrients in the water (Kaygusuz, 2009).

Operations of dams and reservoirs can negatively impact the quality of water downstream river channel below the dam. The water discharged through the turbine is almost free of sediments and nutrients but it can scour and erode the streambed and banks. This scouring effect can have significant negative impacts on the flora, fauna, and structure of biological community in the downstream river channel. In addition to this, dams and reservoirs also change aquatic habitats. Riverine habitat is replaced with reservoirs, and downstream habitat may be altered as a result of modifications in flood regime and trapping of sediments in the reservoir (UNEP, 2000; Ligon, Dietrich, and Trush, 1995).

Headwater streams provide unique habitats for aquatic biota and are extremely important sources of sediment, nutrients, and organic matter for downstream areas. Hydropower dams act as physical barriers and their presence hinder the longitudinal movement of organisms and downstream export of matter and nutrients. In addition, as a result of flow reductions in the de-watered reach of river between dams and turbines, discontinuities between upstream and downstream areas river fragmentations occur (Anderson, Pringle, and Freeman, 2008). De-watered reaches downstream from dams typically have slower water velocities, warmer water temperatures, and shallower habitats compared with adjacent upstream and downstream areas. This change in water quantity leads to habitat alterations, and can eventually impact distribution of aquatic organisms and affect their long-term survival in the river (Anderson, Pringle, and Freeman, 2008).

Any release of polluted water from the ***geothermal plants*** into rivers or lakes can damage aquatic life and make the water unsafe for human and agricultural uses due to presence of poisonous chemicals, minerals and gases in the geothermal fluid used for energy. The most serious environmental effect of the geothermal industry is pollution of fresh water from arsenic. For example, due to discharge of geothermal waste water contaminated with arsenic from the Wairākei geothermal power station in New Zealand, the levels of arsenic in the Waikato River almost always exceed the World Health Organization standard for drinking water (Stewart, 2007). It also contaminates the Waikato River with hydrogen sulphide, carbon dioxide, mercury at concentrations that have adverse, if not calamitous effects (Abbasi and Abbasi, 2000). However, thorough risk and environmental impacts assessment would allow avoiding such problems.

Among the ***ocean*** power technologies, the barrage tidal stations can increase some water pollution upstream. Brackish water waste and polluted polyethylene membranes from the salinity gradient energy (SGE) sites can adversely impact the local marine and river environment. For OTEC technology, catastrophic failure such as thermal fluid escape has only some minor local effects. Up-welling effect of bringing nutrient-rich deep water to the surface can occur. This mixing may be beneficial for aquatic lives but further study is required. If water is discharged at proper depth, effect is essentially eliminated (Vega, 1999). For the wave energy systems, uncertainties exist on the specifics of toxic compounds to be used in the power installations and possibility of their release into the sea water.

For ***wind*** energy production, water is not used, except for making the wind farm equipment and cleaning the rotor blades. Wind energy is one of the technologies least influencing the water sources (US DOE, 2009), regarded to both on-shore and off-shore devices.

There are options and measures available and are in practice to reduce social and environmental impacts of hydropower projects. Several promising concepts for sediment control at intake and removal of sediment from reservoirs and settling basin have been developed and practiced (Chapter 5). The use of regulating pond downstream of the powerhouse enables steady release of water and therefore reduces the risk of erosion.

9.3.5 Ecosystems

Cultivation of bioenergy and biofuel crops can directly affect biodiversity, both positively and negatively. These effects include small scale changes to species abundance at field level, as well as larger scale issues such as changes in landscape diversity, and potential impacts on primary and secondary habitats (Firbank, 2007). Bioenergy cropping has the potential to benefit biodiversity by mitigating climate change, which can have significant impacts on ecosystems and biodiversity.

Cultivation of bioenergy crops may eliminate niches for some species living on that land through conversion processes, but can create niches for a new suite of species (Firbank, 2007). There are three major adverse impacts of introduction of bioenergy crops. ***First*** is the loss of a high quality habitat; either by replacing it with bioenergy crops, or by introducing major changes in land use and management (e.g. increased extraction of wood fuel from woodland). The ***second*** negative impact occurs through introduction of invasive crop species, e.g., giant reed and miscanthus (Barney and Ditomaso, 2008). The ***third*** major negative impact arises when linear habitat features such as lines of trees, hedgerows, water edge and ponds are either added or removed. This can consequently cause losses of habitat and species dispersion (Firbank, 2007). On the positive side, bioenergy crops provide a stabilized vegetation cover that can offer habitat for some elements of native biodiversity (Fan, Freedman, and Gao, 2007).

Construction and operation of water reservoirs/dams for ***hydropower*** generation can cause harm to ecosystems and loss of biodiversity (Rosenberg et al., 1997; IUCN, 2001; Fearnside, 2001; Criag, 2001). Loss of biodiversity compromises the structure and function of ecosystems, which can in turn compromise the economic well-being of human populations. Hydropower development may cause losses of biodiversity well in excess of natural, background losses (Coleman, 1996). For example, the reduction or extirpation of native species through alteration of physical habitat or introduction of exotic species is a form of biodiversity loss connected with large-scale hydroelectric development (Power, Dietrich, and Finlay, 1996). These losses could occur over extensive spatial and temporal scales. Rancourt and Parent (Rancourt and Parent, 1994) documented loss of biodiversity for the La Grande development project in Canada which operates a chain of reservoirs. Fearnside (Fearnside, 2001) listed loss of forests which led to loss of natural ecosystems in the Tucuruı´ Dam in Brazil.

As to the ***geothermal*** power plants, some "open loop" heat pump systems may affect aquatic ecosystems if they draw water from a water body and discharge warmer or cooler water back into the water body, and/or pollute it.

The ***ocean*** power stations do not largely influence land ecosystems. Some adverse effects can occur for the coastal landscapes, mostly due to occupation of the territory during construction. Wave stations can partially block the coast from wave impacted erosion, but they also can re-distribute natural sedimentation in the coastal zone. The tidal barrages can flood the coastal areas depending on the elevations, at least for certain time periods. For the offshore stations, the high voltage transmission cables have the potential to influence the aquatic animals that are sensitive to electromagnetic fields, thus disrupting their ability to navigate (Gill, 2005). The power generation and transmission structures may affect local water movements, which are fundamental to some aquatic species (Montgomery et al., 2000) and also determine the transportation and deposition of sediments (Gill, 2005).

Technology wise, differential impacts of ***ocean*** power infrastructure on ecosystems and biodiversity can occur. The tidal barrages are potentially the most harmful to the marine and coastal ecosystems unless the effects are addressed seriously. The change in water level and possible flooding would affect the vegetation around the coast. The quality of the water in the basin or estuary would also be affected; the sediment levels would change the turbidity of the water and can affect fish and birds. Fish would undoubtedly be affected unless safe fish passes are installed. Decline in fish population would affect population of birds and they will migrate to other areas with more favourable conditions. However, emergence of new environment may allow different species of plant and creature to flourish and their overall impacts need to be independently assessed (ESRU, 2009). However, Colwell (Colwell, 1997) argued that problems could arise during quantification of environmental capital of the recreated environment compared to the original one.

Sea streams (including tidal ones) generally are not as strong as those for a tidal barrage. The latter might have an effect on the aquatic life in that particular area. These site-specific by-products can be avoided or minimized through proper environmental impact assessments (ESRU, 2009). For example, at La Rance station in France, 10 years after the construction, the biodiversity situation was back to normal in the estuary, compared to neighbouring estuaries (Mao and Gerla, 1998).

The SGE ocean technology can influence the local salt and fresh water mixing regime. Each species of aquatic plant and animal is adapted to survive in either marine, brackish, or freshwater environments. The main waste product of this technology is brackish water and its large quantity discharge into the surrounding waters may significantly alter aquatic environment. Fluctuations in salinity will result in changes in the plant and animal community. Variation in salinity occurs where fresh water empties into an ocean or sea, these variations become more extreme on for both bodies of water with the addition of brackish waste waters. Extreme salinity changes in an aquatic environment may be detrimental to both animals and plants due to sudden severe salinity drops or spikes (Montague and Ley, 1993).

Organisms impinged by an OTEC ocean power plant are caught on the screens protecting the intakes, fatal to them. Entrained organisms may be exposed to biocides, and temperature and pressure shock. Entrained organisms may also be exposed to working fluid and trace constituents (trace metals and oil or grease). Intakes should be designed to limit the inlet flow velocity to minimize entrainment and impingement (Vega, 1999). OTEC plant construction and operation may affect fishing. Fish will be attracted to the plant in part due to redistribution of nutrients, potentially increasing fishing in the area. However, the losses of inshore fish eggs and larvae, as well as juvenile fish, due to impingement and entrainment and to the discharge of biocides may reduce fish populations. Through adequate planning and coordination with the local community, recreational assets near an OTEC site may be enhanced (Vega, 1999).

For ***wind*** energy production, fatalities of birds and bats by flying into the turbine rotors have been reported in many regions of the world. In Denmark, overall, less than 1% of the ducks and geese fly close enough to the turbines to be at any risk of collision (Desholm and Kahlert, 2005). In the early 1980s, a large number of raptor fatalities were reported at Altamont Pass, California (Orloff and Flannery, 1992). However, most turbines in North America, have low impacts on birds and bats. Studies by the U.S.-based National Wind Coordinating Committee indicate an average bird kill of two to three birds per turbine each year. Direct mortality and injury of birds have also been reported from the U.K. However, the majority of studies of collisions caused by wind turbines have recorded relatively low levels of mortality (Painter, Little, and Lawrence, 1999).

There are many ways to minimize risks to local and migratory birds and bats. Current wind turbine technology offers solid tubular towers to prevent birds from perching on them. Turbine blades also rotate more slowly than earlier designs, reducing potential collisions. Specialists consider the location of common migratory bird/bat routes and, wherever possible, avoid those areas for wind farms. Other effects such as noise, interference into natural habitats, etc., do not pose serious challenge in most cases if necessary assessment is done before installation. With appropriate precautions, there is almost no effect on biodiversity (see also Chapter 7.6.2). For off-shore wind power farms, no significant negative effect was found, and in some areas, biodiversity has increased due to artificial reefs appearance (Danish Energy Authority, 2006).

9.3.6 Human Health

As was previously mentioned, using biomass fuels instead of fossil fuel produces lower emissions of human health-harming substances and thus helps to improve quality of life (Sims, 2004). However, use of biomass in traditional cooking stoves is a source of indoor air pollution through high particulate emissions and thus constitutes a health hazard. Sugarcane fire has significant health impacts as reported in southeast of Brazil. Elements such as black carbon and tracer elements generated from sugar cane burning were those most associated with both child and elderly respiratory admissions in hospitals (Cançado et al., 2006).

Solar energy is considered a clean energy source with essentially zero emissions in terms of air pollution and greenhouse gas production. As a result, it is not harmful and can contribute to cleaner air and improved public health (Palanivelraja and Manirathinem, 2009). In some cases, PV modules contain materials that are hazardous to human health to waste streams and recycling of materials. A life cycle analysis of batteries for stand-alone PV systems indicates that the batteries are responsible for most of the environmental impacts, due to their relatively short life span and their heavy metal content (Tsoutsos, Frantzeskaki, and Gekas, 2005).

Health impacts of ***hydropower*** reservoirs are well researched. Major health impacts are spread of vector borne diseases associated with the reservoirs itself and irrigation projects. Lerer and Scudder (Lerer and Scudder, 1999) documented health concerns beyond vector-borne diseases which include impacts through changes in water and food security, increases in communicable diseases and the social disruption caused by construction and involuntary resettlement (Table 3).Water supply from hydropower projects for domestic consumption is beneficial for communities (Chapter 5).

Table 9.3. Potential health impacts of large dam projects

Impact Area	Health impact
Upstream catchment and river	Changes in flood security, water related diseases, difficulties with transportation and access to health facilities
Reservoir area	Involuntary resettlement, social disruption, vector borne diseases, water related diseases, reservoir induced seismicity
Downstream river	Food security affected on flood plains and estuaries (farming and fishing), water related diseases, dam failure and flooding
Irrigation areas	Changes in food security, vector borne and water related diseases
Construction activities	Water related diseases, sexually transmitted diseases, HIV/AIDS due to migrated labors, accidents and occupational injuries
Resettlement areas	Communicable diseases, violence and injury, water related diseases, loss of food security
Country/regional/global	Macro-economic impacts on health, inequitable allocation of revenue, health impacts of climate change

Source: (Oud and Muir, 1997).

Geothermal power plants, except for few cases, are clean in terms of human health. However, hydrogen sulphide emissions (0.1 ppmv as against permissible 0.03 ppmv) from the Geysers, California power plant have resulted in complaints of odor annoyance and health impairment (Anspaugh and Hahn, 1979). Concerns raised by the local residents of respiratory diseases, asthma, eye problems, cold and flu from a geothermal energy project in Kenya (Marita, 2002). With established monitoring systems in potential areas of water and air pollution, the geothermal plants become practically safe for people. The hot mineral water can be used for resorts.

Mostly, the ocean power generation is remote from the settled regions, even from the coastal areas. Except for rare situations like possible water pollution behind the tidal barrages, these technologies do not influence the human health directly. Accidents at OTEC plants can lead to limited emission of gases like ammonia and chlorine.

Wind turbines, particularly older designs, emit noise that can be heard near wind farms. According to the U.S. Renewable Energy Policy Project, the noise from a typical wind farm at 350 meters distance can vary between 35 and 45 decibels, a non-harmful level (see chapter 7.6.3.3). Sound levels can grow with increases in wind speeds, and are objectionable to some people. To minimize noise levels, operators are using improved rotor technology, constructing plants away from densely populated areas and including sound-absorbing materials in the generator. The frequency and volume of this noise can be controlled, but not eliminated by wind turbine design. At the same time, wind turbines do not produce infrasound at a level detectable by humans or that has been shown to have any impacts on health (Leventhall, 2006; Rogers, Manwell, and Wright, 2006).

9.3.7 Built Environment

Growing ***bioenergy*** crops can affect the built environment, specifically the visual aspect and settlement routine. Depending on the original land use (prior to growing the energy crops), these tall crops such as Miscanthus and short rotation coppice willow (3 to 5 m high) may impact the character and visual appearance and perception of the landscape (Lovett et al., 2009).

As was mentioned before, ***solar*** energy technologies such as small PV systems and space and water heating systems are typically installed on existing buildings and do not occupy large land areas. Thus, they are not likely to disturb the visual aspects of environments to a great extent. However, large areas are required for central PV systems (Tsoutsos, Frantzeskaki, and Gekas, 2005).

Hydropower projects create both adverse and beneficial impacts on the built environment. Inundation of infrastructure that includes houses, rural roads, business centers, archeological and historical sites usually occur. During construction of Kaptai hydropower project in Bangladesh in the 1960s, damage to human settlements and infrastructure occurred. The lake inundated the homes of 18,000 families and displaced 100,000 tribal people, of which 70% were ***Chakma*** tribal people. The dam also flooded the original Rangamati town and the palace of the Chakma Raja (king) (Parveen and Faisal, 2002). A 50-km stretch of highway was inundated during construction of the Samuel Dam in Brazil (Fearnside, 2005). Hydropower projects also facilitate construction of new infrastructures like roads, highways and urban centres. The reservoirs are usually used for recreational purposes.

Geothermal power plants occupy relatively small area and do not require storage, transportation, or combustion of fuels. These qualities reduce the overall visual impact of power plants in scenic regions. Transmission lines and other power-related infrastructure usually are the same as for other types of power plants or less visible.

For ***ocean*** power plants, visual impacts are particularly important in areas of designated coastline and those used for recreational purposes. Ocean energy infrastructure could cause visual impacts if they are constructed around such areas. Wave energy devices may be potential navigational hazards to shipping as they could be difficult to detect visually or by radar. Several of the areas proposed for wave energy devices around European coasts are in major shipping channels and hence there is always an element of risk that a collision may occur (Thorpe, 1999).

