PLATFORM FOR ACTION ON RENEWABLE ENERGY (PoA)

BRIEFING PAPER

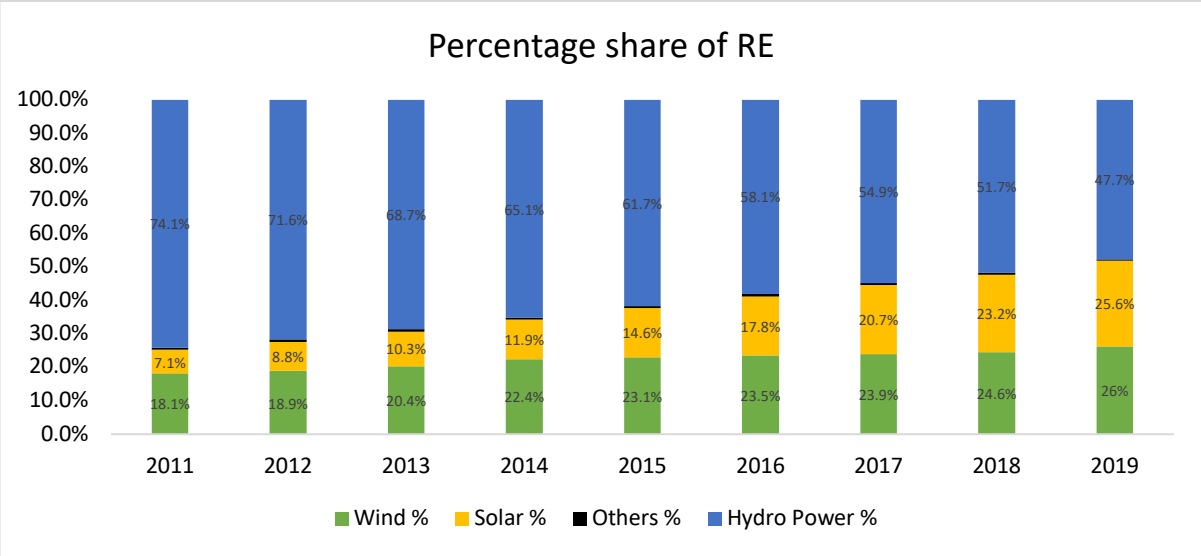
SOLAR ENERGY

Introduction

Solar energy, along with wind power, is one of the key renewable energy technology options for realising a decarbonised power sector and a sustainable energy supply. The solar energy sector can be broadly divided into three sub-sectors viz., solar photovoltaics (PV), concentrating solar thermal power (CSP), and solar thermal heat. Of these, solar PV installations which has grown almost 20 times in the last decade, holds out the most promise to decarbonise electricity generation and to fuel the necessary large scale renewable electrification of services that still run on fossil fuels like transport, heating as well as ensure energy access to the poor and underserved. Besides wind power, PV is suggested to also play a major part in producing renewable hydrogen via electrolysers. The rapid growth of renewable hydrogen for "hard-to-decarbonise" and "hard-to-electrify" sectors like energy-intensive industries (steel, chemicals, fertilisers, etc.) and transport sectors (shipping, heavy duty vehicles, etc.) will complement the move to a rapid phase out of fossil fuels and 100% renewable energy future.

Solar Photovoltaics

Global solar PV capacity additions is estimated to have reached 139 GW in 2020, bringing the global total installed capacity to around 760 GW, including both on-grid and off-grid installations[1]. This record-breaking achievement was despite the supply-chain disruptions and other challenges faced by the sector as a result of the COVID-19 pandemic. Solar PV has become the most competitive option for electricity generation in a growing number of locations, both for residential and commercial applications, and for utility-scale projects as



[1] REN21 (2021), p. 117, Renewables 2021 - Global Status Report

well. Solar PV has presently 25.5% share of the renewable electricity as indicated in the graph in Figure 1.

Figure 1: Cumulative global percentage share of RE capacity
Source: Author, based on raw data from IRENA website[2].

