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Solar Power Green Energy Leading to Net Zero Carbon Emissions

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ABSTRACT: Solar energy is radiant light and heat from the Sun that is harnessed using a range of technologies such as solar power to generate electricity, solar thermal energy (including solar water heating), and solar architecture.[1][2] It is an essential source of renewable energy, and its technologies are broadly characterized as either passive solar or active solar depending on how they capture and distribute solar energy or convert it into solar power. Active solar techniques include the use of photovoltaic systems, concentrated solar power, and solar water heating to harness the energy. Passive solar techniques include orienting a building to the Sun, selecting materials with favorable thermal mass or light-dispersing properties, and designing spaces that naturally circulate air.

In 2011, the International Energy Agency said that "the development of affordable, inexhaustible and clean solar energy technologies will have huge longer-term benefits. It will increase countries' energy security through reliance on an indigenous, inexhaustible, and mostly import-independent resource, enhance sustainability, reduce pollution, lower the costs of mitigating global warming .... these advantages are global".[1]

KEYWORDS: solar energy, green, power, zero carbon, emissions, net, pollution, renewable, mitigation

I.INTRODUCTION

The Earth receives 174 petawatts (PW) of incoming solar radiation (insolation) at the upper atmosphere.[3] Approximately 30% is reflected back to space while the rest, 122 PW, is absorbed by clouds, oceans and land masses. The spectrum of solar light at the Earth's surface is mostly spread across the visible and near-infrared ranges with a small part in the near-ultraviolet.[4] Most of the world's population live in areas with insolation levels of 150–300 watts/m^2, or 3.5–7.0 kWh/m^2 per day.[5]

Solar radiation is absorbed by the Earth's land surface, oceans – which cover about 71% of the globe – and atmosphere. Warm air containing evaporated water from the oceans rises, causing atmospheric circulation or convection. When the air reaches a high altitude, where the temperature is low, water vapor condenses into clouds, which rain onto the Earth's surface, completing the water cycle. The latent heat of water condensation amplifies convection, producing atmospheric phenomena such as wind, cyclones and anticyclones.[6] Sunlight absorbed by the oceans and land masses keeps the surface at an average temperature of 14 °C.[7] By photosynthesis, green plants convert solar energy into chemically stored energy, which produces food, wood and the biomass from which fossil fuels are derived.[8]

The total solar energy absorbed by Earth's atmosphere, oceans and land masses is approximately 122 PW·year = 3,850,000 exajoules (EJ) per year.[9] In 2002 (2019), this was more energy in one hour (one hour and 25 minutes) than the world used in one year.[10][11] Photosynthesis captures approximately 3,000 EJ per year in biomass.[12] The potential solar energy that could be used by humans differs from the amount of solar energy present near the surface of the planet because factors such as geography, time variation, cloud cover, and the land available to humans limit the amount of solar energy that we can acquire. In 2021, Carbon Tracker Initiative estimated the land area needed to generate all our energy from solar alone was 450,000 km^2 — or about the same as the area of Sweden, or the area of Morocco, or the area of California (0.3% of the Earth's total land area).[17]

Solar technologies are characterized as either passive or active depending on the way they capture, convert and distribute sunlight and enable solar energy to be harnessed at different levels around the world, mostly depending on the distance

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from the equator. Although solar energy refers primarily to the use of solar radiation for practical ends, all renewable energies, other than Geothermal power and Tidal power, derive their energy either directly or indirectly from the Sun.

Active solar techniques use photovoltaics, concentrated solar power, solar thermal collectors, pumps, and fans to convert sunlight into useful outputs. Passive solar techniques include selecting materials with favorable thermal properties, designing spaces that naturally circulate air, and referencing the position of a building to the Sun. Active solar technologies increase the supply of energy and are considered supply side technologies, while passive solar technologies reduce the need for alternate resources and are generally considered demand-side technologies.[18]

In 2000, the United Nations Development Programme, UN Department of Economic and Social Affairs, and World Energy Council published an estimate of the potential solar energy that could be used by humans each year that took into account factors such as insolation, cloud cover, and the land that is usable by humans. The estimate found that solar energy has a global potential of 1,600 to 49,800 exajoules (4.4×10^{14} to 1.4×10^{16} kWh) per year