Because ***wind*** farms are composed of large numbers of turbines and tend to be located on or just below ridgelines or within sight of shores, they can often be seen for a long distance. As a result, some people object to the visual impacts of wind turbines. To reduce these impacts, operators sometimes paint wind turbines to blend in with their natural surroundings. During planning for new projects, they also consider the spacing, design and uniformity of the turbines and locate wind farms away from populated centres. Actually, acceptance of wind farms by people increases once the wind power plant has been built, and for some people they seem attractive (Sathyajith, 2006). Wind power development could result in appearance of wind farms in recreational areas, which should be assessed thoroughly. Experience in Europe and U.S. has shown that wind turbines can easily and safely coexist with all types of radar and radio installations (Brenner, 2008).

9.4 Implications of (sustainable) development pathways for renewable energy [TSU: this has been changed from the original title ‘Socio-economic impacts: global and regional assessment’ and needs to be approved by IPCC Plenary]

Environmental consequences of energy consumption have been neglected for too long, because the idea of continuing economic growth is still central to policy makers across the globe. Clearly, it would be preferable to concentrate on providing energy services that will satisfy the needs of the people rather than working towards increasing the capacity of supply, based mainly on non-renewable resources.

It is widely accepted that energy is linked with more or less all aspects of sustainable development. It is an engine for growth and poverty reduction, and therefore it has to be accorded high priority and this has to be reflected in policies, programs and partnerships at national and international levels (WEHAB, 2002). The provision of energy in a sustainable way is therefore pivotal to the aim of achieving sustainable development.

To make global energy systems compatible with sustainable development requires a sustained effort that includes awareness raising, capacity building, policy changes, technology innovation and investment. The shift towards a sustainable energy economy also requires sound analysis of the options by policymakers, good decisions and the sharing of experience and knowledge of individuals and organizations involved in the many practical challenges that such a transition presents. These activities, and the resulting changes, are needed in industrial as well as developing countries (WEHAB, 2002).

These interactions involve science, technology, learning, production, policy and demand, so that entrepreneurs innovate largely in response to incentives coming from the wider innovation system (Foxon, 2008). The technology has to be appropriate for a specific context, so that the target community has the capacity to afford it and to maintain it.

Renewable resources can also become non-renewable if the rate of utilization exceeds the capacity of the planet to recycle them. In other words, excessive consumption can lead to limits in the availability of renewable resources, and consumption itself can become unsustainable (Gutierrez, 2009). Thus, pathways to sustainable use of renewable energy generation and use have to take these limits into consideration.

The feasibility of stabilizing GHG concentrations is dependent on general socio-economic development paths. Climate policy responses should therefore be fully placed in the larger context of technological and socio-economic policy development rather than be viewed as an add-on to those broader policies (Swart, Robinson, and Cohen, 2003). Progress measurement allows understanding how quickly can be built a renewable energy platform, meeting basic human needs, discouraging wasteful consumption and investing in - rather than depleting - natural and cultural capital (Worldwatch Institute, 2008). This requires a transition or a bridge from the current industrial economy’s dependence on fossil fuels to alternative or renewable energy technologies. The shift from our dependence on non renewable, polluting energy resources to renewables will take time and needs to be carefully planned. Policy frameworks will need to be put in place that will enable that transition. In the context of development pathways for renewables and possible implications long-term sustainability aspects of intergenerational, as well as intragenerational equity issues will need to be discussed, to satisfy the basic principle of sustainable development. Criteria for a sustainable energy future include the availability of resources, security of supply, environmental compatibility, as well as social and economic compatibility and energy production that is associated with minimum risks.

9.4.1 Future scenarios of renewables

The previous sub chapters were discussing the impacts of renewables on the environment (9.2), as well as impacts of renewables on socio-economic aspects (9.3). The aim of this subchapter is to consider future scenarios for renewable energy development and define different pathways.

In 2005 renewables produced 16% of world primary energy. Globally, electricity made up 19%, mostly from large hydropower and the rest from other renewables such as wind, biomass, solar, geothermal and small hydropower. Biomass and solar energy contribute to hot water and heating, biofuels provide transportation fuels and energy for industry and power generation. Most renewable technologies, except large hydropower, have been growing at rates of 15-60% annually since the late 1990s. It is this group of technologies that are projected to grow the fastest in the coming decades (Martinot et al., 2002).

Future scenarios of renewables for different regions, different end-user sections and different energy sources need to consider a broad spectrum of possible RETs, as well as the associated risks, the affordability and limitations of the proposed technologies. Furthermore, to achieve low stabilisation targets, not only all technology options have to be evaluated, but also all sources of CO2 and non-CO2 emissions have to be considered (PIK, 2009).

When considering different future scenarios for renewable energy in the context of sustainable development, questions like how are we going to deal with a conventional baseline in terms of equity, trade, security, environment, as well as the impact of subsidies, need to be addressed. What will be possible outcomes in the medium to long-term? And how will this impact on how development pathways are determined.

To determine different pathways it is essential to first have a desired future vision or target and then work out a way on how to achieve that vision or target. In this case the target is an increase in renewable energy deployment which in turn will lead to a more sustainable development pathway. A method used to incorporate sustainable development into the strategic planning process is “backcasting” (Robinson, 1982). The idea behind backcasting is to define the goal or destination and then work backwards from the destination to the current situation. In this case the overarching vision is to keep the level of CO_2 at or below 450 ppm in terms of CO_2 equivalent concentration and keep the global temperature increase at or below 2°C. A part of this vision is the increased use of renewable energy.

As part of an international project on low carbon society scenarios, several global modelling studies like Akimoto (Akimoto et al., 2008) and Remme and Blesl (Remme and Blesl, 2008) have reported renewable electricity as an essential option to achieve deep emissions cut by 2050. Some studies emphasise drastic supply-side decarbonisation pathway, with almost half of primary energy supply comprising solar, wind, biomass, nuclear and CCS by 2050 (Edmonds et al., 2008).

However, as stated earlier, the renewable energy, technology and infrastructure roadmap depends on the desired future vision. This has been amply demonstrated by Fujino et al (Fujino et al., 2008) in a low carbon study of Japan with a target of 70% reduction by 2050 through two different future scenarios – technology-oriented society and nature-oriented society.

Once the pathway has been determined, the potential barriers to development pathways for renewable energy technology innovation/implementation have to be identified. Many barriers are well known, however, overcoming these barriers remains difficult. Other barriers may be less obvious and consequently more difficult to remove. (See subsection 9.1.3 Barriers and Opportunities for more details). For this reason many modelling studies on drastic emissions reduction by 2050 foresee a significant role of renewable energy only after 2020, with other options playing a dominant role in the short run. For instance, Praetorius and Schumacher (Praetorius and Schumacher, 2009) see CCS as a bridging technology toward a renewable energy future.

9.4.2 Global and Regional Development pathways for renewable energy

The development of renewable energy technologies has to take place within the wider context of sustainable development, including economic and social development, protection of the environment and enhancement of equity. This realization is in sync with the growing consensus, as emphatically stated in Akashi et al (Akashi et al., 2007), that the challenges of climate change too are best addressed within the overall context of promoting sustainable development. A sustainable energy system is a system consisting of (renewable energy) technologies, laws, institutions, education, industries and prices governing energy demand and supply for the sustainable development process (Diesendorf, 2007).

Given their large cumulative emissions and higher income levels, the immediate burden of development and financing renewable technologies (RETs) should fall on the shoulders of industrialized countries. This does not mean, however, that many developing countries do not have technology bases that enable them to make significant R&D contributions to RETs. For developed nations, the reduction of the cost/power ratio must drive their research agenda (Wagner, 2004).

To facilitate a global transition to renewable energy will require large investment in national, regional and local energy infrastructures in developing as well as developed countries and economies in transition. For instance, Fujino et al (Fujino et al., 2008) estimate a direct annual cost of 6.7-9.8 trillion yen (or 73-103 billion US$ at 2008-09 exchange rate) for technology investments in renewable energy, CCS and energy efficiency, in order to achieve drastic CO2 reduction on the energy supply side in Japan by 2050. Such a transition will require national governments to channel appropriate financial resources for intensive economy-wide change in technologies, industrial structures, land use and energy infrastructures. These investments will need to come from the public and the private sectors and will have to take many forms, including financial incentives from government; loans and capital investment from banks, private investors, venture capital funds and communities; as well as new innovative markets that contribute to the benefits of renewable energy and energy efficiency (CanREA, 2006).

There are a number of national and international funds that provide grants or interest-free loans to developers of energy efficiency and renewable energy projects. These include among other the Global Environmental Facility (GEF), the Global Village Energy Partnership (GEVP) and the Renewable Energy and Energy Efficiency Partnership (REEEP) (CanREA, 2006). There are a number of innovative funding models available, including the Clean Development Mechanism (CDM); Dealer-Credit Model (Grameen Shakti); Consumer Credit Model; Supplier Credit Model; Energy Service Company Model; Revolving Fund and the Global Environment Facility (GEF). In a global modelling study, Barker et al (Barker, Scieciu, and Stretton, 2008) recommend efficient and targeted use of carbon tax revenues to promote innovation and deployment of low carbon options like those based on renewable energy. They report that such investment effects can lead to a rise in global GDP. Similar mechanism of ‘carbon fee’ to subsidize new renewable energy options is recommended by Johnson (Johnson, 2010).

Developing countries face two main energy challenges; firstly, to meet the energy needs that are essential for economic growth and poverty reduction; secondly, to reduce the threat of regional and global environmental disruptions, particularly addressing the vulnerability of societies to the negative impacts of climate change (Usher, 2007). Barker (Barker, Scieciu, and Stretton, 2008) and Remme (Remme and Blesl, 2008), in global modelling analysis for low carbon society scenarios, indicate a greater share of global emission reduction by the developing countries up to 2050. Hence the energy challenge faced by developing countries is enormous.

To meet the rapidly growing energy needs of present and future populations in developing countries, and to reduce poverty, will require large capital investments (WEHAB, 2002). Many renewable energy companies in developing countries are frustrated by the lack of interest in their businesses from finance institutions, either to finance their operations or to lend to their customers (Usher, 2007).

The large CO2 reduction potential in developing countries can be realized if there is greater alignment between national and global environmental regimes, CO2 mitigation actions are integrated within domestic economic and sustainable development goals, and instruments like CDM are modified appropriately (Shukla, 2008; La Rovere, 2006; Mwakasonda, 2006). Development pathways for renewable energy in developing countries have to ensure that the chosen energy options will be able to improve productivity of resource use, increase economic prosperity and provide positive benefits across all three dimensions of sustainable development (WEHAB, 2002). The development pathway for renewable energy in developing countries has to be compatible with climbing the energy ladder and economic development. Therefore, programs like the UNEP's Rural Enterprise Development programs are a first step towards a pathway for renewable energy in the developing world (Usher, 2007).

A recent initiative dealing with these issues is the African Rural Energy Enterprise Development (AREED) programme which was launched in 2001 under the joint auspices of the United Nations Environment Programme (UNEP), the United Nations Foundation (UNF), E+Co, and UNEP Risoe Centre and with funding from the UNF, SIDA, BMZ and the Dutch government (Akuffo and Obeng, 2008). This initiative has succeeded in developing an ingenious plan of loan provision, building capacity in bankable business plan development, analysing market conditions and identifying efficient energy systems for Small and Medium Enterprises (SMEs). However, according to Akuffo and Obeng (Akuffo and Obeng, 2008), energy SMEs in Africa are facing several constraints and challenges including: lack of relevant policies and institutional framework to provide sufficient leverage for SMEs to tap into new energy business; lack of capacity building in energy system development and commercialization; limited rural energy market; inherently high initial cost of renewables and energy efficient products; and poor access to clean energy financing. This suggests that without an enabling policy framework, SME energy providers in Africa will not be in a position to participate in the emerging energy market. What is needed is a multidimensional approach that has the effect to transform energy systems, social systems, economic systems, and institutions at an unprecedented rate and scale (O'Brien, 2008).

The provision of renewable energy has not been defined as a Millennium Development goal in its own right; nevertheless, access to clean energy services is an important pre-condition not only for environmental sustainability but also for the achievement of most of the other millennium development goals. The development pathways for renewable energy in developing countries have to therefore closely align themselves with the MDGs. Developing countries have to build knowledge and manufacturing capacity in the renewable energy sector within their own countries. It is imperative that researchers and innovators from developing countries remain there and contribute to increasing capacity within their countries instead of leaving the countries to follow a more lucrative career path in a developed country.

Renewable energy can contribute to sustainable development in developing countries, particularly in communities within rural areas which are often not grid connected, in the form of solar home systems (SHSs) for illumination, extending the working day, improving education, reducing the risk of fire from kerosene lamps and improving health problems associated with kerosene lamps. Similarly, wind pumps and solar pumps provide water for irrigation and drinking, improved stoves reduce indoor air pollution, as well as reducing the amount of biomass needed to cook. Biodiesel has the potential to provide energy services for the poor and to create jobs in rural areas (UN-Energy, 2007).

Some developing countries have the opportunity to leapfrog the more polluting fossil fuel based technologies and industries and move directly to more advanced renewable energy technologies and avoid some of the dirty stages of development experienced by industrialised countries The adaptation of technologies to the local context is an essential part of leapfrogging, and the process has to occur in parallel with ongoing social, economic and institutional changes (Sauter and Watson, 2008). Through the leapfrogging concept, developing countries have the strategy to adopt early in their development process the best and most efficient technologies available, so as not to repeat the path followed in the past by industrialized countries, when they industrialized. It is an answer to arguments frequently used to justify a "provisional right to degradation", since the basic needs of the population would have to be met by development at any environmental cost. Adopting the best technologies available, success is founded on the previous understanding of the impacts deriving from the possible choices for a certain society (Goldemberg and Lucon, 2010).

Microenergy, a capillary type of distributed energy generation, is an important option to leapfrog, aiming to provide energy services to the poorer. Adequate technology transfer and microfinance schemes allow small-scale installations to be affordable for application in developing countries, not only reducing occupational, local and global environmental impacts but also helping to break the vicious cycle of poverty. Developing countries cannot afford to be dependent on technology transfer and foreign supply to sustain their technological progress. Instead, technology transfer needs to be coupled with capacity building. This requires finance mechanisms that are appropriate for the specific conditions within which they are applied. In the case of providing finances to the rural poor, Grameen Shakti in Bangladesh has come up with a micro-credit scheme to finance renewable energy technologies to reduce down payment and offer free after sales service solutions that empower women, the disadvantaged, create jobs, facilitate rural development and protect the environment (Barua, 2008).

In the case of developed countries, there are also more sustainable developmental options to consider. Electricity grids across Europe are 40 years old and fast approaching the end of their operating lives. This presents an opportunity for fresh thinking and innovation, exploring possibilities of alternative energy options, based to a large extent on renewable energy resources. The Global Energy Network Institute (GENI) proposed a strategy for developing remote renewable energy sources and linking them to population centers via long distance electrical transmission lines (GENI, 2007).

Most large scale renewable energy sites are located far from population centers. Today, interconnection of renewable energy sources is a viable and feasible energy alternative, from a technological viewpoint (GENI, 2007). With the development of high-voltage valves, it is now possible to transmit DC power at higher voltages and over longer distances.

In 2008 the Trans Mediterranean Renewable Energy Co-operation (TREC) proposed an interconnected grid between Europe, North Africa and the Near East. This is an ambitious plan to turn Europe, North Africa, and the Near East into a super-grid based on renewable resources, ranging from solar (solar CSP and Solar PV), wind, hydro, biomass and geothermal.

To enable the development of renewable energy requires national programs and policies to support renewable energy markets in order to establish renewable friendly laws and regulations, promote renewable friendly building codes and standards, stimulate long term financing and provide sustained financial support for projects

According to PEER (PEER, 2009) the following should happen to stimulate increased energy market by renewable energy: (i) Climate-based subsidies and budget allocations could be increased or new ones introduced; (ii) Subsidies and taxes with harmful climate impacts could be removed or redesigned; (iii) Budget allocations and taxes with favourable side effects from a climate point of view could be increased and; (iv) Rules and texts stipulating the way in which present budget allocations may be used could be more climate-based by stipulating climate-based limits or goals for the administrative bodies that govern these means (PEER, 2009).

