UTILIZATION OF GLOBAL SOLAR RESOURCES

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ABSTRACT

Solar energy is one of the best renewable energy sources with least negative impacts on the environment. Different countries have formulated solar energy policies to reducing dependence on fossil fuel and increasing domestic energy production by solar energy. This paper discusses a review about the different solar energy policies implemented on the different countries of the world. According to the 2010 BP Statistical Energy Survey, the world cumulative installed solar energy capacity was 22928.9MW in 2009, a change of 46.9% compared to 2008. Also this paper discussed the existing successful solar energy policies of few selected countries. Based on literatures, it has been found that FIT, RPS and incentives are the most beneficial energy policies implemented by many countries around the world.

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1. INTRODUCTION

Solar energy has experienced an impressive technological shift. While early solar technologies consisted of small-scale photovoltaic (PV) cells, recent technologies are represented by solar concentrated power (CSP) and also by large-scale PV systems that feed into electricity grids. The costs of solar energy technologies have dropped substantially over the last 30 years. For example, the cost of high power band solar modules has decreased from about $27,000/kW in 1982 to about $4,000/kW in 2006; the installed cost of a PV system declined from $16,000/kW in 1992 to around $6,000/kW in 2008 (IEA-PVPS, 2007; Solarbuzz, 2006, Lazard 2009). The rapid expansion of the solar energy market can be attributed to a number of supportive policy instruments, the increased volatility of fossil fuel prices and the environmental externalities of fossil fuels, particularly greenhouse gas (GHG) emissions.

Theoretically, solar energy has resource potential that far exceeds the entire global energy demand (Kurokawa et al. 2007; EPIA, 2007). Despite this technical potential and the recent growth of the market, the contribution of solar energy to the global energy supply mix is still negligible (IEA, 2009). This study attempts to address why the role of solar energy in meeting the global energy supply mix continues to be so a small.

1.1 Importance of solar energy

Solar energy is one of the cleanest energy resources that does not compromise or add to the global warming. The sun radiates more energy in one second then people have used since beginning of time. Solar energy is often called “alternative energy” to fossil fuel energy sources such as oil and coal. Availability of cheap and abundant energy with minimum environmental and ecological hazards associated with its production and use is one of the important factors for desired improvement in the quality of life of the people. The growing scarcity of fossil fuels has raised global interest in the harnessing of solar energy.

Solar power is a type of energy with great future potential-even though at present it covers merely aminor portion of global energy demands (0.05% of the total primary energy supply); at the moment PV power generates less than 1% of total electricity supply. This is due to solar power still being considered the most expensive type of renewable energies. However, in remote regions of the earth it may very well constitute today’s best solution for a decentralized energy supply [8,9]. According to the 2010 BP Statistical Energy Survey, the world cumulative installed solar energy capacity was 22928.9MW in 2009, a change of 46.9% compared to 2008.

1.2 Global Energy Consumption

World primary energy demand is projected in the Reference Scenario to expand by almost 60% from 2002 to 2030, an average annual increase of 1.7% per year. Demand will reach 16.5 billion tons of oil equivalents (toe) compared to 10.3 billion toes in 2002 which is shown in Table 1. On the other hand, fossil fuels will continue to dominate global energy use. They will account for around 85% of the increase in world primary demand over 2002–2030. And their share in total demand will increase slightly, from 80% in 2002 to 82% in 2030. The share of renewable energy sources will remain flat, at around 4%, while that of nuclear power will drop from 7% to 5% [11]. Oil will remain the single largest fuel in the global primary energy mix, even though its share will fall marginally, from 36% in 2002 to 35% in 2030. Demand for oil is projected to grow by 1.6% per year, from 77MBD in 2002 to 90MBD in 2010 and 121MBD in 2030.

2. CURRENT STATUS OF SOLAR ENERGY TECHNOLOGIES AND MARKETS

2.1 Technologies and resources

Solar energy refers to sources of energy that can be directly attributed to the light of the sun or the heat that sunlight generates (Bradford, 2006). Solar energy technologies can be classified along the following *continuum*: 1) passive and active; 2) thermal and photovoltaic; and 3) concentrating and non-concentrating. Passive solar energy technology merely collects the energy without converting the heat or light into other forms. It includes, for example, maximizing the use of day light or heat through building design (Bradford, 2006; Chiras, 2002).