Solar hot water systems use sunlight to heat water. In middle geographical latitudes (between 40 degrees north and 40 degrees south), 60 to 70% of the domestic hot water use, with water temperatures up to 60 °C (140 °F), can be provided by solar heating systems.[24] The most common types of solar water heaters are evacuated tube collectors (44%) and glazed flat plate collectors (34%) generally used for domestic hot water; and unglazed plastic collectors (21%) used mainly to heat swimming pools.[25]

As of 2015, the total installed capacity of solar hot water systems was approximately 436 thermal gigawatt (GW_{th}), and China is the world leader in their deployment with 309 GW_{th} installed, taken up 71% of the market.[26] Israel and Cyprus are the per capita leaders in the use of solar hot water systems with over 90% of homes using them.[27] In the United States, Canada, and Australia, heating swimming pools is the dominant application of solar hot water with an installed capacity of 18 GW_{th} as of 2005.[18]

In the United States, heating, ventilation and air conditioning (HVAC) systems account for 30% (4.65 EJ/yr) of the energy used in commercial buildings and nearly 50% (10.1 EJ/yr) of the energy used in residential buildings.[28][29] Solar heating, cooling and ventilation technologies can be used to offset a portion of this energy. Use of solar for heating can roughly be divided into passive solar concepts and active solar concepts, depending on whether active elements such as sun tracking and solar concentrator optics are used. Thermal mass is any material that can be used to store heat—heat from the Sun in the case of solar energy. Common thermal mass materials include stone, cement, and water. Historically they have been used in arid climates or warm temperate regions to keep buildings cool by absorbing solar energy during the day and radiating stored heat to the cooler atmosphere at night. However, they can be used in cold temperate areas to maintain warmth as well. The size and placement of thermal mass depend on several factors such as climate, daylighting, and shading conditions. When duly incorporated, thermal mass maintains space temperatures in a comfortable range and reduces the need for auxiliary heating and cooling equipment.[30]

A solar chimney (or thermal chimney, in this context) is a passive solar ventilation system composed of a vertical shaft connecting the interior and exterior of a building. As the chimney warms, the air inside is heated, causing an updraft that pulls air through the building. Performance can be improved by using glazing and thermal mass materials[31] in a way that mimics greenhouses.

Deciduous trees and plants have been promoted as a means of controlling solar heating and cooling. When planted on the southern side of a building in the northern hemisphere or the northern side in the southern hemisphere, their leaves provide shade during the summer, while the bare limbs allow light to pass during the winter.[32] Since bare, leafless trees shade 1/3 to 1/2 of incident solar radiation, there is a balance between the benefits of summer shading and the corresponding loss of winter heating.[33] In climates with significant heating loads, deciduous trees should not be planted on the Equator-facing side of a building because they will interfere with winter solar availability. They can, however, be used on the east and west sides to provide a degree of summer shading without appreciably affecting winter solar gain.[34] Solar cookers use sunlight for cooking, drying, and pasteurization. They can be grouped into three broad categories: box cookers, panel cookers, and reflector cookers.[35] The simplest solar cooker is the box cooker first built by Horace de Saussure in 1767.[36] A basic box cooker consists of an insulated container with a transparent lid. It can be used effectively with partially overcast skies and will typically reach temperatures of 90–150 °C (194–302 °F).[37] Panel cookers use a reflective panel to direct sunlight onto an insulated container and reach temperatures comparable to box cookers. Reflector cookers use various concentrating

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geometries (dish, trough, Fresnel mirrors) to focus light on a cooking container. These cookers reach temperatures of 315 °C (599 °F) and above but require direct light to function properly and must be repositioned to track the Sun.[38] Solar concentrating technologies such as parabolic dish, trough and Scheffler reflectors can provide process heat for commercial and industrial applications. The first commercial system was the Solar Total Energy Project (STEP) in Shenandoah, Georgia, US where a field of 114 parabolic dishes provided 50% of the process heating, air conditioning and electrical requirements for a clothing factory. This grid-connected cogeneration system provided 400 kW of electricity plus thermal energy in the form of 401 kW steam and 468 kW chilled water, and had a one-hour peak load thermal storage.[39] Evaporation ponds are shallow pools that concentrate dissolved solids through evaporation. The use of evaporation ponds to obtain salt from seawater is one of the oldest applications of solar energy. Modern uses include concentrating brine solutions used in leach mining and removing dissolved solids from waste streams.[40]