By the end of 2020, at least 15 countries had enough capacity in operation to meet at least 5% of their electricity demand with solar PV, and this is forecasted to grow both in terms of number of countries as well as in the percentage of electricity demand met from solar PV. Solar PV accounted for around 11.2% of annual generation in the Honduras, and for notable shares also in Germany (10.5%), Greece (10.4%), Australia (9.9%), Chile (9.8%), Italy (9.4%) and Japan (8.5%), among others. The top five markets – China, the United States, Vietnam, Japan and Germany were responsible for almost 66% of newly installed capacity in 2020. In terms of cumulative solar PV capacity China, the United States, Japan, European Union (mostly Germany), and India continued to lead the pack.[3]

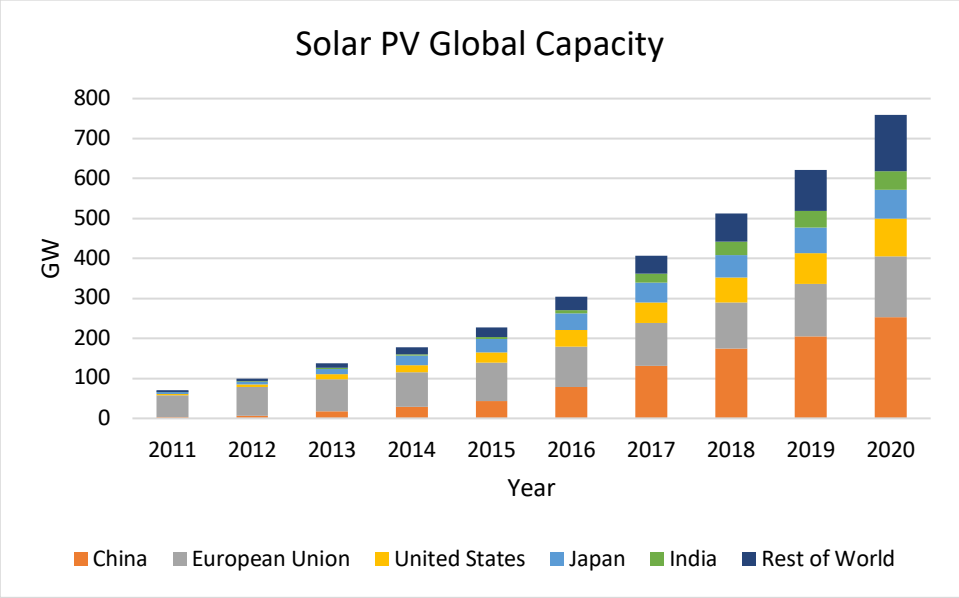


Figure 2: Solar PV Global Capacity by country, and Region
Graph based on data from Renewables 2021 - Global Status Report[4]

Solar PV systems are also one of the most "democratic" renewable technologies, since their modularity and suitability for most geographies in the world, when combined with efficient battery storage, makes it the technology of choice for powering the energy needs of individuals, small-businesses, and communities in remote locations where other energy technologies and systems may not be feasible. In 2020, the global installed capacity of off-grid solar continued to increase with more than 1.5 GW added. However, annual growth in new capacity only saw a 9% increase from 2019, unlike the previous years between 2017 and 2019, where the growth

[2] International Renewable Energy Agency (IRENA) (2021), "Renewable Capacity Statistics 2021", https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2021/Apr/IRENA_RE_Capacity_Statistics_2021.pdf
[3] REN21 (2021), p. 118 - 119, Renewables 2021 - Global Status Report
[4] Graph based on data from REN21 (2021), p. 118 - 119, Renewables 2021 - Global Status Report

had consistently been in double digits. The total capacity of off-grid solar installations is estimated to be nearly 10 GW in 2020.[5]

Concentrating Solar Thermal Power

Global CSP capacity grew just 1.6% in 2020 to 6.2 GW. This was the lowest annual market growth in over a decade that the sector saw and could be attributed to increasing cost competition from solar PV, the expiry of CSP incentive programmes, and a range of operational issues at existing facilities. Market growth also was impacted by construction delays and stoppages in China, India and Chile. China was the only country to add new capacity during 2020 while Spain and the United States, the market leaders in cumulative installed CSP capacity have not added new capacity in seven and five years, respectively. During the decade prior to 2020, CSP costs decreased 68%. CSP costs have declined as a result of multiple factors, including technological innovation, improved supply chain competitiveness, as well as increased growth in CSP capacity in high irradiance regions which, along with increased thermal energy storage (TES) capacity, has boosted the overall capacity factor of the global CSP fleet. However solar PV experienced more than 80% cost decline over the same period.[6]

Towards the end of the year 2020 around 21 GWh of thermal energy storage that was based almost entirely on molten salts, was operating along with CSP plants across five continents. TES capacity, installed mainly alongside CSP, represents a significant proportion of global non-pumped hydropower energy storage capacity and is almost double that of utility-scale batteries.[7]