In contrast, active solar energy technology refers to the harnessing of solar energy to store it or convert it for other applications and can be broadly classified into two groups: (i) photovoltaic (PV) and (ii) solar thermal. The PV technology converts radiant energy contained in light quanta into electrical energy when light falls upon a semiconductor material, causing electron excitation and strongly enhancing conductivity (Sorensen, 2000). Two types of PV technology are currently available in the market: (a) crystalline silicon-based PV cells and (b) thin film technologies made out of a range of different semi-conductor materials, including amorphous silicon, cadmium-telluride and copper indium gallium diselenide1. Solar thermal technology uses solar heat, which can be used directly for either thermal or heating application or electricity generation. Accordingly, it can be divided into two categories: (i) solar thermal non-electric and (ii) solar thermal electric. The former includes applications as agricultural drying, solar water heaters, solar air heaters, solar cooling systems and solar cookers2 (e.g. Weiss et al., 2007); the latter refers to use of solar heat to produce steam for electricity generation, also known as concentrated solar power (CSP). Four types of CSP technologies are currently available in the market: Parabolic Trough, Fresnel Mirror, Power Tower and Solar Dish Collector (Muller-Steinhagen and Trieb, 2004; Taggart 2008a and b; Wolff et al., 2008).

Solar energy technologies have a long history. Between 1860 and the First World War, a range of technologies were developed to generate steam, by capturing the sun‟s heat, to run engines and irrigation pumps (Smith, 1995). Solar PV cells were invented at Bell Labs in the United States in 1954, and they have been used in space satellites for electricity generation since the late 1950s (Hoogwijk, 2004). The years immediately following the oil-shock in the seventies saw much interest in the development and commercialization of solar energy technologies. However, this incipient solar energy industry of the 1970s and early 80s collapsed due to the sharp decline in oil prices and a lack of sustained policy support (Bradford, 2006). Solar energy markets have regained momentum since early 2000, exhibiting phenomenal growth recently. The total installed capacity of solar based electricity generation capacity has increased to more than 40 GW by the end of 2010 from almost negligible capacity in the early nineties (REN21, 2011). Solar energy represents our largest source of renewable energy supply. Effective solar irradiance reaching the earth‟s surface ranges from about 0.06kW/m2 at the highest latitudes to 0.25kW/m2 at low latitudes. Figure 1 compares the technically feasible potential of different renewable energy options using the present conversion efficiencies of available technologies. Even when evaluated on a regional basis, the technical potential of solar energy in most regions of the world is many times greater than current total primary energy consumption in those regions (de Vries et al. 2007).