Clothes lines, clotheshorses, and clothes racks dry clothes through evaporation by wind and sunlight without consuming electricity or gas. In some states of the United States legislation protects the "right to dry" clothes.[41] Unglazed transpired collectors (UTC) are perforated sun-facing walls used for preheating ventilation air. UTCs can raise the incoming air temperature up to 22 °C (40 °F) and deliver outlet temperatures of 45–60 °C (113–140 °F).[42] The short payback period of transpired collectors (3 to 12 years) makes them a more cost-effective alternative than glazed collection systems.[42] As of 2003, over 80 systems with a combined collector area of 35,000 square metres (380,000 sq ft) had been installed worldwide, including an 860 m^2 (9,300 sq ft) collector in Costa Rica used for drying coffee beans and a 1,300 m^2 (14,000 sq ft) collector in Coimbatore, India, used for drying marigolds.

II.DISCUSSION

Solar distillation can be used to make saline or brackish water potable. The first recorded instance of this was by 16th-century Arab alchemists.[44] A large-scale solar distillation project was first constructed in 1872 in the Chilean mining town of Las Salinas.[45] The plant, which had solar collection area of 4,700 m^2 (51,000 sq ft), could produce up to 22,700 L (5,000 imp gal; 6,000 US gal) per day and operate for 40 years.[45] Individual still designs include single-slope, double-slope (or greenhouse type), vertical, conical, inverted absorber, multi-wick, and multiple effect. These stills can operate in passive, active, or hybrid modes. Double-slope stills are the most economical for decentralized domestic purposes, while active multiple effect units are more suitable for large-scale applications.[44]

Solar water disinfection (SODIS) involves exposing water-filled plastic polyethylene terephthalate (PET) bottles to sunlight for several hours.[46] Exposure times vary depending on weather and climate from a minimum of six hours to two days during fully overcast conditions.[47] It is recommended by the World Health Organization as a viable method for household water treatment and safe storage.[48] Over two million people in developing countries use this method for their daily drinking water.[47]

Solar energy may be used in a water stabilization pond to treat waste water without chemicals or electricity. A further environmental advantage is that algae grow in such ponds and consume carbon dioxide in photosynthesis, although algae may produce toxic chemicals that make the water unusable.[49][50]

Solar power is the conversion of energy from sunlight into electricity, either directly using photovoltaics (PV) or indirectly using concentrated solar power. Photovoltaic cells convert light into an electric current using the photovoltaic effect.[60] Concentrated solar power systems use lenses or mirrors and solar tracking systems to focus a large area of sunlight to a hot spot, often to drive a steam turbine.

Photovoltaics were initially solely used as a source of electricity for small and medium-sized applications, from the calculator powered by a single solar cell to remote homes powered by an off-grid rooftop PV system. Commercial concentrated solar power plants were first developed in the 1980s. Since then, as the cost of solar electricity has fallen, grid-connected solar PV systems have grown more or less exponentially. Millions of installations and gigawatt-scale photovoltaic power stations continue to be built, with half of new generation capacity being solar in 2021.[61]

In 2021 solar generated 3.8% (1040 TWh) of the world's electricity-compared to 1% (253 TWh) in 2015 when the Paris Agreement to limit climate change was signed.[62] Wind and solar generated over 10% of the world's electricity in 2021.[62] Along with onshore wind, the cheapest levelised cost of electricity is utility-scale solar.[63]

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Much more low carbon power, such as solar, is urgently needed to limit climate change, but the International Energy Agency said in 2022 that more effort was needed for grid integration and the mitigation of policy, regulation and financing challenges.[64] Development of a solar-powered car has been an engineering goal since the 1980s. The World Solar Challenge is a biannual solar-powered car race, where teams from universities and enterprises compete over 3,021 kilometres (1,877 mi) across central Australia from Darwin to Adelaide. In 1987, when it was founded, the winner's average speed was 67 kilometres per hour (42 mph) and by 2007 the winner's average speed had improved to 90.87 kilometres per hour (56.46 mph).[78] The North American Solar Challenge and the planned South African Solar Challenge are comparable competitions that reflect an international interest in the engineering and development of solar powered vehicles.[79][80]

Some vehicles use solar panels for auxiliary power, such as for air conditioning, to keep the interior cool, thus reducing fuel consumption.[81][82]

In 1975, the first practical solar boat was constructed in England.[83] By 1995, passenger boats incorporating PV panels began appearing and are now used extensively.[84] In 1996, Kenichi Horie made the first solar-powered crossing of the Pacific Ocean, and the Sun21 catamaran made the first solar-powered crossing of the Atlantic Ocean in the winter of 2006–2007.[85] There were plans to circumnavigate the globe in 2010.[86]