Solar Thermal Heat

The growth in the global solar thermal market declined slightly in 2020, with an estimated 25.2 GWh of capacity added worldwide, down 3.6% from 26.1 GWh in 2019. The solar thermal markets were constrained by challenges associated with the COVID-19 pandemic such as the related restrictions and postponed investment decisions by commercial clients, including industries and hotels. However, the reduction was smaller than expected partly due to higher demand from residential owners who spent more time at home, and invested in infrastructure improvements. The total operating capacity for glazed (flat plate and vacuum tube), and unglazed collectors (used mainly for hot water showers and heating swimming pools) reached an estimated 501 GWh by the end of 2020. This provides around 407 terawatt-hours (1,465 petajoules) of heat annually, equivalent to the energy content of 239 million barrels of oil or 2.5 days global oil supply annually.[8] The global potential to replace oil and gas with solar thermal on rooftops for residential hot water, and even district heating (based on piped hot water) in countries with colder seasons is large.

The leading countries for new glazed and unglazed installations in 2020 were China, Turkey, India, Brazil, the United States, Germany and Australia. China dominated the market, accounting for 71% of new global sales, followed by Turkey and India (5% each).

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[5] Solar Power Europe (2021), Pg. 37, Global Market Outlook for Solar 2021-25
[6] REN21 (2021), p. 133-135, Renewables 2021 - Global Status Report
[7] REN21 (2021), p. 135, Renewables 2021 - Global Status Report
[8] REN21 (2021), p. 137, Renewables 2021 - Global Status Report

Future Outlook

The electricity sector emitted 12.3 Gt CO_2 in 2020 (36% of all energy-related emissions)[9], which is more than any other sector, and cleaning up the electricity mix by replacing fossil-fuel based electricity generation with renewable energy is an important part of the energy transition strategy. Solar PV will play a very critical role in energy transition mainly due to its cost leadership. In most regions globally, solar PV already represents the cheapest available source of new electricity generation. This combined with its versatility of being able to cover a wide range of energy requirements ranging from very small residential systems and community mini-grids to utility scale power plants, and the speed in which a project can be taken from planning to commissioning makes it the technology of choice for electricity generation. The Global Market Outlook forecasts cumulative grid-connected solar power capacities to reach 1,870 GW by 2025, according to the most likely scenario. Under optimal conditions, the world could operate PV generation plant capacities as large as 2.147 TW by the end of 2025. In the most likely scenario, it is expected that total global installed PV generation capacity will pass the following milestones over the next 5 years: 900 GW in 2021, 1.1 TW in 2022, 1.3 TW in 2023, 1.6 TW in 2024, and 1.8 TW in 2025.[10]

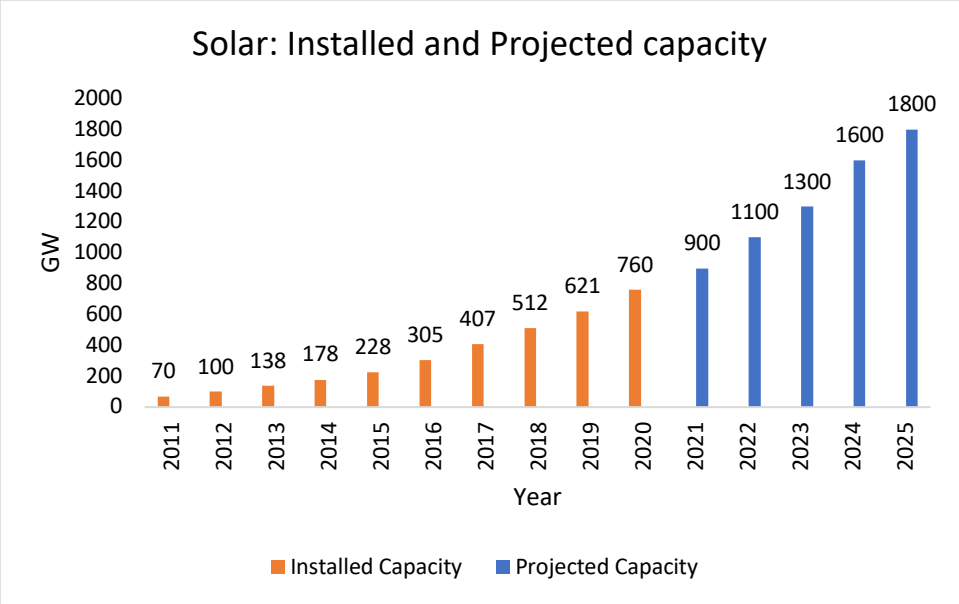

Figure 3: Solar Energy Installed and Projected Capacities[11]