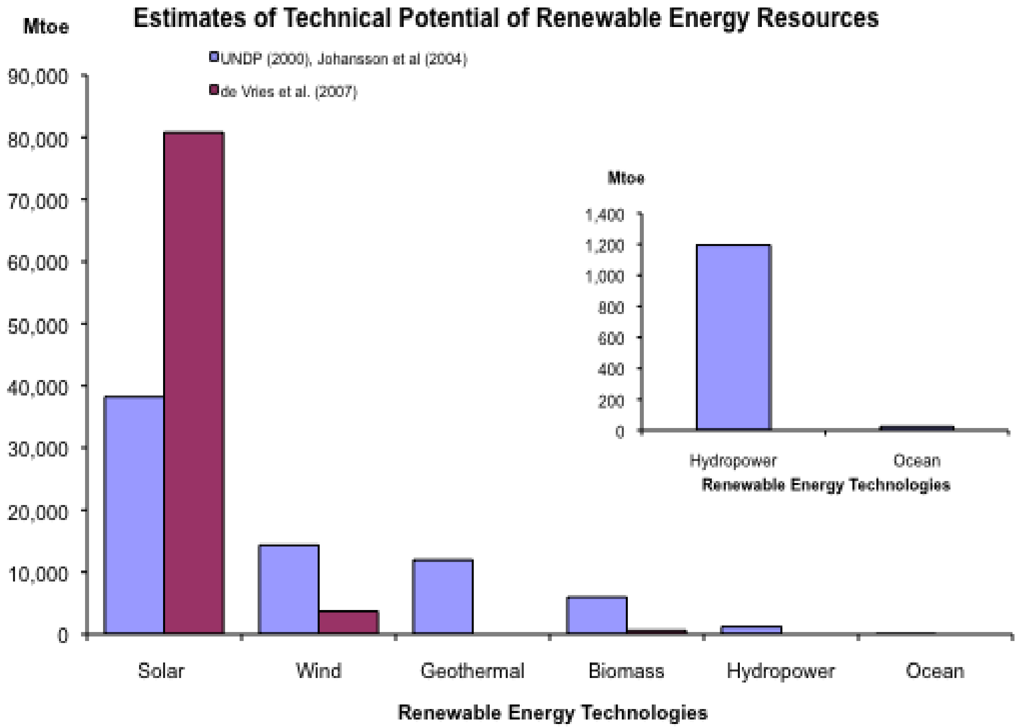

Fig -1: Technical potential of renewable energy technologies

Table 1 presents regional distribution of annual solar energy potential along with total primary energy demand and total electricity demand in year 2007. As illustrated in the table, solar energy supply is significantly greater than demand at the regional as well as global level.

Region	Minimum technical potential	Maximum technical potential	Primary energy demand (2008)	Electricity demand (2008)
North America	4,322	176,951	2,731	390
Latin America & Caribbean	2,675	80,834	575	74
Western Europe	597	21,826	1,822	266
Central and Eastern Europe	96	3,678	114	14
Former Soviet Union	4,752	206,681	1,038	92
Middle East & North Africa	9,839	264,113	744	70
Sub-Saharan Africa	8,860	227,529	505	27
Pacific Asia	979	23,737	702	76
South Asia	907	31,975	750	61
Centrally Planned Asia	2,746	98,744	2,213	255
Pacific OECD	1,719	54,040	870	140
Total	**37,492**	**1,190,108**	**12,267**	**1,446**

Table-1: Regional distribution of annual solar energy potential

2.2 Solar Market:

The installation of solar energy technologies has grown exponentially at the global level over the last decade. For example, as illustrated in Figure 2(a), global installed capacity PV (both grid and off-grid) increased from 1.4 GW in 2000 to approximately 40 GW in 2010 with an average annual growth rate of around 49% (REN21, 2011). Similarly, the installed capacity of CSP more than doubled over the last decade to reach 1,095MW by the end of 2010. Non-electric solar thermal technology increased almost 5 times from 40 GWth in 2000 to 185 GWth in 2010 (see Figure 3). The impetus behind the recent growth of solar technologies is attributed to sustained policy support in countries such as Germany, Italy United States, Japan and China.

2.3 The economics of solar energy:

There is a wide variety of solar energy technologies and they compete in different energy markets, notably centralized power supply, grid-connected distributed power generation and offgrid or stand-alone applications. For instance, large-scale PV and CSP technologies compete with technologies seeking to serve the centralized grid. On the other hand, small-scale solar energy systems, which are part of distributed energy resource (DER)7 systems, compete with a number of other technologies (e.g., diesel generation sets, off-grid wind power etc.). The traditional approach for comparing the cost of generating electricity from different technologies relies on the "levelized cost" method**.**