Similarly, the White Book from the DESERTEC Foundation posits that a scenario that meets all criteria of sustainability will require determined political support and action. It lists five focal points for national and international policy for all countries in Europe, the Middle East and North Africa (EUMENA): (1) Increase support for research, for development and for the market introduction of measures for efficient supply, distribution and use of energy (efficiency focus); (2) Provide a reliable framework for the market introduction of existing renewable energy technologies, based on best practice experience and increase support for research and development for promising enhancements (renewable energy focus); (3) Initiate a EUMENA-wide partnership for sustainable energy. Provide European support to accelerate renewable energy use in MENA (interregional cooperation focus); (4) Initiate planning and evaluation of a EUMENA High Voltage Direct Current super-grid to combine the best renewable energy sources in this region and to increase diversity and redundancy of supply (interconnection focus) and (5) Support research and development for shifting the use of fossil fuels from bulk electricity to balancing power production (balancing power focus) (TREC).

Ashina (Ashina et al., 2010), in a study of low carbon society scenario for Japan by 2050, recommend early and large investments in renewable energy technology options, as that would have multiple strategic advantages like early learning leading to early reduction of technology cost, smoother turnover in energy infrastructures, and higher possibility of alternative options in case a dominant technology fails unexpectedly. Similar conclusions have been arrived at by Strachen (Strachan, Foxon, and Fujino, 2008a) and Akimoto et al, (Akimoto et al., 2008).

In a modelling analysis of a scenario with 80% CO2 reduction in UK by 2050, Strachen (Strachan, Pye, and Hughes, 2008b) highlight the role of international drivers like technology costs, fossil fuel prices, supply of imported resources, international aviation emissions, trading mechanisms and global LCS consensus, in influencing sectoral and technology portfolio distribution of decarbonization efforts including renewable energy options.

It is clear that the governments at several levels – country, province/prefecture, city, village – will have to act early and proactively to influence major changes in the infrastructures, technology and fuel choices and behaviours of businesses and consumers to adopt renewable energy. For instance, the government of Japan initiated in 2009 a long-term project to combat global warming, called “environment model cities,” in which 13 municipalities have been given bold targets to reduce GHG emissions by 50-60 percent by 2030-2050 as compared to 1990 or 2005 levels (Okuoka and et al, 2009). For instance, Kyoto city government has set a target of 50% GHG reduction by 2050 compared to 1990 level. The mitigation initiatives are selected by municipalities to fit local conditions, economy and resources. For example, Sakai city, with help of its own and central government’s subsidies, is set to begin operating in 2011 one of largest solar PV stations in Japan that will provide power to many households, and to install PV facilities in schools. Yasuhara town, being in a mountain area, has launched a project to recycle wood waste from lumber mills for use a fuel for heating greenhouses by farmers. Shimokawa town in Hokkaido has planned to cultivate willows for use as charcoal and processing into bioethanol.

The methodology for analysis required to assess local or city level low-carbon scenarios would have to be different from a country level analysis, as local economies are much more open with uncertain socio-economic activity and easier and fluctuating cross-border flows of people, energy, material and capital. An analysis for Kyoto city using Extended Snapshot tool, as a part of backcasting methos, showed feasibility of the target of 50% GHG reduction by 2030 by means of energy demand reduction in various end-use sectors and a drastic increase of share of renewable energy to 12.6% of primary energy supply by replacing oil and coal (Gomi, Shimada, and Matsuoka, 2009). Similar analysis was done for Shiga prefecture of Japan (Shimada et al., 2007; Gomi et al., 2007). Both the studies found that majority of the 50% GHG reduction by 2030 can be achieved by local (city or prefecture) level actions alone. Such actions include decentralized renewable energy generation and use in end-use sectors, besides centralize renewable electricity, energy efficiency, and behaviour and land use structure changes.

9.4.3 Development pathways for renewable energy in different end-use sectors

Unlike centralized energy generation based on fossil fuel or uranium, distributed energy generation based on local renewable energy sources provides diversity which in turn means greater strength in guarding against unforeseen events. It offers a risk management strategy that reduces the potential of adverse impacts resulting from interruptions in supply, or excessive price rises in any single supply sector.

9.4.3.1 Built-environment

Buildings consume a lot of energy. Direct emissions from buildings grew by 26% between 1970 and 1990 (IPCC, 2007). Furthermore, the buildings sector has a high level of electricity use and therefore the total of direct and indirect emissions in this sector is much higher (75%) than direct emissions (IPCC, 2007) In recent years, there has been a lot of emphasis placed on energy efficiency. To meet this energy demand, renewable energy can be used. The built environment offers many opportunities for this. Roofs can be used to produce renewable heat with solar collectors, or renewable electricity with solar panels. In addition, renewable heat can be extracted from the ground, using heat pumps. In some cases small wind turbines can be mounted on the roofs to produce electricity. Through the combination of efficient use of energy and the use of local, energy sources, a situation can be achieved where renewable energy meets the biggest part of the energy demand in buildings (ECN) [TSU: reference incomplete].

Low energy houses, also known as green buildings, eco houses or low carbon houses will need to be used in combination with renewable energy technologies. For example, in Guangzhou, China, a 71 story office building combines an energy efficient design with both solar and wind power to operate at zero net-energy consumption (Ayres and Ayres, 2010).

According to the EU Commission, in low energy buildings, as much as 80% of the operational costs can be saved through integrated design solutions. By 2009, around 20.000 low energy houses had been built, mainly in Germany and Austria (European Commission, 2009). The EU Commission aims to have all new home constructions meet the standards set for low energy houses (Ayres and Ayres, 2010).

Outside Europe, similar developments are happening; for example, Japan is currently discussing plans to adopt a goal for zero energy buildings by 2030 and some US states such as California are moving in that direction (European Commission, 2009). In the US, the first passive house was completed in 2009, in Berkley, California (Ayres and Ayres, 2010).

9.4.3.2 Transport

Today's transport sector is predominantly based on combustion of fossil fuels, making it one of the largest sources of urban and regional air pollution and greenhouse gases. The growth in direct emissions from transport between 1970 and 1990 was 120% (IPCC, 2007). However, the movement of goods and people is crucial for social and economic development. Consequently, there is a need to move towards sustainable mobility. Solutions need to be found that address mid-term, as well as long term concerns about transportation, energy and emissions.

According to UNEP (no date) this requires: (i) Urban planning, changing lifestyles and production patterns to reduce the need for transport at the source; (ii) Rethinking transport systems, promoting inter-modality and encouraging the use of the most energy efficient mode of transport, i.e., wherever possible switch from air to rail, from the personal vehicle to public transport or non-motorized transportation and; (iii) Improving fuel efficiency of each mode of transport, and promoting the use of alternative fuels. UNEP has identified three key areas of work to assist countries: (1) The improvement of urban planning to promote inter-modality; (2) The diffusion of cleaner technologies and the deployment of relevant policies that drive them to reduce environmental impacts and (3) The introduction of price signals that capture the full costs of different modes of transport.

Options to develop pathways for renewable energy in the transport sector include increasing the energy from biomass from local resources; i.e. ethanol and bio-diesel, preferably from non-edible crops, so that it does not conflict with food security (as the initiative of Shimokawa town in Japan mentioned in 9.4.2). Explore the potential of the electric car using electric motors, based on electricity generated from renewable energy sources. Hybrid cars and to lesser extent battery cars[1] are a proven technology. Additionally, hydrogen and fuel cells based on renewable energy generation have the potential to play a part in transportation. Several countries are involved in hydrogen bus projects, including Brazil, the US, the UK and a number of other European countries. An LCA of emissions of these proposed options needs to be considered.

9.4.3.3 Land-use

Renewable energy and land use is not without its controversy. Some environmentalists argue that the increased use of renewable energy would have severe environmental consequences. Key renewable energy sources, including solar, wind, and biomass, would all require vast amounts of land if developed up to large scale production (Pearce, 2006). Between 1970 and 1990 direct emissions from agriculture grew by 27%, and the total land use, land use change, and forestry grew by 40% (IPCC, 2007).

The EU Parliament (European Parliament, 2009) places importance on monitoring the impact of biomass cultivation, such as through land use changes, including displacement, the introduction of invasive alien species and other effects on biodiversity. It further posits that biofuels should be promoted in a manner that encourages greater agricultural productivity and the use of degraded land.

Educating policy makers as well as the general public of the true impacts of renewable energy through land use changes has to be part of the strategy towards the development of renewable energy on a larger scale.

9.4.3.4 Other end-use sectors

Industry is vulnerable to climate change, and the industrial sector is responsible for a significant share of energy use and CO2 emissions. Achieving sustainable development requires the implementation of cleaner production processes. Industry has a large potential to address climate change issues by enhancing energy efficiency and increasing the use of renewable energy. Biomass is widely used to generate energy for some industries, in particular in the pulp and paper industry. In Europe it is the largest producer and user of renewable energy sources with 50% of its primary energy consumption coming from bio-energy (CEPI (Confederation of European Paper Industries), no date). Biomass is also widely used in countries like Brazil to produce energy as a by-product from sugarcane. Industry can also use solar or wind as a source for its energy. Concentrated solar power is being considered for electricity generation as well as process heat. The International Energy Agency (IEA) is presenting a roadmap for CSP at a summit in June 2010 in Valencia, Spain. It expects CSP to become competitive for peak and mid-peak loads by 2020 in the sunniest places if appropriate policies are adopted. The overall contribution of CSP is anticipated to provide 11% or more of the global electricity demand by 2050 (Environmental Expert, 2010).

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[1] Zebra high-energy battery made from common salt, ceramics and nickel is able to store four times more energy than a lead acid battery holding the same weight and allows a range of up to 400 km (http://www.solartaxi.com/technology/zebra-battery/)

Agriculture has a large role to play in the production and consumption of solar, wind, geothermal, and biomass energy. In the US as well as the EU, farmers are selling energy; for example, electricity generated from wind turbines, biofuels, and products from biomass.

Bioenergy to replace fossil fuels can be sourced from agricultural feedstocks such as dedicated energy crops and by-products or waste from agricultural production. The IPCC report (IPCC, 2007) estimated that the energy production potential from agricultural residues varies between 15 and 70 EJ/yr. “Organic wastes and residues together could supply 20-125 EJ/yr by 2050, with organic waste making a significant contribution (IPCC, 2007)(p. 519).

Dedicated energy crops have still more potential, and according to an estimate by the European Molecular Biology Organization, energy crops could deliver 800 EJ per year without jeopardizing global food supply (1 EJ = 1 × 1018 J) which is considerably more energy than is now consumed globally — 2006 consumption was 500 EJ (Hunter, 2008).

9.4.4 Development pathways for renewable energy in different energy sources

The challenges associated with renewable energy technologies, like intermittency of wind generated grid power and storage of electricity from solar power are well documented. To facilitate development pathways for renewable energy technologies it is therefore essential to finance research to find solutions to these challenges.

Besides the more conventional storage technologies including hydro-pumped and compressed air storage for electricity generation there are examples of alternative, existing storage technologies, like the Vanadium Redox Flow Battery (VRB), which was developed and commercialized by the University of New South Wales (UNSW) Australia. According to the UNSW website, it has shown to have high energy efficiencies between 80 and 90% in large installations and is low cost for large storage capacities. (Skyllas-Kazacos, no date).

Biomass has the potential to supply large amounts of CO2 neutral energy, when not entailing deforestation. It is already competitive in some markets. Currently about 13% of the world’s primary energy supply is covered by biomass. Industrialized countries source around 3% of their energy needs from biomass, while Africa’s share ranges from 70-90% (WBCSD, 2006). Current use of agricultural biomass for non-food purposes, including energy, amounts to around 9% of agricultural biomass being harvested and grazed for food (Wirsenius, no date). Thus, agricultural products and residues, as well as dedicated energy crops, are a key part of the overall supply of biomass. In 2005 roughly 46 EJ out of the total supply of 490 EJ were derived from biomass making it the most important renewable primary energy source (Sims et al., 2007).

Possible negative impacts associated with large scale biomass farming need to be considered. A framework is required to address issues of land ownership, de-forestation and land-clearing, displacement of people, competition with food production and in some cases emissions from fuel-wood negatively impacting on indoor air quality (See 9.3.1 for more detail on bio-energy).

In addition to residues and purpose grown energy crops, waste products like animal wastes, human wastes (e.g. anaerobic digestion of sewerage sludge to produce bio-gas or inter-esterification of tallow to give bio-diesel) have large potential for carbon neutral energy production. Similarly, municipal solid waste, either combusted in waste-to-energy plants or placed in landfills with the methane gas collected for electricity and heat production play some part (Sims, 2004). Human and animal waste has been in use in countries like China and India for some time to produce biogas (methane) in anaerobic digesters, and the technology is being introduced in some African countries. Its potential as a source of energy for lighting and cooking and waste treatment, particularly in densely populated areas, has to be looked at more seriously.

Box 9.2. Biogas from human Waste – the case of Rwanda (KIST, 2005)

Large prisons, with typically 5,000 prisoners, are a legacy of the troubled past of Rwanda. Sewage disposal from such concentrated groups of people is a major health hazard for both the prison and the surrounding area. The prisons also use fuelwood for cooking, putting great pressure on local wood supplies. A large-scale biogas scheme was developed for prisons in Rwanda to treat toilet wastes and generate biogas for cooking. The after-treatment, bio-effluent is used as fertiliser. Biogas digesters are not a new idea, but in Rwanda has been applied on an enormous scale with great success. A linked system of underground digesters avoids the sight and smell of sewage. System construction provide on-the-job training to both civilian technicians and prisoners. The biogas piped to prison kitchens halves the use of fuelwood. Fertiliser benefits both crop production and fuelwood plantations. Starting operation in 2001, plants are now running in six prisons with a total population of 30,000 people. Annual fuelwood saving is about 27,000 m3 - about 10,000 tonnes of CO_2 equivalent per year. It is expected to install three more each year. The systems installed in Rwanda have an impressive international heritage: the original design came from China, was modified by Germans and finally scaled up and refined by a Tanzanian engineer working in Rwanda. Each individual digester has 50 or 100m3 in volume, built up on a circular, concrete base using bricks made from clay or sand-cement. A 100m3 plant can store 20m3 of gas, but may generate up to 50m3 per day, so it is important that the gas is consumed regularly. Great care is taken to ensure that the effluent is safe to use as fertilizer, with regular laboratory checks for viruses, bacteria and worms. It is used only for crops that stand above ground, such as papaya, maize, bananas, tree tomato and similar tree crops. A prison with a population of 5,000 people produces between 25 and 50 cubic metres of toilet wastewater each day. Using a 500m3 system (five linked digesters), this produces a daily supply of about 250m3 of biogas for cooking. Plants are purchased by the Ministry of Internal Security (£50,000 for a 500m3 plant) through phased payments, with the final 5% paid only after 6 months of satisfactory operation. Trained prisoners operate the systems. To date, over 30 civilians and 250 prisoners have received training, and three private biogas businesses have been started. A certification body keeps quality standards high, avoiding failures that would damage the biogas sector as a whole. There is clear potential for widespread replication of these biogas plants, in Rwanda and many other countries. The International Committee of the Red Cross (ICRC) is a key partner which, together with the government of the Netherlands, has assisted in financing the programme.

Direct solar produces minor emissions during operation, and the overall life cycle environmental performances are improving. For example, all PV technologies generate far less life-cycle air emissions per GWh than conventional fossil-fuel based electricity generation technologies (Fthenakis and Hyung, 2009). Furthermore, because it generates mainly decentralized energy, direct solar potentially increases job opportunities and income in rural areas, particularly in developing countries. Possible negative impacts to consider are issues around land occupation for large solar thermal installations, resulting in change of albedo. The up front costs are relatively high but there are no fuel costs (see 9.3.1 for more detail on direct solar).