In 1974, the unmanned AstroFlight Sunrise airplane made the first solar flight. On 29 April 1979, the Solar Riser made the first flight in a solar-powered, fully controlled, man-carrying flying machine, reaching an altitude of 40 ft (12 m). In 1980, the Gossamer Penguin made the first piloted flights powered solely by photovoltaics. This was quickly followed by the Solar Challenger which crossed the English Channel in July 1981. In 1990 Eric Scott Raymond in 21 hops flew from California to North Carolina using solar power.[87] Developments then turned back to unmanned aerial vehicles (UAV) with the Pathfinder (1997) and subsequent designs, culminating in the Helios which set the altitude record for a non-rocket-propelled aircraft at 29,524 metres (96,864 ft) in 2001.[88] The Zephyr, developed by BAE Systems, is the latest in a line of record-breaking solar aircraft, making a 54-hour flight in 2007, and month-long flights were envisioned by 2010.[89] As of 2016, Solar Impulse, an electric aircraft, is currently circumnavigating the globe. It is a single-seat plane powered by solar cells and capable of taking off under its own power. The design allows the aircraft to remain airborne for several days.[90]

A solar balloon is a black balloon that is filled with ordinary air. As sunlight shines on the balloon, the air inside is heated and expands, causing an upward buoyancy force, much like an artificially heated hot air balloon. Some solar balloons are large enough for human flight, but usage is generally limited to the toy market as the surface-area to payload-weight ratio is relatively high.[91] Solar chemical processes use solar energy to drive chemical reactions. These processes offset energy that would otherwise come from a fossil fuel source and can also convert solar energy into storable and transportable fuels. Solar induced chemical reactions can be divided into thermochemical or photochemical.[92] A variety of fuels can be produced by artificial photosynthesis.[93] The multielectron catalytic chemistry involved in making carbon-based fuels (such as methanol) from reduction of carbon dioxide is challenging; a feasible alternative is hydrogen production from protons, though use of water as the source of electrons (as plants do) requires mastering the multielectron oxidation of two water molecules to molecular oxygen.[94] Some have envisaged working solar fuel plants in coastal metropolitan areas by 2050 – the splitting of seawater providing hydrogen to be run through adjacent fuel-cell electric power plants and the pure water by-product going directly into the municipal water system.[95] In addition, chemical energy storage is another solution to solar energy storage.[96]

Hydrogen production technologies have been a significant area of solar chemical research since the 1970s. Aside from electrolysis driven by photovoltaic or photochemical cells, several thermochemical processes have also been explored. One such route uses concentrators to split water into oxygen and hydrogen at high temperatures (2,300–2,600 °C or 4,200–4,700 °F).[97] Another approach uses the heat from solar concentrators to drive the steam reformation of natural gas thereby increasing the overall hydrogen yield compared to conventional reforming methods.[98] Thermochemical cycles characterized by the decomposition and regeneration of reactants present another avenue for hydrogen production. The Solzinc process under development at the Weizmann Institute of Science uses a 1 MW solar furnace to decompose zinc oxide (ZnO) at temperatures above 1,200 °C (2,200 °F). This initial reaction produces pure zinc, which can subsequently be reacted with water to produce hydrogen.[99]

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III.RESULTS

Thermal mass systems can store solar energy in the form of heat at domestically useful temperatures for daily or interseasonal durations. Thermal storage systems generally use readily available materials with high specific heat capacities such as water, earth and stone. Well-designed systems can lower peak demand, shift time-of-use to off-peak hours and reduce overall heating and cooling requirements.[100][101]

Phase change materials such as paraffin wax and Glauber's salt are another thermal storage medium. These materials are inexpensive, readily available, and can deliver domestically useful temperatures (approximately 64 °C or 147 °F). The "Dover House" (in Dover, Massachusetts) was the first to use a Glauber's salt heating system, in 1948.[102] Solar energy can also be stored at high temperatures using molten salts. Salts are an effective storage medium because they are low-cost, have a high specific heat capacity, and can deliver heat at temperatures compatible with conventional power systems. The Solar Two project used this method of energy storage, allowing it to store 1.44 terajoules (400,000 kWh) in its 68 m³ storage tank with an annual storage efficiency of about 99%.[103]

Off-grid PV systems have traditionally used rechargeable batteries to store excess electricity. With grid-tied systems, excess electricity can be sent to the transmission grid, while standard grid electricity can be used to meet shortfalls. Net metering programs give household systems credit for any electricity they deliver to the grid. This is handled by 'rolling back' the meter whenever the home produces more electricity than it consumes. If the net electricity use is below zero, the utility then rolls over the kilowatt-hour credit to the next month.[104] Other approaches involve the use of two meters, to measure electricity consumed vs. electricity produced. This is less common due to the increased installation cost of the second meter. Most standard meters accurately measure in both directions, making a second meter unnecessary.