3. ESTIMATED FUTURE GROWTH OF SOLAR ENERGY AND BARRIERS TO REALIZING GROWTH:

Advocates of solar energy claim that it will play a crucial role in meeting future energy demand through clean energy resources. Existing projections of long-term growth (e.g., until 2050) of solar energy vary widely based on a large number of assumptions. For example, Arvizu et al. (2011) argue that expansion of solar energy depends on global climate change mitigation scenarios. In the baseline scenario (i.e., in the absence of climate change mitigation policies), the deployment of solar energy in 2050 would vary from 1 to 12 EJ/yr. In the most ambitious scenario for climate change mitigation, where CO2 concentrations remain below 440 ppm by 2100, the contribution of solar energy to primary energy supply could reach 39 EJ/yr by 2050. EPIA/Greenpeace (2011) produces the most ambitious projections of future PV installation. The study argues that if existing market supports are continued and additional market support mechanisms are provided, a dramatic growth of solar PV would be possible, which will lead to worldwide PV installed capacity rising from around 40 GW in 2010 to 1,845 Gas CC (Min) Gas CC (Max) Coal^ (Min) Coal^ (Max) Solar PV (Min) Solar CSP (Min) Solar CSP (Max) $- $50 $100 $150 $200 $250 $300 $350 0 1 0 2 0 3 0 4 0 5 0 6 0 7 0 8 0 9 0 100 US$/MWh US$/tCO2 19 GW by 2030. The capacity would reach over 1000 GW in 2030 even with a lower level of political commitment. A study jointly prepared by Greenpeace International and the European Renewable Energy Council (Teske et al., 2007) projects that installed global PV capacity would expand to 1,330 GW by 2040 and 2,033 GW by 2050. A study by the International Energy Agency (IEA, 2008) estimates solar power development potential under two scenarios that are differentiated on the basis of global CO2 emission reduction targets. In the first scenario, where global CO2 emissions in 2050 are restricted at 2005 level, global solar PV capacity is estimated to increase from 11 GW in 2009 to 600 GW by 2050. In the second scenario, where global CO2 emissions are reduced by 50% from 2005 levels by 2050, installed capacity of solar PV would exceed 1,100 GW in 2050. Like solar PV, projections are available for CSP technology. A joint study by Greenpeace, the European Solar Thermal Power Industry (ESTIA) and the International Energy Agency projects that global CSP capacity would expand by one hundred-fold to 37 GW by 2025 and then skyrocket to 600 GW by 2040 (Greenpeace et al., 2005). Teske et al. (2007) project that global CSP capacity could reach 29 GW, 137 GW and 405 GW in 2020, 2030 and 2050, respectively. IEA (2008) projects that CSP capacity could reach 380 GW to 630 GW, depending on global targets for GHG mitigation14.In the case of solar thermal energy, the global market could expand by tenfold to approximately 60 million tons of oil equivalent (Mtoe) by 2030 (IEA World Energy Outlook 2006). A more optimistic scenario from the European Renewable Energy Council (2004) projects that solar thermal will grow to over 60 Mtoe by 2020, and that the market will continue to expand to 244 Mtoe by 2030 and to 480 Mtoe, or approximately 4% of total global energy demand, by 2040.It would be also relevant to envisage the contribution of solar energy to the global energy supply mix. According to EREC (2004), renewable energy is expected to supply nearly 50% of total global energy demand by 2040. Solar energy alone is projected to meet approximately 11% of total final energy consumption, with PV supplying 6%, solar heating and cooling supplying 4% and CSP supplying 1% of the total. Shell (2008) shows that if actions begin to address the challenges posed by energy security and environmental pollution, sources of energy other than fossil fuels account for over 60% of global electricity consumption, of which one third comes from solar energy. In terms of global primary energy mix, solar energy could occupy up to 11% by 2050. Notwithstanding these optimistic projections, the existing literature identifies a range of barriers that constrains the deployment of solar energy technologies for electricity generation and thermal purposes. These barriers can be classified as technical, economic, and institutional and are presented in Table 3. Technical barriers vary across the type of technology. For example, in the case of PV, the main technical barriers include low conversion efficiencies of PV modules15; performance limitations of system components such as batteries and inverters; and inadequate supply of raw materials such as silicon. In the case of stand-alone PV systems, storage is an important concern, as is the shorter battery life compared to that of the module. Furthermore, safe disposal of batteries becomes difficult in the absence of a structured disposal/recycling process. With regard to solar thermal applications, there are two main technical barriers. They are limits to the heat carrying capacity of the heat transfer fluids and thermal losses from storage systems (Herrmann et al. 2004; IEA 2006a). In addition, as seen in Table 3, there are constraints with regard to system design and integration as well as operating experience for system optimization. For example, lack of integration with typical building materials, designs, codes and standards make widespread application of solar space and water heating applications difficult. In the case of CSP, technologies such as the molten salt-in-tube receiver technology and the volumetric air receiver technology, both with energy storage systems, need more experience to be put forward for large-scale application (Becker et al., 2000). Moreover, solar energy still has to operate and compete on the terms of an energy infrastructure designed around conventional energy technologies.