As per the estimates of the International Energy Agency (IEA), the heating equipment market continues to be dominated by fossil fuel-based equipment, and less-efficient conventional electric heating technologies, which make up almost 80% of new sales. Heat pumps and renewable heating equipment such as solar hot water systems are around 10% of overall sales. Heat pumps are the largest electrification opportunity in the buildings sector, displacing heating

[9] International Energy Agency |(2021) , p. 40, World Energy Outlook 2021

[10] Solar Power Europe (2021), Pg. 29, Global Market Outlook for Solar 2021-2

[11] Based on data from REN21 (2021), p. 118 - 119, Renewables 2021 - Global Status Report, and Solar Power Europe (2021), Pg. 29, Global Market Outlook for Solar 2021-25

from fossil fuel boilers. To be in line with the IEA's Sustainable Development Scenario (SDS), the share of clean energy technologies such as heat pumps, solar thermal heating, low-carbon district energy systems and biomass boilers, as well as hydrogen boilers and fuel cells, needs to exceed 80% of new heating equipment sales by 2030.[12] Another use of solar heat from PVT technology (solar panels coupling PV and thermal heat production) is now emerging and promises to enlarge the traditional solar domestic hot water segment of the market.

Challenges and Bottlenecks

Despite being one the fastest growing renewable energy sources, solar power faces several challenges. The challenges faced by this sector can be classified into technical, financial, environmental and political, as summarized in Table 2.

Table 2: Major challenges for deployment of Solar Energy

Technical	Financial	Environmental	Political
• Seasonality and weather-dependence. • Low efficiency • Needs for energy storage system	• Investment priorities in developing countries	• Competition from other land uses • Bio-diversity hazard • E-waste generation	• Government policies • Tariff rates

Technical challenges
The biggest challenge that solar energy faces is that of seasonality and weather-dependence. The fact that solar energy cannot be made available 'on-demand' like energy generated from fossil fuels makes it imperative to combine it with efficient storage, adding to the cost of delivered energy. In cases and where this exists, the connection to an effective grid distribution network across larger regions to balance radiation variability in 24 hours and permit for supply flexibility as well as most efficient and affordable production is necessary.

Financial challenges
Due to the low cost of implementing solar plants compared to other renewable energy, this sector does not face as many financial challenges. In developing countries though, it might need help with investments. The tariff rates defined need to enable producers to recover the costs.

Environmental challenges
Larger utility scale power plants require a lot of space, and often installations face the challenge of having to compete with alternate uses of land, where the opportunity cost makes solar power

[12] IEA (2020), Heating, IEA, Paris https://www.iea.org/reports/heating

unviable. However, floating solar and agricultural PV are options being explored to overcome this challenge. Solar panels have a life of around 25 years, and recycling the solar panels is a challenging problem. Recycling units need to collaborate closely with plants for e-waste management.

Political challenge
For the progress of any renewable energy, government support is of utmost importance. Favourable policies and tariff rates defined by the government need to support the development of solar power plants.

Technological development and challenges: While utility scale solar PV, CSP, and even district heating solar thermal heat continue to grow in many countries, policies and legislation to mandate for instance via building codes solar PV and solar thermal where possible and appropriate on all building roofs is very useful. This could also include installing new emerging ultrathin PV technology on sun-exposed facades and windows as well as along railroad tracks or highways to avoid land sealing. That would also require significant expansion of local low voltage grids to guarantee smooth connections in all directions. For instance, Germany has recently decided to establish solar on all buildings aiming at an additional 200 GW residential solar power until 2030 from the about 56 GW that is already installed and provided almost 10% of all national electricity by end 2020. Floating solar should grow large, and could contribute via shading to reduce evaporation losses of fresh water in hydropower dams in hotter, sunnier countries.

Conclusion
Solar energy is one of the most important sources of clean and renewable energy in humankind's efforts to a 100% transition from fossil fuels in global energy systems. In most regions globally, solar PV already represents the cheapest available source of new electricity generation. This combined with its versatility of being able to cover a wide range of energy requirements ranging from very small residential systems and community mini-grids to utility scale power plants, and the speed in which a project can be taken from planning to commissioning makes it the technology of choice for electricity generation. While 90% of the installed solar thermal systems are used for water heating in homes, their application is beginning to broaden to industrial and district energy systems and this could play an important role in meeting industrial heating requirements which are currently being met by fossil fuels.