Pumped-storage hydroelectricity stores energy in the form of water pumped when energy is available from a lower elevation reservoir to a higher elevation one. The energy is recovered when demand is high by releasing the water, with the pump becoming a hydroelectric power generator. An electric aircraft is an aircraft that runs on electric motors rather than internal combustion engines, with electricity coming from fuel cells, solar cells, ultracapacitors, power beaming,[135] or batteries.

Currently, flying manned electric aircraft are mostly experimental demonstrators, though many small unmanned aerial vehicles are powered by batteries. Electrically powered model aircraft have been flown since the 1970s, with one report in 1957.[136][137] The first man-carrying electrically powered flights were made in 1973.[138] Between 2015 and 2016, a manned, solar-powered plane, Solar Impulse 2, completed a circumnavigation of the Earth.[139]

In an increasingly carbon-constrained world, solar energy technologies represent one of the least carbon-intensive means of electricity generation. Solar power produces no emissions during generation itself, and life-cycle assessments clearly demonstrate that it has a smaller carbon footprint from "cradle-to-grave" than fossil fuels.

Of the more than 10,000 terawatt-hours (TWh) of electricity generation produced by the countries of the Organization for Economic Cooperation and Development (OECD), solar currently accounts for just 8 TWh. Yet solar technologies, including photovoltaics, concentrating solar power and solar thermal constitute the fastest growing energy source in the world. With clear market signals from Governments, these low-carbon technologies could provide more than 30 per cent of the world's energy supply in aggregate by 2040.

Photovoltaics (PV) are perhaps the most well-known and fastest growing sector of solar technology. PV devices generate electricity directly from sunlight via an electric process that occurs naturally in certain types of material. Groups of PV cells are configured into modules and arrays, which can be used to power any number of electrical loads. PV energy systems have very good potential as a low-carbon energy supply technology. A September 2006 joint paper by scientists from Brookhaven National Laboratory, Utrecht University and the Energy Research Center of the Netherlands demonstrates that crystalline silicon PV systems have energy payback times of 1.5 to 2 years for South European locations and 2.7 to 3.5 years for middle-European, while thin film technologies have energy payback times in the range of 1 to 1.5 years in South Europe.

Accordingly, life-cycle carbon dioxide (CO2) emissions for PV are now in the range of 25 to 32 g/kWh. In comparison, a combined cycle gas-fired power plant emits some 400 g/kWh, while a coal-fired power plant with carbon capture and storage, about 200

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g/kWh. Nuclear power emits 25 g/kWh on average in the United States; only wind power is better with a mere 11 g/kWh. For silicon technology, clear prospects for a reduction of energy input exist, and an energy payback of one year may be possible within a few years as silicon growth processes become more efficient. As a result, this could decrease the life-cycle CO2 emissions to 15 g/kWh.

The global photovoltaic sector has been growing at an average of over 40 per cent in the last eight years, manufacturing over 2,200 megawatts in 2006. PV have become competitive in all market segments, particularly grid-connected applications, as more investment in the sector has produced major advances in automation, manufacturing efficiencies and throughput. Several leading countries -- Germany, Japan and the United States, representing two thirds of the global market -- have provided market support programmes to drive down costs. The growth of PV has driven a very classic "experience curve" decline in manufacturing prices. Data fairly clearly demonstrate an 18 to 20 per cent "progress ratio" -- for every doubling in the cumulative production of solar cells, prices come down about one fifth. Currently, solar modules are selling globally from \$3 to \$5 per watt, while installed systems are generally sold at between \$6 and \$10 per watt. Solar energy is the cheapest option for providing power to locations more than half a mile from existing electricity and is generally competitive without subsidies in regions with high energy prices. The PV industry is striving to reduce system costs by 50 per cent by 2015, at which point PV will be cost-competitive with retail electricity costs in most of the United States and other developed countries.