	PV	**Solar Thermal**
Technical Barriers	**1.**The efficiency constraint: 4% to 12% (for thin film) and under 22% (for crystalline) in the current market (EPIA/Greenpeace, 2011). **2**. Performance limitations of balance of system (BOS) components such as batteries, inverters and other power conditioning equipments (Rickerson et al., 2007, Beck and Martinot, 2004; O"Rourke et al., 2009). **3.** Silicon supply: strong demand for PV in 2004 and 2005 outpaced the supply and partly stalled the growth of solar sector (Wenzel, 2008; PI, 2006). **4.** Cadmium and tellurium supply for certain thin film cells: these two components are by-products from respectively the zinc mining and copper processing and their availability depends on the evolution of these industries (EPIA/Greenpeace, 2011).	**1.** Heat carrying capacity of heat transfer fluids. **2.** Thermal losses and energy storage system issues with CSPs (Herrmann et al., 2004; IEA, 2006a). Supply orientation in the design of solar water heaters when product diversity is needed to match diverse consumer demand profiles. **3**.For solar water heating, lack of integration with typical building materials, existing appliances and infrastructure, designs, code
Economic Barriers	**1.** High initial capital cost and the related lack of easy and consistent financing options forms one of the biggest barriers primarily in developing countries (Beck and Martinot, 2004). **2**. Investment risks seen as unusually high risks by some financial institutions because of lack of experience with such projects (Goldman et al., 2005; Chaki, 2008 **3.** Cost of BOS is not declining proportional to the decline in module price (Rickerson et al., 2007). **4.** The fragility of solar development partnerships: many PV projects are based on development partnerships and with the early departure of a partner the revenue to complete, operate and maintain the system may falter (AhiatakuTogobo, 2003).	1. High upfront cost coupled with lengthy payback periods and small revenue streams raises creditworthiness risks. 2. The financial viability of domestic water heating system is low. 3. Backup heater required in water heating systems to provide reliable heat adds to the cost. 4. Increasing cost of essential materials like copper make water heating and distribution costly. 5. Limited rooftop area and lack of building integrated systems limit widespread application.

Table-2: Barriers to the Development and Deployment of Solar Energy Technologies

4. POTENTIAL POLICY INSTRUMENTS TO INCREASE SOLAR ENERGY DEVELOPMENT:

As illustrated earlier, by and large solar energy technologies are not yet cost-competitive with conventional energy commodities at either the wholesale or retail levels. Therefore, any significant deployment of solar energy under current technological and energy price conditions 24 will not occur without major policy incentives. A large number of governments have decided to increase solar energy development, using a range of fiscal, regulatory, market and other instruments 16 . In fact, the strong growth in solar energy markets, notably those for gridconnected solar PV and solar thermal water heating, has been driven by the sustained implementation of policy instruments in Europe, the United States and some developing countries to induce or require increased use of solar power. This section briefly presents key characteristics of policy instruments that support solar energy for both electric and direct heating applications. A large number of policy instruments have been implemented to increase power supplies from solar PV and CSP. The key instruments we highlight here include feed-in-tariffs, investment tax credits, direct subsidies, favorable financing, mandatory access and purchase, renewable energy portfolio standards and public investment. Three rationales are commonly offered for utilizing these policies. One is to encourage the use of low-carbon technology in the absence of a more comprehensive policy for greenhouse gas mitigation, like a carbon tax. The disadvantage of this approach for greenhouse gas mitigation is that it does not create incentives for cost-effective mitigation choices. The second rationale is that expanded investments will ultimately help drive down the costs of those technologies through economies of scale and learning-by-doing. There is clear evidence that scaling-up has driven down unit costs for PV, though not yet to the point that it is cost-effective with conventional alternatives in most cases. CSP is still relatively a pioneer technology with only a few medium-scale investments and no larger-scale investments, though some are planned. It remains to be seen how scale economies and learning-by-doing will lower its costs. The third and most unambiguous rationale is that subsidization of small-scale, off-grid PV (and other renewable energy sources) to bring electricity to remote and poor areas lacking access is a powerful.