Electrical production from geothermal results in an order of magnitude less CO2 per kilowatt-hour of electricity produced compared to burning fossil fuels (Bloomfield, Moore, and Jr., 2003). However, there are some site specific emissions associated with energy production form geothermal. Similar to other renewable technologies it has potential to improve employment opportunities in developing countries. The capital costs are still high; however, variable costs are low. (See 9.3.1 for more detail on geothermal energy).

Hydro power has the capacity to store energy, as well as water for irrigation. However, large hydro dams release methane emissions, have high lifecycle emissions, mainly during construction, and potential to displace people and damage existing settlements. Energy price is very cost competitive. (See 9.3.1 for more detail on hydropower).

Ocean power, particularly wave and tidal power has potential to provide base load energy with no emissions during operations. However, some emissions may arise during manufacturing and installation of the devices. Tidal power may require large structures that have environmental impacts (See 9.3.1 for more detail on ocean energy).

Wind power is the most-cost-effective renewable energy technology producing electricity (except for large hydropower) with some lifecycle emissions but no emissions during operation. It has a positive impact on rural economies. There are some issues about visual and noise pollution, as well as risk of collision for birds and bats (see 9.3.1 for more detail on wind energy).

Development pathways for different energy sources vary; some like wind, hydropower and bio-energy are already competitive and well established; others like direct solar, geothermal and ocean power in particular require assistance to advance their development and scale up production.

9.5 Policy framework for renewable energy in the context of sustainable development [TSU: this has been changed from the original title ‘Implications of (sustainable) development pathways for renewable energy’ and needs to be approved by IPCC Plenary]

On the global level there is a recognized need for the international community to strengthen its commitment to the scaling up of renewable energy development and use, especially in developing countries (BIREC, 2005).

International organizations like the UN Framework Convention on Climate Change (UNFCCC) (i.e. Clean Development Mechanism), the International Energy Agency, the UN Development Program (UNDP), Energy and Environment, the UN Division of Sustainable Development, the World Bank Energy Program, the UNDP/World Bank ESMAP (Energy Sector Management Assistance Program) and others play an important role in building capacity and improving financing and transfer of technology know-how for renewable energies. For example, UNEP has made support for renewable energy a top priority in its call for a “Global Green New Deal” at the recently held COP14 in Poland (Sawyer, 2009).

Similarly, organizations like the Renewable Energy and Energy Efficiency Partnership (REEEP), , the Global Network on Energy for Sustainable Development (GNESD), the Global Village Energy Partnership (GVEP), the International Network for Sustainable Energy (INFORSE), the UNEP Sustainable Energy Finance Initiative, the World Council on Renewable Energy (WCRE), the World Alliance for Decentralized Energy (WADE), the World Business Council for Sustainable Development (WBCSD) and the World Renewable Energy Congress/Network (WREC/WREN) all aim to accelerate the global market for sustainable energy by acting as international and regional enablers, multipliers and catalysts to change and develop sustainable energy systems.

The International Renewable Energy Agency (IRENA) is a relative newcomer to assist in the promotion of future oriented development pathways for renewable energy. IRENA is the first international organization exclusively focused on the issues of renewable energies. It is a first, but important step on the global level to have a body that aims to close the gap between the large potential of renewables and their relatively low market in energy consumption.

The World Summit for Sustainable Development (WSSD), the Bonn International Conference for Renewable Energies, the G-8 Gleneagles Summit, and other international and regional initiatives all play an important role to promote renewable energy.

On the regional level there is a need to build stronger partnerships between governments, regional authorities and municipalities, energy producers and consumers, market intermediaries, non governmental organizations (NGOs) and financial institutions in order to facilitate a common understanding of the issues, challenges and constraints related to renewable energy development, and to pave the way for greater cooperation among all groups in society (Slavov, 2000).

There is a growing body of regional organisations involved in the advancement of renewable energy technologies. For example, the European Union energy policy aims to create a single, liberalised energy market (electricity and gas) at the EU level that is both transparent and efficient; to diversify sources for greater security of supply; to reduce energy consumption and promote development of new forms of renewable energy (European Parliament, 2007).

On a national level, organizations like NREL in the US have a role to play in the area of R&D, as well as the dissemination about renewable energy to consumers, homeowners and businesses. Similarly, organizations the American Wind Energy Association (AWEA), the Basel Agency for Sustainable Energy (BASE), the Brazilian National Reference Center on Biomass etc assist the development of renewable fuels and electricity that advance national energy goals in their respective countries.

The role of national governments is to provide an enabling policy framework, through government institutions to stimulate technical progress and speed up the technological learning processes so that RETs will be able to compete with conventional technologies, once the environmental costs have been internalised (see Chapter 11 for more detail). Firstly, renewable energy solutions on the local level should be resource and need driven. Local participation in selecting appropriate solutions is important. Studies like the ones conducted by Gregory (Gregory et al., 1997), Nieuwenhout (Nieuwenhout et al., 2000), Taylor (Taylor, 1998) and Lloyd, Lowe and Wilson (Lloyd, Lowe, and Wilson, 2000) stress the importance of technical reliability. To ensure the reliability of a system it is important that local installers and maintenance personnel are adequately trained. The need for improved education programs and improved accreditation of installers for remote areas was recognised in a recent market survey by the Australian Cooperate Research Centre (CRC) for Renewable Energy (ACRE) (Lloyd, Lowe, and Wilson, 2000). Secondly, the renewable energy solution has to be appropriate and fit in with the specific local context. Innovations based on Western style consumerist ideology should not always be presumed to offer the best or only solution to a problem. That does not mean that traditional technology is necessarily preferable. What it does suggest however, is to allocate equal importance to both Western technology and traditional technology, when considering available options and solutions.

The developers of sustainable energy technology based on renewable energy on the local level face the difficulty of designing a system or product that remains flexible enough to be able to adapt to a number of different social, cultural, political, economic and environmental situations and peculiarities and take local knowledge into account, and at the same time can be mass-produced, in order to remain competitive.

9.5.1 Required instruments for sustainable development pathways for renewable energy

Appropriate policy instruments for sustainable development pathways for renewable energy are required on the global, regional, national as well as local level. The available instruments are similar to those used in environmental policies, with similar discussion involved in their choice.

At the international level, multilateral as well as bilateral agreements like the current Kyoto Protocol are imperative to provide a global framework for the promotion of sustainable development pathways for renewable energy. The three instruments or mechanisms that help industrialized countries achieve their Kyoto emission reduction targets agreed to by allowing them to reduce the cost of reduction are emission trading (ET), joint implementation(JI) and clean development mechanism (CDM). These three instruments provide the conditions for the development of pathways for renewable energy development in developing as well as industrialized nations.

The use of subsidies to promote the development of renewable energies worldwide includes the gradual phase out of subsidies to the fossil fuel and nuclear energy production and consumption and instead increasing the provision of subsidies to renewable energy production and use.

At the regional level, the EU proposes a mandatory target of 20% of renewable energy sources in gross inland consumption by 2020, as well as a minimum target for biofuels of 10% of overall consumption of petrol and diesel in transport for 2020.

In the Asia-Pacific region there is a recognized need to strengthen the policy framework to accelerate the implementation of policies towards achieving sustainable development pathways for renewable energy.

At the national level a mix of command and control or regulatory instruments, as well as market based incentives is required. Two of the main instruments are feed in tariffs and certificate markets. These two policy instruments form an essential tool to achieve the desired transformation towards sustainable development in the context of the global climate challenge. Some evidence suggests that countries with successful renewable energy programs are those that have legislated a feed-in tariff, which ensures fixed prices for every kWh that is being produced by renewable energy sources and is fed into the grid. For example, Germany brought in the Renewable Energy Sources Act, (EEG) in 2000, introducing feed-in tariffs, with fixed payment per kWh for a period of 20 years with steady reductions of the payment amounts at a rate of 1.5% per annum (BMU, 2008). Similarly, in 2009, South Africa adopted the Renewable Energy Feed-In Tariff (REFIT) to facilitate the large scale deployment of concentrated solar power (CSP) in an attempt to shift its electricity generation away from coal to mitigate GHG emissions (Edkins, Winkler, and Marquard, 2009). Other mechanisms like the renewable portfolio standard (RPS) have been used in a number of European countries as well as the United States. The RPS has proven to be quite successful in a number of states in the US (US DOE, 2009).

In addition, defining national targets and setting bidding systems, establishing markets for tradable permits for CO2 emissions, green certificate markets and renewable energy certificates are important instruments to promote the development of RETs. Other financial incentives for renewables and energy efficiency are in the form of corporate and personal tax credits, subsidies, as well as loan and grant programs.

9.5.2 Impacts of Renewable Energy on Use of Resources

The deployment of renewable energy is very often pointed out as one of the most important steps on the way to a more sustainable future. Wind power, solar and geothermal power and heat, biofuels and other forms of renewable energy are often called “green”, for they are believed to have no adverse impacts to the environment. Even though this is only partially true, generation of power and heat from renewable sources per se has indeed very little impact on the environment in terms of emissions of polluting substances, unlike the conventional fossil fuel-based technologies.

It is important to understand, however, that in order to produce the conversion technologies, install them, operate, maintain and dismantle them, a broad spectrum of activities and industries needs to be involved, which certainly impact the use of natural resources like water and land. This does not mean to say that renewable energy utilisation is not an ‘environmentally friendly’ option in comparison to conventional fossil fuel technologies. On the contrary, emissions and other negative impacts to the environment are certainly lower for renewable energy technologies. (Pfaffenberger, Jahn, and Djourdjin, 2006)

However, it should be noted that future development of renewable sources could be constrained by air, land, water and other requirements. This issue is specific to each project, because compatibility with requirements differs widely. The constraints depend on many factors, among others population density and compatibility of a project with other requirements.

Two approaches are often used to evaluate resource utilization caused by different generation technologies. Elementary approaches quantify the use of air, land and water (among others) directly utilized in the energy conversion process. More sophisticated approaches identify direct and indirect use of the resources involved. This kind of analysis is used to quantify all the resources involved in the complete life-cycle of the electricity generation process.

A life-cycle assessment (LCA) is an environmental assessment of all of the steps involved in creating a product. Its goal is to give an all inclusive picture of the environmental impacts of products, by taking into account all significant ‘‘upstream’’ and ‘‘downstream’’ impacts. In the power sector, the assessment includes extraction, processing and transportation of fuels, building of power plants, production of electricity and waste disposal. (Gagnon, Bélanger, and Uchiyama, 2002).

Comparative analysis of resources used by power generation systems should take into account the intermittency of the generation technology, thus, resource per energy or average power are preferred instead of resource per installed capacity. For example, it would not be fair to compare bioenergy to windpower in terms of m^2/MW (Gagnon, Bélanger, and Uchiyama, 2002).

It is possible to evaluate the water requirements along the life-cycle for a generation technology, a concept defined as Water Footprint (WF). The WF of a product (commodity, good or service) is defined as the volume of fresh water used for the production of that product at the place where it was actually produced. Most of the water used is not contained in the product itself. In general, the actual water content of products is negligible compared to their WF (Gerbens-Leenes, Hoekstra, and van der Meer, 2009).

9.5.3 Public awareness on RE potential and opportunities

Most renewable energy applications have traditionally been perceived very favorable by the general public maybe with exceptions around some large hydro dams and parts of the bioenergy agenda. Many solar, wind and bioenergy initiatives have originally been rooted in local community initiatives contributing directly to the positive perception. With up-scaling and having the development of new installations being driven by other stakeholders, typically utilities or private power companies it is not evident that the positive public perception is immediately maintained. Increased public resistance to new large installations have been experienced in many countries also beyond the more narrow “not in my backyard” type concerns. Public awareness and acceptance is therefore a very important part of the climate mitigation driven need to rapidly and significantly scaling up the adoption and deployment of RE technologies. Such large scale implementation can only successfully be undertaken with the understanding and support from the public and this will require dedicated awareness raising on the achievements of existing RE options and the opportunities, prospects, and potentials associated with wider scale applications (Barry, Ellis, and Robinson, 2008).

However, poor perception of the benefits of renewable energy technologies will continue to override success registered in the market. In some developing countries (Egypt, Zimbabwe, Tanzania, Ghana), local entrepreneurs who have managed to corner the market with renewable technologies such as solar home systems, solar panels etc. can act as agents of change. For this to happen, they need to have a platform to demonstrate success and respond to informational needs that may arise from potential users. Specific groups such as the finance and industrial sectors, bank and government officials in key finance and economic ministries, private sector, entrepreneurs need to be targeted in order to increase their confidence and uptake in renewables. In addition, the link to sustainable development benefits needs to be clearly articulated to further expand the market for renewable and increase its uptake. For instance, biogas plants have been identified as quite an attractive renewable option given the fact that it can be used as sanitation or agricultural project with energy spin off. Countries in East, North and West Africa have populations that are highly reliant on agriculture; thus pumping technologies such as wind pumps can help boost opportunities for irrigation, guarantee a stable water supply, enhance agricultural productivity and boost livelihood opportunities. Also, the benefits of renewable energy technologies such as PV that can serve rural energy needs such as communication, education, and health need to be shared – often this technology can be used in combination with other energy options for optimal value and for sustainability. Other ancillary benefits relating to avoided emissions for certain renewable as well as the knock-on effect on improved air quality need to be demonstrated to attract women entrepreneurs.

Awareness raising is evidently only one necessary component in gaining public acceptance for increased RE deployment; it will require more direct engagement at the local level for specific policies and installations and often need to be seen as part of a broader sustainable development process. Increased awareness of opportunities for direct use of RE installations e.g. solar water heaters or PV systems in households is a distinct part of the overall expansion of RE utilization.

Providing relevant and carefully targeted information to the different stakeholders including the general public in order to respond to concerns over climate change related issues, and to the private sector to leverage commercial interest and investments in RE, is found to be key and is already happening in many countries (Wolsink, 2007). Various types of information on RE technologies are relevant and the dissemination channels may vary. Examples of these include TV, Internet, social networks, publications, meetings, child education and demonstration. TV is already in use quite widely for information campaigns, corporate promotion, direct marketing, and could also include documentaries providing information about RE applications, climate change aspects etc. The Internet is similarly widely used for providing access to information and awareness material and an increasing number of innovative applications are available for esp. the youth engagement (games, YouTube videos, forums, etc.). Social networks either web based (like Facebook or MySpace) or more traditionally organized can be effective in facilitating communication and impacting opinions. Also to mention are different types of publications (from newspaper articles to leaflets to simple slogan statements and many more), public meetings, talks and quiz games, the inclusion in education curriculum from kindergarten level and upwards and direct demonstration plants with public access. These options may not all apply equally well in all developing countries although some definitely would be highly relevant. Additional specific options for developing countries may include: (i) the involvement of community organisations; (ii) engagement of local leaders/elders in information, decision making and maintenance; (iii) engagement of local communication providers e.g. mobile phone outlets and (iv) use of local radiostations.

It should also be noted that there are many strong economic and political interests vested in the energy sector and opponents to increase RE utilization have significant financial resources to provide information and lobby policy makers. As an element of RE technology support programmes many national or cross–national governmental institutions have initiated RE promotion campaigns aiming to increase public awareness and thus influencing choices of end consumers (see e.g. (European Commission, 2006). Interest groups, NGO’s, trade associations, and industry organizations, among others, may also play a central role in this regard.

Experience shows that such efforts as well as related demand side management initiatives may have a large impact on the choices made by consumers and RE deployment over time (Christiansen, 2002). Private sector actors generally show interest in accessing more specific technical and economic data; including availability of RE input resources, technology reliability and commercial maturity, sourcing opportunities, technology cost effectiveness, etc. All part of the information basis that companies require to judge the relevance of entering into new business opportunities either directly or as part of corporate image building. Lately the issue of "carbon footprint" and carbon neutrality have become important corporate concerns for many larger national and multinational companies leading to increased focus on options in clean energy supply, enhanced efficiency and carbon trading.