As PV technology becomes increasingly affordable and available, its potential as a major source of low-carbon energy grows. In a 2004 report entitled Solar Generation, Greenpeace and the European Photovoltaic Industry Association (EPIA) estimated that, by 2020, PV could provide 276 TWh of energy -- equivalent to 1 per cent of the global demand projected by the International Energy Agency (IEA). The study assumed that the PV market would grow at a compound annual growth rate of 30 per cent until 2020, well below the 45-per cent growth that the industry averaged from 2002 to 2007. This would replace the output of 75 new coal-fired power stations and prevent the emission of 664 million tons of CO2 annually. Moreover, the report found that with a 15-per cent growth rate from 2020 to 2040, the solar output could be more than 9,000 TWh, which would be 26 per cent of the projected global demand.

IV.CONCLUSIONS

Concentrating solar power (CSP) plants are utility-scale generators that produce electricity by using mirrors or lenses to efficiently concentrate the sun's energy. Two principal CSP technologies are parabolic troughs, which use rows of curved mirrors to drive conventional steam turbines; and the dish-Stirling engine systems, which are shaped much like large satellite dishes and covered with curved mirrors that heat liquid hydrogen to drive the pistons of a Stirling engine. Life-cycle assessment of the emissions produced, together with the land surface impacts of CSP systems, show that they are ideally suited to reduce greenhouse gases (GHG) and other pollutants, without creating other environmental risks or contamination. According to the European Solar Thermal Industry Association, 1 MWh of installed solar thermal power capacity results in the saving of 600 kilograms of CO2. The energy payback time of CSP systems is approximately five months, which compares very favourably with their lifespan of 25 to 30 years.

During the 1980s and early 1990s, developers built nine concentrating solar power plants in California's Mojave Desert for a total of 330 MW. Then, for nearly two decades no new plants were built due to the weakening of the United States federal support for renewables and plummeting energy prices. However, CSP has experienced a renaissance in the last two years. An 11-MW plant in Spain -- the first in Europe -- became operational in March 2007, while a 64-MW plant in Nevada is in its final stages of construction. Currently, over 45 CSP projects worldwide are in the planning stages, with a combined capacity of 5,500 MW.

With more than 200 GW of resource potential in the American southwest and thousands more throughout the world, CSP offers a rapidly scalable means of low-carbon electricity generation. A September 2005 report by the European Solar Thermal Industry Federation (ESTIF), Greenpeace and the IEA SolarPACES found that "there are no technical, economic or resource barriers to supplying 5 per cent of the world's projected electricity needs from solar thermal power by 2040". The authors calculated that CSP could produce 95.8 TWh/year by 2025, avoiding 57.5 millions tons of CO2 annually for a cumulative 362 million tons in the next 20 years. By 2040, they found that CSP could produce as much as 16,000 TWh per year.

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Solar thermal systems provide environmentally friendly heat for household water and space heating. Simple collectors, usually placed on the roof of a house or building, absorb the sun's energy and transfer the heat. In many climates, a solar heating system can provide a very high percentage (50 to 75 per cent) of domestic hot water energy. Since, on average, water heating accounts for around 30 per cent of a home's CO2 emissions, a solar water heater can reduce its total emissions by more than 20 per cent. Many countries are encouraging increased use of solar hot water technology. Worldwide, installations grew 14 per cent in 2005 to an installed base of 88 GW thermal equivalent, with 46 million houses equipped with the systems. China leads the way, with 62 per cent of the installed capacity, while Israel has the highest per-capita usage, with 90 per cent of all homes taking advantage of the technology. The IEA Heating and Cooling Program in April 2007 calculated that this global installed solar thermal capacity reduces CO2 emissions by approximately 30 million tons each year. In January, ESTIF proposed an ambitious target of installing 1 square metre of collector area by 2020 for every European -- 320 TWh of installed capacity. Meanwhile, in March, the United States National Renewable Energy Laboratory calculated the current technical potential of solar water heating in the United States at 1 quad of primary energy savings per year, equivalent to an annual CO2 emission reduction of about 50 to 75 million metric tons.[129]

Solar energy is an obvious choice for a carbon-smart, reliable energy future. Greater reliance on this comparatively untapped energy resource will help mitigate climate change while stimulating economies, creating jobs and increasing grid integrity and security. However, without robust international and national policy support for solar and other renewable energy sources, society will continue down the path of over-reliance on highly price-volatile, insecure and carbon-intensive energy sources. Incentives for early adopters, regulatory policies and education initiatives must all be in place to jump-start the mass-market adoption of solar energy. With clear market signals, the industry can build up low-carbon solar energy on a scale large enough to help solve our global energy challenges.