5. IMPLEMENTATION OF POLICIES TO INCREASE SOLAR ENERGY DEVELOPMENT:

5.1. Policy mix:

The policy landscape for solar energy is complex with a broad range of policy instruments driving market growth. The rapid market growth of solar energy in Germany and Spain could be attributed to the feed-in-tariff systems that guarantee attractive returns on investment along with the regulatory requirements mandating 100% grid access and power purchase. On the other hand, federal and state incentives, along with regulatory mechanisms such as RPS, get credit for the rapid deployment of solar energy in the United States. In both markets, the policy landscape is in a transitional phase. In Germany, the FiT level is being reduced whereas in the United States, upfront incentives are being shifted toward performance-based incentives. It is, however, uncertain if the transition will produce expected results. The decrease in the FiT, the primary basis for investors‟ confidence, could drive investors away from solar energy markets. The rapid growth of the grid-connected PV and CSP market is largely attributed to a policy suite that guarantees attractive returns on investment, along with regulatory requirements such as grid connectivity and power purchase commitments required to motivate investments. While FITs played an instrumental role in Germany and Italy, a mix of policy portfolios that includes federal tax credits, subsidies and rebates, RPS, net metering and renewable energy certificates (REC) facilitated solar energy market growth in the United States.21 Similarly, New Jersey developed a policy mix that combined a broad range of federal and state incentives to drive rapid market growth: a policy portfolio consisting of RPS, federal tax credits, grants, drove the rapid growth of the PV market in New Jersey. In the Southwest United States, the combination of excellent solar resources, the 30% federal tax credit, and RPS policies has resulted in a rebirth of solar thermal electric generation. In two of the three states exploring solar thermal electric, the existence of a solar- or distributed generation-specific RPS tier has also played a role in increasing project development.

5.2 Implementation challenges:

Sensitivity to policy costs is more significant in developing country markets such as India, China, Brazil, Philippines and Bangladesh than in more developed economies. Thus, a common approach toward renewable energy technologies, seen in developing countries, is to “rationalize development and deployment strategy” (MNRE 2006) of renewable energy technologies. For instance, India planned in its eleventh Five-Year plan (2007-2012) to install 15,000 MW of grid-connected renewable energy and it was widely believed that this market expansion would be driven by wind, micro-hydro and biomass, as the plan recognized that solar PV would be an option only if the prices come down to levels comparable to micro-hydro. More recently, the National Solar Mission promoting solar power in India has been launched. The first phase (2009-2013) targets increases in the utility grid power from solar sources, including CSP, by over a 1 GW (ESMAP, 2011a). By 2022, 20 GW of solar capacity is to be added in India. The approach to the renewable energy mix in China, Philippines and Bangladesh represents similar priorities of rationalizing the policy costs. In Brazil, as in other developing countries, the minimal policy cost is ensured via technology-specific and reserve energy auctions (ESMAP, 2011b) as the cheapest renewable energy projects are implemented first. Solar PV is recognized as serving a niche market that is very important in developing countries – electrification of rural and peri-urban areas that do not yet have access to the electric 36 grid. There are vigorous efforts to expand the market for Solar Home Systems (SHS) as a means toward rural electrification. However, rural and peri-urban areas are characterized by low income households that may not be able to afford solar energy technologies unless they are substantially subsidized. Until now, the approach is to provide subsidies either via government funds or through international donors. However, a subsidy is a short-term support, not a long-term solution. CSP and solar water heating are comparatively cheaper than solar PVs. These could be cost competitive with conventional fuels if existing subsidies to the latter are reduced or removed. However, fossil fuel subsidies are politically sensitive in many countries and their removal might take time. Thus far, CSP has not found much success in a developing country context. Unlike Solar PV, CSP is limited to utility scale applications and as such is often out of consideration in the traditional utility generation market due to current prices. Thus, developing country governments have adopted a cautious policy approach to this market, focusing more on pilot scale projects, as with grid-connected solar PV. Through its National Solar Mission, India is the first developing country to take a step towards the installation of CSP capacity. Unlike in electric applications, solar heating applications enjoy limited policy support as instruments like FITs and RPS are not applicable for heating applications. Moreover, it is more difficult to measure and verify solar water heating performance, and so performance-based incentives are harder to enact.