Besides national initiatives, international platforms for RE information, clearing houses, networks and knowledge sharing forums on RE technology options like Renewable Energy Policy Network for the 21st Century (REN 21) may play important roles, on a broader international scale, for augmenting deployment of RE technologies. REN21 is a global policy network that provides a forum for international leadership on renewable energy. Its goal is to bolster policy development for the rapid expansion of renewable energies in developing and industrialised economies. Other examples include the Energy and Environmental Technologies Information Centres (EETIC) and the Global Renewable Energy Policies and Measures Database and others. The recently established International Renewable Energy Agency (IRENA) is expected to play an important international role in the future in this area. IRENA's mission is to promote the widespread and increased adoption and sustainable use of all forms of renewable energy. IRENA's Member States pledge to advance renewables in their own national policies and programs, and to promote, both domestically and through international cooperation, the transition to a sustainable and secure energy supply.

It is of key importance that information needs to be targeted at and be accessible for very different types of stakeholders and consequently the total spectrum is very broad ranging from small scale rural household RE technology options to large scale off–shore windfarms. This can in most cases not be covered by the same institutions and targeting information at the many different stakeholders is a key challenge both in terms of format and timing.

9.5.3.1 Institutional capacity – policy, encouragement and enforcement

At the national level there are a variety of policy instruments, measures, and activities relevant for policy makers and governmental institutions to increase the deployment of RE technologies (Beck and Martinot, 2004). The adoption of such policies may be directed towards supporting various stages in the RE promotion process from basic R&D at universities, private companies, or non–profit institutions, to demonstration, commercialization, and full deployment stage.

Experiences from countries that have effectively promoted private investments in renewable energy show that national strategies, policies and targets are key elements (REN 21, 2006). Most existing successful national renewable energy strategies have wider goals, such as security of energy supplies, environmental protection, climate change mitigation, renewable energy industry development, and ultimately sustainable development (enhancing energy access, alleviating poverty, addressing gender and equity issues, etc).

Information, data and capacity constraints is often a barrier both for the setting of broad policy priorities and for drafting actual sector-specific legislation. The same constraints may also prevent the private industries, including finance companies, from estimating more accurately the risks of cleaner energy technology investments, and stifles more widespread adoption of cleaner energy technologies by industry especially in many developing countries. Limited institutional and human capacities are a particularly important concern amongst governmental agencies, which face growing demands in the area of climate change, but lack of capacity also hampers the private sector's ability to organize itself in a more effective manner.

Strategies for promoting certain RE technologies may therefore aim at accelerating the innovation process in specific stages of the technology push – and market pull continuum (IEA, 2000). Ranging from identifying an interesting technology and developing it into a product, and only then searching for a marketplace. To the other extreme where the marketplace needs are first analysed and then focus is on developing a new product to meet that need. As stated the reality is often a continuum with a combination of approaches even for a specific technology. However, the institutional capacity to make strategic choices and support schemes for RE implementation often is limited and need to be built in the relevant agencies and organizations.

This need for capacity development for making appropriate planning efforts on RE is most urgent in developing countries, however, the capacity of many industrialized countries to develop and implement RE policies and technologies is still limited (Assmann, Laumanns, and Uh, 2006). This often constitutes a significant and real barrier to increased utilization and deployment of RE technologies (Painuly, 2001).

Furthermore, the process of implementing RE policies spans from goals and targets setting to implementing concrete activities and finally to monitor and verify the results and this requires different types of institutional capacity to secure effective outcomes. Many developing countries have typically received support to develop national policies and plans but lack support for ensuring the successful implementation and follow-up.

Decision making and policy implementation has also in many countries changed from solely being the responsibility of certain government levels to increasingly involving various private sector stakeholders, NGO's, and civil society. This shift is incorporated in the inclusive concept of governance, which reflects the need to involve and give influential mandate to relevant parties in order to reach desired and successful outcomes (REN 21, 2006).

Participatory approaches to encourage stakeholder involvement as well as local democracy considerations are therefore key issues to achieve wider support of deployment of RE initiatives in a broader sustainable development context. Planning efforts and governmental intervention in the area of various RE technologies may also be understood as one element, i.e. the institutional infrastructure, of the technology system of innovation in question (Jacobsen and Johnson, 2000). Therefore, increasing RE technology deployment depends on a comprehensive understanding of other involved actors and the interactions between them in this innovation system.

In very broad terms, policies can be grouped into seven main categories i) research, development and demonstration incentives; ii) investment incentives; iii) tax measures; iv) incentive tariffs; v) voluntary programs; vi) mandatory programs or obligations; and vii) tradable certificates. (REN 21, 2006). The evolution of these policies since the 1970s reflects among other things, an increased market orientation or policies moving from regulation towards economic policy tools. Presently, feed-in tariffs, obligations and tradable green certificates are emerging as the main policy instruments in many developed and increasingly some developing countries. Investment incentives and various tax measures do, however, remain important mechanisms to stimulate renewable energy investment, and it remains to be seen if the current financial crisis will affect policy tools in a potential move back towards more direct government regulation.

The gradual shift from regulatory approaches towards more economic and market oriented policy tools also has implications for the expertise required to develop and implement policies reflecting back on the need for new approaches on the capacity building side. This links in many developing countries with broader shift of the whole perception of RE implementation from niche applications and demonstration projects to having targets and policies at national level. The elements in the new paradigm are illustrated in Table 4 from Martinot (Martinot et al., 2002).

Table 4: New Approaches to Renewable Energy Market Development in Developing Countries

Old Paradigm		New paradigm
Technology assessment	⇨	Market assessment
Equipment supply focus	⇨	Application, value-added, and user focus
Economic viability	⇨	Policy, financing, institutional, and social needs and solutions
Technical demonstrations	⇨	Demonstrations of business, financing, institutional and social models
Donor gifts of equipment	⇨	Donors sharing the risks and costs of building sustainable markets
Programs and intentions	⇨	Experience, results, and lessons

Source: (**Martinot** et al., 2002)

9.5.4 Technical capacity – development and deployment

In most cases, the proprietary ownership of RE technologies is in the hands of private sector companies and not in the public domain and the diffusion of technologies also typically occurs through markets in which companies are key actors (Wilkins, 2002).

This necessitates a need to focus on the capacity of these actors to develop, implement and deploy RE technologies in various countries. Therefore, besides considering capacity development at the institutional level, the importance of increasing technological capability at the micro or firm–level needs to be addressed (Figueiredo, 2003; Lall, 2002). The concept of firm–level technological capabilities has in this regard been put forward to characterise the ability of companies, as a whole, to utilise technological knowledge efficiently to assimilate, use, replicate, adapt, and generate changes in existent technologies and the ability to develop new technologies, products, and processes (Lall, 1992; Bell and Pavitt, 1993; Dutrénit, 2004). Companies, as organisations, may incrementally accumulate such capabilities over time enabling the company to undertake progressively more demanding, dynamic and innovative activities. This is by no means an automatic process and the literature identifies both failures and successful outcomes of companies' aspirations to increase their technologies capabilities (Metcalfe, 1995; Figueiredo, 2003).

An important strand of literature especially addresses the factors important for capability accumulation in firms in late–industrialising or emerging economies (Sharif, 1994; Hobday, 1995; Perkins and Neumayer, 2005; Mathews, 2007). In many developing countries, the initial focus will be on attainment of basic level capabilities to conduct operational functions and maintenance of RE technologies and/or to manufacture minor sub–components(Chandra and Zulkieflimansyah, 2003; Bell, 2007). In others, companies may be aspiring to achieve higher levels of innovative capability to adapt and develop RE technologies to changing circumstances. The types of capabilities needed are many-sided and country specific, and concerns various company related functions, including prefeasibility phase activities, project engineering, investment decisions, product and process organisation, and more (Jacot, 1997; Lorentzen, 1998).

A variety of factors may have an effect on fostering the accumulation of technological capabilities for RE technology deployment at the firm-level. Organisational intra-firm aspects are important but macro level structures such as industry specific regulations, political and economic factors, legal issues, cultural and social factors, etc., plays an equally important role. The supporting structure of technology-specific, national, or regional system of innovation for increased RE deployment may therefore be influential (Jacobsen and Johnson, 2000). National and cross-national company partnerships as well as technical assistance and joint cooperation programs for RE technologies may also influence capability accumulation positively.

Capacity building and technical support by or for the public sector can usefully address issues that facilitate more rapid development and implementation of RE by private companies and can for example cover issues like resource and technology data, testing and licensing, research and development. Resource and technology is an area for capacity development especially for developing countries, but also in many industrialised countries is the lack of appropriate data on resources and technology performance an important barrier to increased RETs implementation. Regarding testing and licensing, an important contribution to the successful development of the wind industry was the enforcement of strict testing and licensing procedures – still applicable – which helped ensure that quality of the developed turbines was high and in this way increased the credibility of a new technology. This approach is increasingly replicated in other technology areas and will facilitate credibility both with the end user and with the financing institutions involved in providing capital for the up-front investment. Linked with the more official certification approach could be campaigns aimed at companies creating better awareness of the importance of strict quality assurance to guarantee reliable services and products. Many early experiences with RE technologies in the seventies were based on poor quality products and provided a longer term setback on the market. Concerning research and development, governments individually or in the context of regional or bilateral collaboration will need to step up the investments in general technological advances and demonstrations both on individual technologies, integrated energy systems or implementation measures. Compared to other areas like nuclear fusion and fission the funds devoted to RE research and development have been on a much lower scale. For example the OECD country governments in 2005 are estimated to have spent 9.6 billion USD on energy related research with approx. 1.1 billion for renewable broadly and 3.9 billion on nuclear (OECD, 2008, 2008). This is not arguing for lowering funding for nuclear research but significantly increasing the R&D for RE as is being demonstrated by several countries that have substantially increased funding during 2008-09.

In the context of the UNFCCC technology transfer has been a permanent issue as part of the negotiations and there is a strong focus in current talks to have new dedicated efforts as part of a possible new agreement. This is expected to among other issues to focus on: (i) Development of effective policy frameworks to accelerate the transfer, deployment and dissemination of existing and new technological solutions; (ii) Strengthen investment, research, innovation, information and skills sharing, dissemination and uptake of clean technologies, through bilateral and multilateral partnerships; (iii) Promote sustained and joint efforts between government and the private sector, including the financial sector, to promote the market for new technologies; (iv) Provide technical support to developing countries in conducting and improving their technology needs and in transforming such assessments into bankable technology transfer projects that meet the standards of potential financiers and; (v) Develop international energy management standards to increase the efficient use of existing and future technologies in industry and other sectors.

9.6 Synthesis (consequences of including environmental and socio-economic considerations on the potential for renewable energy, sustainability criteria)

9.6.1 Sustainable renewable energy

From the policy perspective, the main attractions of renewable energy are their security of supply, and the fact that they are environmentally relatively benign compared to fossil fuels. Most forms of renewable energy are available within the borders of one country and or not subject to disruption by international political events. Central and State Governments in many countries have enacted laws and regulations to promote renewable energy and to encourage sustainable technologies. In doing so, they had to define what they meant by “renewable” and “sustainable”, deciding what would be eligible for subsidies and tax concessions. Lobbying frequently interfere in this process, resulting definitions of “renewable” and “sustainable” are often different than their original meaning (Frey and Linke, 2002). At political meetings, the term “sustainable energy” is usually more prescriptive than “energy for sustainable development” (Spalding-Fecher, Winkler, and Mwakasonda, 2005). The questions of renewable and sustainable energy now figure prominently on the political agendas and have their roots in two distinct issues: while renewability is a response to concerns about the depletion of primary energy sources, sustainability is a response to environmental degradation of the planet and leaving a legacy to future generations of a reduced quality of life (Frey and Linke, 2002). Able to provide cost-effective and environmentally beneficial alternatives, the attributes of renewable energy technologies (e.g. straightforward implementation, modularity, flexibility, low operating costs, local availability, security of long-term supply) differ considerably from those for traditional, fossil fuel-based energy technologies (e.g., large capital investments, long implementation lead times, operating cost uncertainties regarding future fuel costs). In this sense, renewable energy technologies are often fully assessed and leading to conclusions of being less cost-effective than the traditional options. Renewable energy resources have also some problematic but often solvable technical and economic challenges (like being generally diffuse, not fully accessible, sometimes intermittent and regionally variable) and may cause local impacts which give rise to concerns and opposition to the development, further fuelled by uncertainties and misinformation (Upreti and van der Horst, 2004). Weighting positive against negative effects can be a complex task. An example are “small hydro” plants pre-defined as renewable and sustainable, whereas “large hydro” is not labelled as this by some legislators, with wide definition variations from jurisdiction to jurisdiction. , from as little as 1MW to as much as 100MW capacity (Frey and Linke, 2002). Another case is bioenergy, as demands grow due to cost-effective strategies for the reduction of greenhouse gas emissions. Trade of biomass-related products changed the traditional view that such fuels should be used in the region where it was produced due to high transport costs and limited availability. There are different reasons for international biomass trade, but the most important drivers are the lower prices (even when sea transport is included), enhanced supply security, favourable energy and subsequent greenhouse gas balances, market access and enhanced socio-economic development. However, concerns arise on the potential negative impacts of bioenergy related activities, e.g. competition with food production; deforestation or high input of agrochemicals; increased water use and many other indirect effects. Criteria and tools are searched for that help to avoid that biomass, unsustainably produced, is sold as a sustainable resource. Previous experiences in the forestry (since 1993) and agricultural (since 1991) sectors are useful tools containing sustainability criteria and indicators (Lewandowski and Faaij, 2006).

9.6.2 Assessment tools and policy implications

The environmental impacts associated with RE clearly vary by technology, location, availability of resources (e.g., water), the potential for human exposure, and local ecological susceptibilities. Tools for environmental impact and sustainability include: (i) life cycle assessment (LCA), to assess the environmental burden of products (goods and services) at the various stages in a product’s life cycle (“from cradle-to-grave”); (ii) environmental impact assessment (EIA), assessing the potential environmental impact of a proposed activity, assisting a decision making process; (iii) ecological footprints analysis, an estimation of resource consumption and waste assimilation requirements of a defined human population or economy in terms of corresponding productive land use; (iv) sustainable process index (SPI), measuring a process producing goods in terms of total land area required to provide raw materials, process energy (solar derived), infrastructure and production facility and disposal of wastes; (v) material flux analysis (MFA), an accounting tool to track the movement of elements of concern through a specified system boundary; (vi) risk assessment, to estimate potential impacts and the degree of uncertainty in both the impact and the likelihood it will occur; (vii) exergy, analysis of the quality of a flow of energy or matter, estimating its useful part. Energy potential surveys and studies have a useful role in promoting renewables. Existing energy utilities are important to determining the adoption and contribution of renewable energy technologies and their integration to the system. The importance of effective information exchange, education and training programs lie in the fact that the use of renewable energy often involves awareness of perceived needs and sometimes a change of lifestyle and design. Energy research, technology transfer and development, together with demonstration projects, improve information and raise public awareness, stimulating a renewable energy market. Financial incentives reduce up-front investment commitments and encourage design innovation (Dincer and Rosen, 2005).

Proper assessments and comparisons of such issues typically require a life-cycle assessment (LCA) approach. Ideally, an LCA will characterize the flows of energy, resources, and pollutants across the life-cycle of an RE technology, which includes activities related raw materials acquisition, manufacturing, transportation, installation and maintenance, operation, and decommissioning. The ecological and human impacts associated with such flows are further characterized across a range of impact metrics (e.g., global warming potential, human health damages, ecotoxicity, and land use). As such, LCA provides a framework for assessing and comparing RE technologies in an analytically-thorough and environmentally-holistic manner. Formal LCA methodologies have evolved over the past 20 years (SAIC, 2006), and have been steadily refined and improved over time through various international working groups (e.g., (UNEP, 2009), professional associations (e.g., (ACLCA, 2009)), and methodological standards initiatives (e.g., (ISO, 2006). As discussed in previous chapters, LCA is now being applied with increasing frequency to environmental analyses of RE technologies, most notably biofuel systems, wind energy, and solar energy. This report also shows that LCA considerations are increasingly being adopted by governments to guide far-reaching policies that accelerate RE technology adoption, such as California's Low Carbon Fuel Standard (California Energy Commission (CEC), 2009) and the U.S. EPA's Renewable Fuel Standard (United States Environmental Protection Agency (EPA), 2009). Despite the increasingly widespread application of LCA to RE technologies, key analytical limitations and challenges exist. Notably, most LCAs of RE technologies focus predominantly on life-cycle energy and GHG emissions characterization, with less attention to other key resource inputs (e.g., water) and environmental impact categories (e.g., ecological and human health impacts). The narrow focus on energy and GHG emissions can probably be attributed to several key factors: (1) the relative ease of data access for life-cycle fuels and GHG emissions compared to more obscure data required for emissions related to other environmental impacts; (2) the obvious policy relevance of understanding GHG emissions abatement potentials of RE technologies; and (3) a lack of scientific methods and consensus on characterizing localized impacts such as land use, biodiversity loss, and ecological and human health impacts. It will be important to address these challenges moving forward so that RE technologies can be assessed across a fuller spectrum of environmental impacts, such as those discussed previously in Section 9.3. More complete LCAs would allow for better understanding of the potential tradeoffs across this diverse range of impacts—and possible unintended consequences associated with large-scale RE technology deployment—such that they can be managed and mitigated through the appropriate policy measures.