Giving Life With the Sun: The Darfur Solar Cookers Project

For the 200,000 displaced citizens of Darfur living in refugee camps in Chad, the simple task of cooking a meal poses serious risks. Since wood for cooking is scarce in the desert region, refugees must travel several miles outside the camp to gather firewood, where they are highly vulnerable to attacks by the Janjaweed militia and other predators. A 2005 report by Médecins Sans Frontières found that 82 per cent of rape attacks occur when women are outside the populated villages, usually while searching for firewood. But in the Iridimi camp with 17,000 refugees in eastern Chad, families have cut their firewood use by 50 to 80 per cent, using simple solar cookers to prepare their meals.

Most solar cookers work on sunlight being converted to heat energy that is retained for cooking. While there are many successful designs, the most adaptable to the needs of refugees is CooKit, from Solar Cookers International, which is made of cardboard or other local material and is cut into a specific shape to effectively reflect the solar light rays toward a black metal pot. The pot, when painted black on the outside, absorbs and retains solar heat. A clear polypropylene bag tied around it creates an insulating barrier and allows the pot to easily reach 250? Fahrenheit (about 121? Celsius), which is more than enough to cook several litres of food in a few hours.[135]

The KoZon Foundation, a Dutch non-governmental organization that trains women in developing countries to solar-cook, brought the devices to the Iridimi camp for the first time in February 2005, after it obtained funding from the Dutch Foundation for Refugees and a project approval from the United Nations High Commissioner for Refugees (UNHCR). KoZon volunteer, Derk Rijks, and Chadian trainee, Marie-Rose Neloum, provided 100 cookers to several women refugees for a demonstration, which proved to be a success.

A second demonstration was organized in April 2005, in which KoZon trained and tested the ability of the refugees themselves to manufacture 120 cookers, emphasizing the creation of a self-sustaining economic activity. A basic workshop, completed in February 2006, provided the necessary tools and space for the manufacture of the cookers. Several refugees were also trained as "auxiliary trainers", who would teach others how to solar-cook.

The Solar Cooker Project accelerated in May 2006, when a coalition of 55 synagogues in southern California in the United States, the Jewish World Watch (JWW), stepped in to fund the large-scale introduction of the cookers throughout the Iridimi camp. The coalition works to combat genocide and other human rights violations worldwide, and its women's committee takes on volunteer

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projects that particularly impact women. "The only way you fight death is by giving life, and the only way that you can overcome genocide is to ameliorate the suffering", said JWW founder, Rabbi Harold M. Schulweis. "In this case you have defenseless women without any protection, subject to the sadism of the Janjaweed. To be able to give them the smallest amount of protection and security is of primary significance."[139]

The Project has so far trained 4,500 women and supplied 10,000 cookers to refugees. The Iridimi camp now manufactures approximately 1,000 solar cookers a month as replacements (the cookers typically last for six months), while supplying excess cookers to the 22,000 refugees in the nearby camp in Touloum. The Project has also reduced the number of foraging trips by approximately 70 per cent, thus lowering the risk of attacks on women and girls. The cookers also provide economic opportunities, not only in their direct manufacture, but also by giving refugees some free time for other activities, rather than cooking and collecting firewood. Many of the women are now engaged in basketry, knitting and other handiwork selling in Europe, by special arrangement with UNHCR and the airlines.

The Project has also reaped significant environmental benefits for the people and the region. By reducing firewood consumption, it has slowed down the deforestation process. The zero-pollution cookers have reduced smoke in the camp, consequently providing health and quality-of-life benefits for refugees. Project partners believe that with the support of the United Nations, the Project could bring solar cookers to the rest of the 200,000 refugees in Chad.

"As important as it is to alert the world, there is nothing that alerts the world more than action", said Rabbi Schulweis. "For the United Nations to adopt this would be a reinvigoration. It's illustrative of what can be done even in impoverished countries, even in countries that are divided and scared to death because of internal warfare, that at least we can shield them and give them protection. It raises the solar industry into something that has a moral character, as well as an entrepreneurial character. In this age, we need not only high technology but also high morality."[139]

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