5.3 Solar energy development under policies for climate change mitigation

Greenhouse gas mitigation policies and activities help support renewable energy development, including solar energy. Various incentives and mandates designed to trigger GHG mitigation have helped promote solar energy in industrialized countries. In the case of developing countries, the Clean Development Mechanism (CDM) under the Kyoto Protocol has been the main vehicle to promote solar energy under the climate change regime. The CDM allows industrialized countries to purchase GHG reductions achieved from projects in developing countries, where reducing GHG emissions is normally cheaper than in industrialized countries. As of July 2011, there are 6,416 projects already registered or in the process of registration under the CDM. Of these, 109 projects are solar energy projects with annual 37 emission reduction of 3,570,000 tons of CO2. Out of these 109 projects, 89 are located in China, South Korea and India. However, the solar energy projects account for a very small fraction (< 1%) of total emission reductions from the total CDM projects already registered or placed in registration process (UNEP Risoe, 2011). One reason for the small share of solar energy projects in the global CDM market is cost. As noted, solar energy technologies remain costly, and at present they are not economically competitive with other CDM candidates such as wind power, small hydro, landfill gas, and biomass cogeneration. The high upfront capital investment cannot be recovered even if the revenue generated from sales of emission mitigation at standard (non-subsidized) rates is included along with revenue from electricity sales. In addition, solar energy projects to date come in smaller sizes than other CDM options; transaction costs incurred in various steps during the CDM process (e.g., validation and registration of projects and monitoring, verification and certification of emission reductions) do not vary that much with project size and are often prohibitive for solar energy projects that are already less attractive compared to their competitors. To increase the share of solar energy projects in the CDM, one approach is to give solar energy technologies some additional premium for other economic and social benefits. However, other technologies can provide these benefits with lower impacts on electricity costs, so the strength of this argument is open to question. The transaction costs of diffused, small-scale solar CDM projects could be reduced by bundling them into single larger projects, as with “programmatic CDM” schemes22 . Further simplification of CDM registration process for solar energy projects could be accomplished by avoiding additionality screening, as they meet the additionality criterion by default given their costs. With or without CDM, further capacity building in developing countries to enhance technical and managerial skills for market participants is necessary (BMU, 2007).

6. CONCLUSIONS

Physically, solar energy constitutes the most abundant renewable energy resource available and, in most regions of the world, its theoretical potential is far in excess of the current total primary energy supply in those regions. Solar energy technologies could help address energy access to rural and remote communities, help improve long-term energy security and help greenhouse gas mitigation.

The market for technologies to harness solar energy has seen dramatic expansion over the past decade – in particular the expansion of the market for grid-connected distributed PV systems and solar hot water systems have been remarkable. Notably, centralized utility scale PV applications have grown strongly in the recent years; off-grid applications are now dominant only in developing markets. Moreover, the market for larger solar thermal technologies that first emerged in the early 1980s is now gathering momentum with a number of new installations as well as projects in the planning stages.

While the costs of solar energy technologies have exhibited rapid declines in the recent past and the potential for significant declines in the near future, the minimum values of levelized cost of any solar technologies, including tower type CSP, which is currently the least costly solar technology, would be higher than the maximum values of levelized costs of conventional technologies for power generation (e.g., nuclear, coal IGCC, coal supercritical, hydro, gas CC) even if capital costs of solar energy technologies were reduced by 25%. Currently, this is the primary barrier to the large-scale deployment of solar energy technologies. Moreover, the scaling-up of solar energy technologies is also constrained by financial, technical and institutional barriers.

Various fiscal and regulatory instruments have been used to increase output of solar energy. These instruments include tax incentives, preferential interest rates, direct incentives, loan programs, construction mandates, renewable portfolio standards, voluntary green power programs, net metering, interconnection standards and demonstration projects. However, the level of incentives provided through these instruments has not been enough to substantially increase the penetration of solar energy in the global energy supply mix. Moreover, these policy instruments can create market inefficiencies in addition to the direct costs of requiring more- 39 costly electricity supplies to be used. While not discussed in this paper, these indirect impacts need to be considered in assessing the full opportunity cost of policies to expand solar power production.

Carbon finance mechanisms, in particular the CDM, could potentially support expansion of the solar energy market. While some changes in the operation of the CDM could increase solar investment, the price of carbon credits required to make solar energy technologies economically competitive with other technologies to reduce GHG emissions would be high.

The fundamental barrier to increasing market-driven utilization of solar technologies continues to be their cost. The current growth of solar energy is mainly driven by policy supports. Continuation and expansion of costly existing supports would be necessary for several decades to enhance the further deployment of solar energy in both developed and developing countries, given current technologies and projections of their further improvements over the near to medium term. Overcoming current technical and economic barriers will require substantial further outlays to finance applied research and development, and to cover anticipated costs of initial investments in commercial-scale improved-technology production capacity.

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