As discussed in Chapter 2, a number of fundamental methodological challenges exist as well. Major issues include lack of credible data to conduct full LCAs for most RE technologies, defining sound functional units such that RE technologies can be properly compared to each other and to existing fossil fuel sources, and consensus on analytical system boundaries. Furthermore, for increased policy relevance LCA needs to move beyond characterization of straightforward RE technology "footprints" (i.e., an attributional LCA approach) towards analyses that assess the impacts of RE technologies in more dynamic and macro-economic contexts (i.e., a consequential LCA approach).

A move toward the latter approach would allow the full effects RE technologies on environmental, social, and economic systems to be assessed simultaneously for more informed policy making.

Still, as this report shows, the application of LCA to RE technologies has provided many important insights to date. Previous LCAs have shed light on the net energy and GHG emissions balances of RE technologies compared to fossil fuels, vastly increased our knowledge of the complex life-cycle systems and environmental interactions associated with RE technologies, increased our understanding of potential environmental tradeoffs, and uncovered key methodological and data challenges. As such, this work has laid a critical foundation for continuously improving LCA as a policy-relevant decision-making tool for RE policies.

9.6.3 Sustainable energy policies in developing and developed countries

Energy policy came to the fore with the oil crisis of the 1970s, bringing about considerable concerns over security of energy supply, environmental issues, competitiveness of economies and regional development. Before then, governments had largely paid attention to electrification via grid extension and created large integrated monopolies that generated, transmitted and distributed electricity. In most countries in Western Europe governments were engaged in nuclear power development. In some countries governments also involved themselves in the supply of oil, coal and/or natural gas. Renewable energy sources, with the exception of hydropower in countries having significant hydropower potential, attracted very little interest (Johansson and Turkenburg, 2004). With the crisis, research, development and deployment of renewable energy had flourishing years, until the relative political stability in the Middle East reduced international oil prices, making it difficult for renewable energies to compete in the market. There were exceptions, such as hydropower, an already mature technology. Other renewables, such as biomass, solar and wind, evolved considerably during the crisis, with reducing costs and significant environmental advantages over non-renewable technologies that provided the basis for a new growth after the late 1990´s (Frey and Linke, 2002). Practical experience has shown that support for renewable energy technology development is a way to build a competitive industry that will have a global market, as alternatives to conventional energy sources are increasingly sought.

Energy for sustainable development has three major pillars: (1) more efficient use of energy, especially at the point of end-use, (2) increased utilization of renewable energy, and (3) accelerated development and deployment of new and more efficient energy technologies (Johansson and Turkenburg, 2004). The 9th Session of the CSD, held 16–27 April 2001 in New York, was the first time energy was addressed in an integrated way within the United Nations system. The conclusions of CSD9 are particularly important because they formed much of the basis for the UN World Summit on Sustainable Development (WSSD, also known as “Rio+10) negotiations in Johannesburg, 2002 (Johansson and Turkenburg, 2004). Energy was probably the most intensely debated subject at the WSSD. Proposals were made at WSSD to adopt a global target for renewable energy, increasing the share to 10% by 2010. Although no agreement was reached, the final text recognized the importance of targets and timetables for renewables (Johannesburg Plan of Implementation, paragraph 19) a text that significantly advanced the attention given to energy in the context of sustainable development. Setting a target for renewable energy was one of the most controversial issues during the WSSD. The fundamental issue was whether to set any global target at all. Energy continues to be a ‘cross-cutting issue’, with no dedicated institutional structure for energy within the UN system[2]. Several voluntary energy initiatives (called “Type 2”, contrasting

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[2] UN-Energy is an interagency mechanism on energy, established to help ensure coherence in the UN system’s multi-disciplinary response to the World Summit on Sustainable Development (WSSD) and to ensure the effective engagement of non-UN stakeholders in implementing WSSD energy-related decisions. It aims to promote system-wide collaboration in the area of energy with a coherent and consistent approach since there is no single entity in the UN

with “Type 1” multilateral agreements) were launched at WSSD, but without the character of an international negotiating forum. Political leadership still does not exist on both energy access and cleaner energy. (Spalding-Fecher, Winkler, and Mwakasonda, 2005).

The Clean Development Mechanism (CDM), established under the Kyoto Protocol, is an important driver for renewable energy technologies. However, it is not totally clear that when renewable energy policies may establish mandatory targets, these can or cannot conflict with the additionality criteria of CDM projects. An answer may be in the CDM Executive Board (CDM EB, 2009) decision which has stated that national and/or sectoral policies or regulations that give positive comparative advantages to less emissions-intensive technologies over more emissions-intensive technologies (e.g. public subsidies to promote the diffusion of renewable energy or to finance energy efficiency programs) that have been implemented since 11 November 2001 may not be taken into account in developing a baseline scenario (i.e. the baseline scenario should refer to a hypothetical situation without the national and/or sectoral policies or regulations being in place). Host countries decide whether a project meets its sustainable development needs, but criteria and indicators can be based on previously agreed principles or obligations, such as the Millennium Development Goals or the nationally-prepared Poverty Reduction Strategy Papers. Limitations of comprehensive approaches are the complexity, site and project specificities difficult to the international policy community establishing cross-country frameworks comparability.

The world´s energy system is a very large market and relatively small changes can have a significant influence on efforts to reach sustainability. According to Goldemberg (Goldemberg, 2006b), approximately 1.5 trillion dollars were spent in 2004 on primary energy - without considering the cost of secondary conversion, such as electricity production or fuel refining. Subsidies are difficult to estimate. In the period 1995-98, subsidies to fossil fuels are estimated to be around USD 151 billion per year (coal USD 53 bln/yr; oil USD 52 bln/yr; gas USD 46 bln/yr) while to nuclear these amounted to USD 16 billion/yr and to renewables USD 9 bln/yrbsidies comprise all measures that keep prices for consumers below market level or keep prices for producers above market level or that reduce costs for consumers and producers by giving direct or indirect support, in a wide variety of public interventions not directly visible but is hidden in public and economic structures. Policies that aim to promote the instigation of renewables, but fail to deliver a reliable and economically beneficial supply in the long-term, fail to contribute to the concept of sustainability. To change this situation, solutions encompass extending the life of fossil fuel reserves and expanding the share of renewable in the world energy system through top down and bottom up policies. The best example of a top down approach is the Kyoto Protocol, which established mandatory targets for countries for the reduction of greenhouse gas emissions. A Renewables Portfolio Standard (RPS) is a policy that states may use to remove market barriers to renewable power and ensure that it continues to play a role in the competitive environment that follows restructuring of the electricity generating industry. In their simplest form, Renewables Portfolio Standards specify that a percentage of all electricity generated must come from specified renewable energy sources such as wind, hydroelectric, solar energy, landfill gas, geothermal, and biomass (Goldemberg, 2006a).

National renewable energy policies in South Africa, Egypt, Nigeria and Mali were analyzed by Bugaje (Bugaje, 2006). Main constraints to access of other forms than fuelwood of energy in the rural areas are the high capital costs for electrical grid connection, installation and maintenance of appliances and limited distribution of petroleum fuels due to the poor or lack of private or public transport, as well as limited support services. Renewable energy resources, abundant in all the African countries, would provide a major breakthrough in finding a solution to this energy crisis.

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system that has primary responsibility for energy. Secretariat services are provided by the United Nations Department of Economic and Social Affairs – DESA (UN-Energy, 2006).

While South Africa and Egypt present very encouraging models of renewable energy harnessing and utilization, Mali provides a case study of urgency in addressing sustainable energy policy especially in view of the environmental degradation associated with the traditional energy use patterns. Nigeria is a case of abundance of resources - both conventional and renewable - but lack of infrastructural support to harness the renewable resources. South Africa seeks to increase significantly the share of renewable energy. Egypt has policies to develop and diffuse the application of solar (thermal and photovoltaic), wind and biomass energy technology in the local economy.

For large emerging economies energy choices and the related strategic policies are required at the earliest opportunity, to fulfill four key objectives: (1) to deliver the power needed for economic growth and sustainable development; (2) to ensure security of energy supply; (3) to ensure that energy supply and use are conducted in ways that safeguard public health and the environment; (4) to achieve an equitable distribution of energy services (Weidou and Johansson, 2004). In developed countries, there are examples of how sustainable development strategies constituted by a combination of savings, efficiency improvements and renewables can be implemented. Two major challenges are how to integrate a high share of intermittent resources into the energy system (especially the electricity supply) and how to include the transportation sector in the strategies. Reaching this stage of making sustainable energy strategies the issue is not only a matter of savings, efficiency improvements and renewables. It also becomes a matter of introducing and adding flexible energy technologies and designing integrated energy system solutions (Lund, 2007). Even if technology developments will reduce the specific consumption, the world energy demand is likely to increase in line with its population. Energy and material efficiency and the integration of the renewable resources will therefore have to play a major role for sustainable development. The challenge concerns not only the technologies at the conversion and useful energy level, but also the energy management and infrastructures (Marechal, Favrat, and Jochem, 2005)3.

The Organization for Economic Cooperation and Development, together with the International Energy Agency (OECD, 2008) have organized a dataset of existing renewable energy policies by country, describing issues related to sustainable development. Policies were classified by type (Regulatory Instruments; Financing; Incentives, subsidies; Education and Outreach; Policy Processes; Voluntary Agreement; RD & D; Tradable Permits; Public Investment), by target source (Bioenergy, Geothermal, Hydropower, Ocean, Solar, Multiple RE Sources) and sector (Electricity, Framework Policy, Heating & Cooling, Transport and Multi-sectoral Policy). Examples of such RE-SD policies in force in developing countries include: (i) biofuels promotion laws with Environmental Impact Assessment procedures (Argentina); (ii) promotion of best practices (through UK in several countries); (iii) mandatory solar stills for schools (Barbados); (iv) mini-grid projects (Brazil); (v) mandatory biofuels blending requirements (Brazil, Phillipines); (vi) solar in buildings (China, Fiji, Ghana, South Africa, Uganda); (v) subsidies to renewables in rural areas (China); (vi) efficiency improvements (Turkey) also with closure of inefficient facilities (China); (vii) feed-in tariffs (India); (ix) RE targets (Israel); (x) women empowerment (Mali); (xi) R&D (Russia, Singapore).

9.7 Gaps in Knowledge and Future Research Needs

As noted in the introductory section, there is a two-way relationship between sustainable development and renewables. Renewable sources can reduce emissions that will help to better manage the process of climatic change but this reduction may not be adequate to lower temperature increases to tolerable levels. Sustainable development pathways can help achieve these reductions

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[3] The Board of the Swiss Institutes of Technology suggests pathways to the 2000W per capita society (Marechal et al, 2005)

by lowering the overall need for energy particularly fossil fuel supply. Pathways that improve energy access and infrastructure in rural areas for example can lead to less-carbon-intensive energy demand thus reducing the need for overall energy supply. Identifying, documenting and quantifying such pathways and their impact on renewables is a critical need.

A related important step is to identify non-climate policies that affect GHG emissions and sinks, and ways these could be modified to increase the role of renewable energy sources. Often such policies have to be context specific requiring research and analysis that is local or regional.

The current set of global models has rarely looked at development paths with non-climate policies. Development of such models requires a broader set of researchers with strong quantitative SD background who can help define and understand various development paths such as those described in Appendix A. This applies to both industrialized and developing countries.

Renewables mitigation and adaptation capacity will be critical in the future as implementation of projects and programs begins to play an increasingly important and time-sensitive role. Limiting temperature increases to 2 degrees C for instance requires that global emissions peak within the next decade. Even if agreements are reached soon to limit global emissions, capacity building to implement renewable energy policies, programs and projects will be essential. Turning capacity into rapid action will require cooperation among all stakeholders.

Future research will need to examine the role of renewable energy and its implications on the pursuit of sustainable development goals. Several chapters in this report provide information on the implications of renewable energy sources on various SD attributes. These are noted in Tables 1 and 2, which includes both quantitative and descriptive information about the impacts. Missing in the table is a complete understanding of the life-cycle analysis (LCA) of the implications of the use of renewable energy. The biofuels chapter contains the most information on this topic, but it correctly notes that methods, tools, and data sources are not of sufficient quality and comparability yet. Future work will need to focus on this important aspect of renewable energy, which has few and in some case virtual no direct GHG emissions but may have significant indirect emissions.

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Appendix A: RE and conventional technologies: Impact on selected SD indicators

Each cell entry assumes that:
1. Renewable resource is available, and energy and/or electricity is produced on site.
2. Local emissions may vary by regional grid and site; a range may be provided where data are available.
3. Information below is both qualitative and quantitative (when available). Quantitative data is all supported by public reference (annexed to interested parties).
4. Units of measure used by references for each indicator are included in the table (example: gCO2/kWh). Equivalence table given at end when different units are used by different references.
5. For costs, most updated information from IEA was preferred.

ENVIRONMENTAL ISSUES

Selected Environmental SD	***RE Technologies***						***Conventional Fossil Fuel Technologies***			***Nuclear***
	Bio-Energy	***Direct Solar***	***Geothermal***	***Hydro***	***Ocean***	***Wind***	***Oil***	***Gas***	***Coal***	
Emissions and Air Quality. Unit: gCO_2e/kWh	Renewable electricity technologies have inherently low life-cycle CO2 emissions as compared to fossil-fuel-based electricity production, with most emissions occurring during manufacturing and deployment. Renewable electricity generation also involves inherently low or zero direct emissions of other regulated atmospheric pollutants, such as sulfur dioxide, nitrogen oxides, and mercury. (**NAP**, 2010)									

	Sustainable GHG emissions, but there is a risk of unsustainable harvesting. Net GHG emissions in most cases of land use change. Local emissions vary according to fuel and technology, including end of pipe controls. (Ranges available from the US EPA AP-42 database) Fuelwood 120 (**Adamantiades** and Kessides, 2009) (92-156) (**Dones**, Heck, and Hirschberg, 2003) LCA Biomass (35 - 178) (**Varun** and Bhat, 2009)	Minor emissions during operations. Lifecycle emissions are more important. PV 90 (**Evans**, Strezov, and Evans, 2009) (9.4 – 300) (**Varun** and Bhat, 2009) 60 (**Adamantiades** and Kessides, 2009) 79 (**Dones**, Heck, and Hirschberg, 2003) (50-160) (**Voorspools**, Brouwers, and D'haeseleer, 2000) Equivalent Life Cycle (19 – 59) (**Jacobson**, 2009) LCA PV (53.4 – 250) (**Varun** and Bhat, 2009) (60-130) (**Voorspools**, Brouwers, and D'haeseleer, 2000) Solar Thermal (36.2 – 202) (**Varun** and Bhat, 2009)LCE (8.5 – 11.3) (**Jacobson**, 2009) (13.6-202) (**Varun** and Bhat, 2009)	Site specific emissions, including sulfur compounds. Lifecycle emissions. Hydrothermal (0-40.3) (**Tester** et al., 2006) 170 (**Evans**, Strezov, and Evans, 2009) (15.1 – 55) (**Jacobson**, 2009) (0-40.3) g/kWh (**Kagel**, Bates, and Gawell, 2007; **Kagel** and Gawell, 2005)	Site specific methane emissions from some reservoirs, high range, few reservoirs of global total 41 (**Evans**, Strezov, and Evans, 2009) (3-27) (**Dones**, Heck, and Hirschberg, 2003) (17 – 22) (**Jacobson**, 2009) Lifecycle emissions, mainly in construction phase. LCA's of hydro indicates: Run off River 3.7 – 18 (**Varun** and Bhat, 2009) Reservoirs (Japan) 237 (**Varun** and Bhat, 2009) Storage 4.5 (**Varun** and Bhat, 2009) Small Hydro (18 - 74.9) (**Varun** and Bhat, 2009)	No emissions during operations. Lifecycle emissions. Neutral (**O'Rourke**, Boyle, and Reynolds) Tidal 14 (**Jacobson**, 2009) Wave 21.7 (**Jacobson**, 2009)	No direct emissions during operations. Lifecycle CO2 emissions due to manufacturing, transport, & installation reported (2.8 – 7.4) (**Jacobson**, 2009) Onshore 9.7 (**Schleisner**, 2000) (24-27) (**Voorspools**, Brouwers, and D'haeseleer, 2000) Offshore 16. 5 (**Schleisner**, 2000) (7.9-9.2) (**Voorspools**, Brouwers, and D'haeseleer, 2000) (14-21) (**Dones**, Heck, and Hirschberg, 2003) Some limited additional CO2 emissions due to balancing reserves needed to manage wind output variability. (25) (**Evans**, Strezov, and Evans, 2009) (16,5-123.7) (**Varun** and Bhat, 2009) LCA (9.7 – 123.7) (**Varun** and Bhat, 2009) (9-25) (**Voorspools**, Brouwers, and D'haeseleer, 2000) 6.6 (**Vestas**, 2006)	Oil 870 (**Adamantiades** and Kessides, 2009) (519-1190) (**Dones**, Heck, and Hirschberg, 2003) 758 (**Tester** et al., 2006) 758g/kWh (**Kagel** and Gawell, 2005) Diesel 730 (**Adamantiades** and Kessides, 2009) LCA Oil Fired 742.1 (**Varun** and Bhat, 2009) Fossil Fuel Plants release 8.5 billion metric tons of carbon directly into the atmosphere (**Adamantiades** and Kessides, 2009)	543 (**Evans**, Strezov, and Evans, 2009) 550 (**Tester** et al., 2006) (485-991) (**Dones**, Heck, and Hirschberg, 2003) Natural Gas 650 (**Adamantiades** and Kessides, 2009) 550g/kWh (**Kagel** and Gawell, 2005) Natural Gas CC 440 (**Adamantiades** and Kessides, 2009) LCA Gas Fired 607.6 (**Varun** and Bhat, 2009)	1004 (**Evans**, Strezov, and Evans, 2009) (949-1280) (**Dones**, Heck, and Hirschberg, 2003) 994 (**Tester** et al., 2006) 994g/KWh (**Kagel**, Bates, and Gawell, 2007), (**Kagel** and Gawell, 2005) Lignite 1240 (**Adamantiades** and Kessides, 2009) Hard Coal 1060 (**Adamantiades** and Kessides, 2009) LCA Coal Fired 975.3 (**Varun** and Bhat, 2009) CCS 255-442 (**Jacobson**, 2009)	No emissions during operations. Emissions during the life cycle may be significant, in mining, uranium enrichment, decommission etc. Potential of radioactive emissions in case of accidents and leakages. LCA 24.2 (**Varun** and Bhat, 2009) LCA (2-4) (**Voorspools**, Brouwers, and D'haeseleer, 2000) 30 (**Adamantiades** and Kessides, 2009) (in the complete nuclear power chain) (9 – 70) (**Jacobson**, 2009) (8-11) (**Dones**, Heck, and Hirschberg, 2003)

Selected Environmental SD	***RE Technologies***						***Conventional Fossil Fuel Technologies***			***Nuclear***
	Bio-Energy	***Direct Solar***	***Geothermal***	***Hydro***	***Ocean***	***Wind***	***Oil***	***Gas***	***Coal***	

Water Quantity and Quality Unit: m3//MWh. Indicates water consumption, unless indicated	Agrochemicals may affect water quality . Irrigation required in non-rain fed areas. Possibility of competition with other water uses. Water for cooling thermal plants. Thermal pollution. Leakages can affect ground water quality and recharge. Biodiesel-vegetables 3500000 m3/MWh (**La Rovere**) Biodiesel-perennials 1200000 m3/MWh (**La Rovere**) Biomass (1134 - 1814) Lt/MWh (**Rio Carrillo** and Frei, 2009) Waste (residue) (756 - 1814) Lt/MWh (**Rio Carrillo** and Frei, 2009) Fossil/Biomass steam turbine Open Loop (0.757-1.136) m3/MWhe (**Hightower**, 2009) Closed Loop (1.136-1.817) m3/MWhe (**Hightower**, 2009) Biomass 1.329m3/MWha (**Pasqualetti** and Kelley, 2008) Water Footprint (24 – 143) m3/GJ (**Gerbens-Leenes**, Hoekstra, and Meer, 2009)	Limited water usage and pollution during manufacturing and utilization Can be utilized to disinfect biologically contaminated water Concentrating Solar 2.801m3/MWhe (**Hightower**, 2009) PV 10 kg/kWh (**Evans**, Strezov, and Evans, 2009) 0.0 m3/MWhe (**Hightower**, 2009) Solar Thermal 1.177m3/MWha (**Pasqualetti** and Kelley, 2008) Large Solar Thermal (3.028-3.785) m3/MWha (**Pasqualetti** and Kelley, 2008) PV < 0.004 m3/MWha (**Pasqualetti** and Kelley, 2008) Water Footprint Solar Thermal 0.3 m3/GJ (**Gerbens-Leenes**, Hoekstra, and Meer, 2009)	Minor water usage in the binary-cycle plants (most of them use air cooled circuit) Sulfur emission could be transformed into acid and acid rain. Zero for Geothermal flag cycle generation (0.012 – 0.300) m3/kWh (**Evans**, Strezov, and Evans, 2009) Geothermal 5.110m3/MWhe (**Hightower**, 2009) < 0.0189m3/MWha (**Pasqualetti** and Kelley, 2008)	Possibility for water storage; limited water pollution in the reservoirs from biomass rotting. Release of sediment from water sometime may cause downstream erosion 0.036 m3/kWh (**Evans**, Strezov, and Evans, 2009) 0.715 – 3.145 m3/MWh (**Rio Carrillo** and Frei, 2009) WC for electricity generation in supply lakes (10.000 – 70.000) (**Rio Carrillo** and Frei, 2009) Water footprint 22 m3/GJ (**Gerbens-Leenes**, Hoekstra, and Meer, 2009)	N/A	Limited water usage and pollution during manufacturing and utilization Water Footprint 0-1 m3 /MWh (**Evans**, Strezov, and Evans, 2009)	Risk of spills (0 – 1.814) m3/MWh (**Rio Carrillo** and Frei, 2009) Water Footprint 1.1 m3/GJ (**Gerbens-Leenes**, Hoekstra, and Meer, 2009)	m3/MWh (**Evans**, Strezov, and Evans, 2009) (0.94 - 39.6) m3/MWh (**Rovere** et al.) (0 – 1.814) m3/MWh (**Rio Carrillo** and Frei, 2009) Cycle Combined Open Loop 0.379 m3/MWhe (**Hightower**, 2009) Close Loop 0.681 m3/MWhe (**Hightower**, 2009) Open Loop 1.862 m3/MWha (**Pasqualetti** and Kelley, 2008) CC 1.325 m3/MWha (**Pasqualetti** and Kelley, 2008) Water Footprint 0.1 m3/GJ (**Gerbens-Leenes**, Hoekstra, and Meer, 2009)	Water usage for washing; pollution due to this 0.078 m3/kWh (**Evans**, Strezov, and Evans, 2009) (0.756 -1.815) m3/MWh (**Rio Carrillo** and Frei, 2009) (1.931-2.074) m3/MWha (**Pasqualetti** and Kelley, 2008) Integrated Gasification Combined-Cycle 0.681 m3/MWhe (**Fillmore**, 2009) Water Footprint 0.2 m3/GJ (**Gerbens-Leenes**, Hoekstra, and Meer, 2009)	Water usage for cooling; risk of high pollution 4.1 m3/MWh (**Rovere** et al.) (1.512 – 2.722) m3/MWh (**Rio Carrillo** and Frei, 2009) Nuclear Steam Turbine Open Loop 1.514 m3 /MWhe (**Hightower**, 2009) Closed Loop (1.514-2.725) m3/MWhe (**Hightower**, 2009) 2.972 m3/MWha (**Pasqualetti** and Kelley, 2008) Water Footprint 0.1 m3/GJ (**Gerbens-Leenes**, Hoekstra, and Meer, 2009)

Selected Environmental SD	***RE Technologies***						***Conventional Fossil Fuel Technologies***			***Nuclear***
	Bio-Energy	***Direct Solar***	***Geothermal***	***Hydro***	***Ocean***	***Wind***	***Oil***	***Gas***	***Coal***	

Land and soil Unit: m^2/GWh	Agricultural land occupation for growing, possible soil pollution. Biofuels can provide long-term GHG emission mitigation even if displacing vegetation with considerable carbon stocks. Nevertheless, sugar cane plantation implemented only over tropical forests does not contribute to C mitigation and should be avoided due its negative carbon balance and other impacts caused to the environment. (**Pacca** and Moreira, 2009) Biodiesel-wastes 0.04 Biodiesel-vegetables 25,069 m^2/kW (**Rovere** et al.) Biodiesel-perennials 4,200 m^2/kW (**Rovere** et al.) (101 - 193) m^2/GJ (**Fthenakis** and Hyung)	Land occupation for large solar thermal power but usually unused for other purposes Solar Thermal 3561 m2/GWh (**Kagel**, Bates, and Gawell, 2007) 3200 m2/GWh (**Tester** et al., 2006) 2500 m2/GWh annual PV (28 -64) (**Evans**, Strezov, and Evans, 2009) 3237 m2/GWh (**Kagel**, Bates, and Gawell, 2007) 7500 m2/GWh (**Tester** et al., 2006) (164 - 549) m2/GWh (**Fthenakis** and Hyung) 20000 m2/GWh annual(**Tampier**, 2002) Solar Thermal Tower 552 m2/GWh (**Fthenakis** and Hyung) Solar Thermal Parabolic Trough 366 m2/GWh (**Fthenakis** and Hyung)	Limited land occupation; some risk of soil pollution. No soil pollution in currently operating plants. (18 - 74) (**Evans**, Strezov, and Evans, 2009) 404 m2/GWh (**Kagel**, Bates, and Gawell, 2007) 3750 ha/TWh annual(**Tampier**, 2002) 160-900 m2/GWh (**Tester** et al., 2006)	Land submergence for reservoirs, may include some productive soils (73 – 750) (**Evans**, Strezov, and Evans, 2009) Large hydro 75,000 ha/TWh annual(**Tampier**, 2002) Reservoirs (2,350 - 25,000) m2/GWh (**Fthenakis** and Hyung) Run of River 3 m2/GWh (**Fthenakis** and Hyung) 28 ha/TWh annual (**Tampier**, 2002) (1300 - 10500) m2/GW (**Rudnick** et al., 2008)	Minor land occupation on coasts	Limited land occupation (1030 – 3230) m2/GWh (**Fthenakis** and Hyung, 2009) 72 (**Evans**, Strezov, and Evans, 2009) 1335 m2/GWh (**Kagel**, Bates, and Gawell, 2007) 50 m2/kW (**Rovere** et al.) 116,666 m2/GWh annual (**Tampier**, 2002)	Land occupation for mining and processing; possibility of soil contamination (250-2000) m2/GWh annual(**Tampier**, 2002)	Land occupation for developing gas fields and processing and supply installations Natural Gas 0.222 m2/kW (**Rovere** et al.) (250-2000) m2/GWh annual(**Tampier**, 2002)	Significant land occupation for mining, processing and wastes 3642 m2/GWh (**Kagel**, Bates, and Gawell, 2007) 5700 m2/GWh (**Tester** et al., 2006) 3630 m2/GWh annual (**Tampier**, 2002)	Land occupation for mining, processing and wastes 1.74 m2/kW (**Rovere** et al.) 480 m2/GWh annual(**Tampier**, 2002) 1200 m2/GWh (**Tester** et al., 2006)

Selected Environmental SD	***RE Technologies***						***Conventional Fossil Fuel Technologies***			***Nuclear***
	Bio-Energy	***Direct Solar***	***Geothermal***	***Hydro***	***Ocean***	***Wind***	***Oil***	***Gas***	***Coal***	
Hazardous Waste Risk Unit: tons	Possibility for waste from by-products	N/A	Risk of pollution by toxic water and air. Residual water is usually re-injected into reservoir.	sediments and nutrients during failure of a dam or during flood water	N/A	Minor volumes of hazardous waste produced during manufacturing process.	Risk of spills	Gas leak from the pipeline and fire hazard from the gas field could be dangerous	Risk of fires in waste fields	High risk 12,000 metric tons a year from the world's nuclear power plants, ie, 4.6875 kg/GWh (**Adamantiades** and Kessides, 2009)

Ecosystems and biodiversity	Monoculture growing; Adverse impacts on biodiversity for land clearance; Positive impacts on local biodiversity from stabilized vegetation cover	Some limitation of solar irradiation on the soil surface	Hot water spills, introduction of thermally tolerable species. No major impacts on ecosystems and biodiversity	Biodiversity loss from inundation of forests. New lake habitats created, may replace terrestric with aquatic biodiversity. Alteration of downstream habitat for modification of flood regime and lack of nutrients in the released water	Limitation of biodiversity near dams and some turbines. Introduction of mollusks and water plants on constructions	Direct bird and bat fatalities; some impacts on ecosystem structure. Impacts are modest compared to other human activities, and can be reduced through careful siting.	Change of vegetation and wildlife in the mining and processing areas	Some change of vegetation and wildlife in the gas field areas Fire hazard could be dangerous to ecosystem and biodiversity	Significant change of vegetation and wildlife in the mining areas and waste fields	Risk of radiation-influencing changes in biodiversity

Selected Environmental SD	***RE Technologies***						***Conventional Fossil Fuel Technologies***			***Nuclear***
	Bio-Energy	***Direct Solar***	***Geothermal***	***Hydro***	***Ocean***	***Wind***	***Oil***	***Gas***	***Coal***	
Natural and built environment/ Visual Aspect	Sometimes positive (blossoming cultures, young forest, etc.). Displacement of poor from the marginal and degraded land	Large areas occupied by installations. Change of albedo; large solar stacks can affect visual aspect of built environment.	Some concerns for impacts on natural areas that might share their use with recreation, and SPA. Potential impacts on natural geothermal features such as geysers	Can cause damage to existing built environment like settlements; New structures can add positive impacts Dams and reservoirs can be used for recreation, navigation, water supply, flood control etc.	Sometimes large structures (dams, barriers, etc.)	Visual impacts can be significant, but depend on project location, attitude of local population, and other factors. Visual impacts, land and marine usage and nuisance effects can be major obstacles for acceptance. Risk of collision for birds and bats; infrasound effects. Complaints from some people; good for other people	Very large mining and processing structures; stacks with fire	Large mining and processing structures	Large waste fields, sometimes large structures	Large constructions and stacks

Selected Environmental SD	***RE Technologies***						***Conventional Fossil Fuel Technologies***			***Nuclear***
	Bio-Energy	***Direct Solar***	***Geothermal***	***Hydro***	***Ocean***	***Wind***	***Oil***	***Gas***	***Coal***	
Local Emissions Unit : mg/KWh$_{el}$	Emissions contribution to air quality. Indoor PM, CO from fuel wood. PM, CO, NOx from harvest burning and land clearing (including deforestation). CH_4 (17 – 124) N_2O (14 – 130) NO_x (258 – 1360) CO (18 5 – 898) SO_2 (26 – 315) (**Pehnt**, 2006)	PV / Parabolic CH_4 220 / 35.2 N_2O 1.9 / 0.2 NO_x 340 / 72.9 CO 141 / 85.4 SO_2 288 / 46.7 (**Pehnt**, 2006)	Hot Dry Rock CH_4 103.4 N_2O 2.6 NO_x 188.9 CO 208 SO_2 61.6 (**Pehnt**, 2006)	Small Hydro CH_4 (21 – 29) N_2O (0.4 – 0.7) NOx (36 – 49) CO (59 – 74) SO_2 (17 – 28) (**Pehnt**, 2006)		onshore /offshore CH_4 24.1 / 9.8 N_2O 0.2 /-- NO_x 31.1 / 20.9 CO 96.8 /-- SO_2 39.5 /35.4 (**Pehnt**, 2006)	Significant emissions of pollutants (PM, SOx, NOx, VOCs, heavy metals) and GHGs,	Significant emissions of pollutants (less than oil and coal, except NOx in some cases) and GHGs, some of which can be mitigated	Significant emissions of pollutants (PM, SOx, NOx, VOCs, heavy metals) requiring controls for reduction.	No emissions during operations.

SOCIAL ECONOMIC ISSUES

Selected Environmental SD	***RE Technologies***						***Conventional Fossil Fuel Technologies()***			***Nuclear***
	Bio-Energy	***Direct Solar***	***Geothermal***	***Hydro***	***Ocean***	***Wind***	***Oil***	***Gas***	***Coal***	
Employment Opportunities Unit: Employment Ratio/MW Include: construction, installation, operation and maintenance.	Studies present employment estimates in terms of jobs and job years, and it is important to understand the difference. For example, a study may predict the creation of 15 job years. This is not the same thing as saying 15 jobs. Fifteen job years can mean one job that lasts for 15 years or it can mean 15 jobs that last for one year. It is important to explain carefully or question what the study is showing for potential job impacts. (**EPA**, 2010) $1 million invested in wind or P produces 5.7 job-years vs 3.9 job-years for coal power. $1 million in energy savings in Oregon produces about $400,000 in additional wages per year. (**EPA**, 2010)									

	Increased job opportunities, particularly in rural areas Biomass electric Employment ratio/MW 4 Construction & Installation 0.14 O&M (**Moreno** and López, 2008) Biodiesel 0.32 Employment/kToe of primary energy generated (**del Río** and Burguillo) Biodiesel-wastes 30 jobs/MWh (**Rovere** et al.) Biodiesel-vegetables 98.6 Jobs/MWh (**Rovere** et al.) Biodiesel-perennials 9.76 Jobs/MWh (**Rovere** et al.) Sugarcane bio-energy (3711-5392) Jobs-year/TWh (**Goldemberg**, 2006a) Wood energy (733-1067) Jobs-year/TWh (**Goldemberg**, 2006a) 0.21 Jobs-year/GWh (over lifetime of project) (**Wei**, Patadia, and Kammen, 2010)	Jobs in rural and urban areas Solar PV Employment ratio/MW 34.6 Construction & Installation 2.7 O&M (**Moreno** and López, 2008) 7.69 Employment/kToe (**del Río** and Burguillo) (29,580- 107,000) Jobs-year/TWh (**Goldemberg**, 2006a) 0.87 Jobs-year/GWh (over lifetime of project) (**Wei**, Patadia, and Kammen, 2010) Solar Thermal Employment ratio/thousand m2 2.5 Construction & Installation 5 O&M (**Moreno** and López, 2008) 0.23 Jobs-year/GWh (over lifetime of project) (**Wei**, Patadia, and Kammen, 2010)	High on local scale compared to natural gas. Because drilling and plant construction must be done at the site of a geothermal resource, local workforce can get better employment opportunities 0.25 Jobs-year/GWh (over lifetime of project) (**Wei**, Patadia, and Kammen, 2010)	Medium Employment ratio/MW 18.6 Installation & Construction 1.4 O&M (**Moreno** and López, 2008) (**Moreno** and López, 2008) Hydro 250 Jobs-year/TWh (**Goldemberg**, 2006a) Small hydro 120 Jobs-year/TWh (**Goldemberg**, 2006a) 0.27 Jobs-year/GWh (over lifetime of project) (**Wei**, Patadia, and Kammen, 2010)	High on local scale (Marine energy roadmap)	Employment in manufacturing, installation, and operations. 918-2400 Jobs-year/TWh (**Goldemberg**, 2006a) Direct employment at present estimated at 500,000. (**Global Wind Energy Council (GWEC)**, 2010a) Employment ratio/MW 13 Construction & Installation 0.2 O&M (**Moreno** and López, 2008) 0.36 Employment/kToe (**del Río** and Burguillo) (20 - 45) Jobs/MWh (**Rovere** et al.) 0.17 Jobs-year/GWh (over lifetime of project) (**Wei**, Patadia, and Kammen, 2010) $1 billion investment in wind generator components creates 3,000 full-time equivalent (FTE) jobs. (**EPA**, 2010) $1 million invested in wind in Iowa produces 2.5 job-years (**EPA**, 2010)	High 260 Jobs-year/TWh (**Goldemberg**, 2006a) Connecticut Employment 2005-2020 (Average annual increase) 430 (**EPA**, 2010)	High 250 Jobs-year/TWh (**Goldemberg**, 2006a) (0.0375–0.075) Jobs/MWh (**Rovere** et al.) 0.11 Jobs-year/GWh (over lifetime of project) (**Wei**, Patadia, and Kammen, 2010) Connecticut Employment 2005-2020 (Average annual increase) 1668 (**EPA**, 2010)	High 370 Jobs-year/TWh (**Goldemberg**, 2006a) 0.11 Jobs-year/GWh (over lifetime of project) (**Wei**, Patadia, and Kammen, 2010)	Small 75 Jobs-year/TWh (**Goldemberg**, 2006a) 0.0002 Jobs/MWh (**Rovere** et al.) 0.14 Jobs-year/GWh (over lifetime of project) (**Wei**, Patadia, and Kammen, 2010)
Income and Livelihood	Increase in income in agricultural and forestry sector	Increase income in rural areas of developing countries	Improve livelihood and income in developing countries	Medium – possible loss of productive land. However increase in energy, irrigation	Not developed	Tax payments, land rents, and use of local services can help revitalize the economy of rural communities.	Increases Income – but has negative impact on livelihood in places	Improve livelihood and income	Income generation- High risk occupation	High income generation in a small sector – Living with risk

Economics critical unknowns: □The price of electricity in the future, how prices will be structured, and the explicit or implicit price of CO_2 imposed by any future climate policy (**NAP**, 2010)**.**

Selected Environmental SD	***RE Technologies***						***Conventional Fossil Fuel Technologies***			***Nuclear***
	Bio-Energy	***Direct Solar***	***Geothermal***	***Hydro***	***Ocean***	***Wind***	***Oil***	***Gas***	***Coal***	
Energy Generation/Supply Costs/ Levelised generation cost. Unit: US/MWh. Source: IEA/OECD/NEA 2010 (**IEA/OECD/NEA**, 2010) & IEA 2008(**IEA**, 2008)	Opportunities for co-generation – reducing cost 2009 (50 – 140) 2050 (49 – 123)	Still relatively high- but becoming more competitive 2009 PV 5% discount rate (215 – 600) 10% discount rate (333 – 600) CSP 2009 (136 - 243) 2030 PV 2030 (140 – 305) CSP 2030 (70 – 220)	Capital-intensive, with low variable costs and no fuel costs Hydrothermal 2009 (65–80) 2030 (30 - 87) 2050 (29 - 84) Hot dry rock (150 – 300) year 2005. (80 – 200) year 2030. (60 – 150) year 2050	High-capacity, low-cost means of energy storage Large Hydro 2009 (45 – 105) 2030 (30 – 115) 2050 (30 – 110) Small Hydro 2009 (48 – 156) 2030 (52 – 130) 2050 (49 – 120)	Not developed Tidal Barrage (60 – 100) year 2005 (50 – 80) year 2030. (45 - 70) year 2050. Tidal Current 2009 (195 -220) 2030 (45 -90) 2050 (40 – 80) Wave (195 -220) 2030(45 -90) 2050(40 -80)	Can be competitive with fossil generation in limited situations. Onshore 5% discount rate (48 – 163) 10% discount rate (70 – 234) Offshore 5% discount rate (101 – 188) 10% discount rate (146 – 261) Onshore cost reduction by 2050: 15-35%, Offshore cost reduction by 2050: 20-45% (**IEA**, 2008)	Fluctuating Price; competitive but subsidized for some uses	Competitive – but subsidized for some uses 5% discount rate (67 – 105) 10% discount rate (76 – 120)	Competitive – but subsidized for some uses 5% discount rate (54 – 120) 10% discount rate (67 – 142)	Competitive – but subsidized 5% discount rate (29 – 82) 10% discount rate (42 – 137)

Additional items to add to price of energy supplied	The cost of new transmission and upgrades to the distribution system will be important factors when integrating increasing amounts of renewable electricity. Transmission improvements can bring new resources into the electricity system, provide geographical diversity in the generation base, and allow improved access to regional wholesale electricity markets. -The structure of renewable portfolio standards, tax policies (production and/or investment tax credits), and other policy initiatives directed at renewable electricity (**NAP**, 2010)				

Selected Environmental SD	***RE Technologies***						***Conventional Fossil Fuel Technologies***			***Nuclear***
	Bio-Energy	***Direct Solar***	***Geothermal Energy***	***Hydro Power***	***Ocean Energy***	***Wind***	***Oil***	***Gas***	***Coal***	

Investment Unit: US/kW Sources: IEA, 2008 (**IEA**, 2008) & IEA/OECD/NEA 2010 (**IEA/OECD/NEA**, 2010)	Potential for large and small scale investment 2009 (2,960 – 3,670) 2030 (2,550 – 3,150)	Large potential for investors - solar growth 30% every year from 2000 to 2005 PV 2009 (5,730 – 6,800) 2030(2,010 -2,400) CSP 2009 (3,470 – 4,500) 2030 (1,730 -2,160)	Asian countries urging large investment in geothermal Hydrothermal 2009 (3,470 –4,060) 2030 (3,020 – 3540) 2050 (1,400 – 4,900) Hot dry rock 2005 (5,000 – 15,000) 2030 (4,000 – 10,000) 2050 (3,000 – 7,500)	Large and small projects still expanding Large Hydro 2009 (1,970 – 2,600)2030(1,940 – 2,570)Small Hydro 2005 (2,500 – 7,000) (2,200 – 6,500) year 2030. (2,000 -6,100) year 2050.	Developing market Tidal Barrage (2,000 – 4,000) year 2005 (1,700 – 3,500) year 2030. (1,500 - 3,000) year 2050. Tidal Current (7,000 - 10,000) year 2005 (5,000 - 8,000) year 2030. (3,500 – 6,000) year 2050. Wave (6,000 - 15,000) year 2005 (2,500 - 5,000) year 2030. (2,000 – 4,000) year 2050.	Capital investment needs are significant, both for wind projects and associated transmission infrastructure, but world's fastest growing energy source Onshore (**IEA/OECD/NEA**, 2010) 2009 (1,900 – 3,700) 2030 (1440 – 1,600) Offshore (**IEA/OECD/NEA**, 2010) 2009 (2890 – 3200) 2030 (2280 – 2530) Onshore: (1,350 – 2,000) Offshore: (3,200 – 4,600)	Demand increase – Mainly in upstream – risk because of uncertainty over remaining reserves	Demand increase Acts as driver Uncertainty of remaining reserves is risk GNL CC (520- 1800)	Large potential because of expansion in the coal sector – China, India, US 2009 Without CCS (900 – 2,800) With CCS (3,223-6,268)	Heavily promoted to combat climate change – re-emerging investment opportunities III+ 2,600 (current) 2,100 (year 2025) IV 2,500 (year 2030) 2,000 (year post 2050)

Selected Environmental SD	***RE Technologies***						***Conventional Fossil Fuel Technologies***			***Nuclear***
	Bio-Energy	***Direct Solar***	***Geothermal Energy***	***Hydro Power***	***Ocean Energy***	***Wind***	***Oil***	***Gas***	***Coal***	
Displacement of people people/MW	Case specific. Large scale biomass farming requires adequate land ownership, which may cause displacement of people in some cases and on others may provide jobs in the rural area and therefore additional settlements.	Very unlikely to cause displacements. Providing decentralized energy enhances access and thus better dwellings in isolated areas, relieving population pressure in urban areas.	Case specific, but people displacement may be very rare and in small scale. Improves decentralized energy and settlements close to the energy source.	Case, site, technology specific. Risks of significant displacements, requiring adequate assessments and compensation. (0 – 120) (**Rudnick** et al., 2008)	Very unlikely to cause displacements. Providing decentralized energy enhances access and thus better dwellings in isolated areas, relieving population pressure in urban areas.	Very unlikely to cause significant displacements, but some onshore projects can cause nuisances that effects in local communities, Effects can be minimized by appropriate siting rules and procedures.	Pipelines and other infrastructure projects may displace people. Local pollution from refineries may also have such effects.	Pipelines and other infrastructure projects may displace people.	Mining and quarrying, as well as local pollution (e.g. water contamination) may cause displacements.	Relatively few local displacements close to the power plant. Large accidents can cause very large scale displacements.
Gender equity	Improved biomass systems (e.g. efficient cookstoves) enhance lifestyles and lighten domestic workload. Large scale biomass provides jobs on a gender friendly basis. Biomass power & biomass gasification is relevant for both men and women. (**IRADe**, 2009)	Improved systems enhance lifestyles. Decentralized energy has potential to provide more and gender friendly jobs. Solar PV Plants is relevant for both men and women. (**IRADe**, 2009)	Gender neutral.	Gender neutral. Small Hydro is partially relevant for women. (**IRADe**, 2009)	Gender neutral.	Gender neutral. Power wind is relevant for both men and women. (**IRADe**, 2009)	Conventional energy, usually gender neutral. However, some fuels (e.g. kerosene and LPG) may be the first substitutes to fuelwood for climbing the energy ladder thus promoting gender neutrality,	Gender neutral. Biogas plant is specifically relevant for women (**IRADe**, 2009).	Usually gender neutral, but primitive use of this solid fuel causes domestic health impacts, affecting mainly women, children and the elderly.	Gender neutral.

Water Security	Water usage, wastewaters	Medium	Low	High	Too early to know	Medium	Spills	NA	Coal washing, water contamination	Potential high contamination

Selected Environmental SD	***RE Technologies***						***Conventional Fossil Fuel Technologies***			***Nuclear***
	Bio-Energy	***Direct Solar***	***Geothermal Energy***	***Hydro Power***	***Ocean Energy***	***Wind***	***Oil***	***Gas***	***Coal***	
Poverty Reduction	Cooking, jobs	Reduces poverty	Low	Medium - high	Low	Medium - high	High	High	High	Low
Sanitation	Improved landfills	NA	NA	NA	NA	NA	(-)medium	NA	(-)high	NA
Food Security	Competition for land, cooking, source of fertilizers.	Drying grains					Fertilizers, cooking.	Cooking	NA	NA
Energy Security	Secure source more subject to climate conditions	Secure	Secure source	Secure source more subject to climate conditions	Early technology	Intermittent available	Geopolitical issues, finite	Geopolitical issues, finite.	Largely available	Diversifies sources but poses risks
Energy Access	Wide, easy access particularly for the poor	Easy access particularly for poor.	Limited	Somewhat limited		Somewhat limited				
Energy Affordability	High affordability	Upfront costs	Upfront costs	Long project life, cheap energy after investment is amortized	High initial costs	Competitive technology, providing energy at nearly same cost as conventional				

Infra-structure	Roads for biomass transport	Required, for large scale CSP	Required	Long transmission lines, large dams	Required	Transmission lines		Very intensive in infra-structure.		Security related infrastructure, final waste disposal sites