Sunny days are ahead, but not without challenges

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There is a strong linkage between the anthropogenic emissions of greenhouse gases and global warming. At present, emissions of greenhouse gases are the highest in history. This is expected to play a significant role in widespread impacts on human and natural systems through climate change. To arrest the grave consequences, on 12 December 2015, representatives of 195 countries agreed to the final global pact, known as the Paris Agreement, to reduce emissions. Major steps for achieving emission reduction are to promote usage of low-carbon renewable energy, improving energy efficiency, and moving towards a sustainable society. A significant portion of the renewable energy essentially originates from solar radiation. Solar energy is abundant and available almost everywhere. Theoretically, converting a small fraction of the solar radiation available on earth (about 3.87×10^6 EJ/year) is sufficient for all energy services required by mankind (about 550 EJ/year).

Solar thermal technologies for low-temperature applications, such as domestic hot water supply, space heating, low-temperature cooking, heating of swimming pools, drying of agricultural products, low-temperature process heating, etc., have already been commercialized. Total installed capacity of low-temperature solar collectors is about 200 Gigawatt thermal. Depending on the location, the energy payback period is in the range of 1.3–4.0 years. It is estimated that the present deployment of these technologies result in an annual carbon dioxide emissions

reduction of about 40 million metric tons. Another potential application of low-temperature solar heat is to reduce energy demands for heating, cooling, ventilation, and lighting in buildings through passive solar architecture principles.

The biggest challenge is tapping the omnipresent sunlight for the higher temperature use. Sunlight needs to be concentrated to achieve higher temperature for power generation and process heat applications. Four basic commercially available concentrating solar thermal technologies are linear Fresnel reflector, parabolic trough collector, solar power tower, and paraboloid dish. Land and water requirements (for cleaning and cooling) are the major drawbacks associated with these technologies. According to the special report of Intergovernmental Panel on Climate Change, life-cycle greenhouse gas emissions are about 14–32 g of carbon dioxide-equivalent per kWh of thermal energy output with an energy payback period of about half a year. For high-temperature process heat applications, concentrating solar thermal technologies have proven commercially successful. For electrical power generation, these technologies are yet to reach grid parity, that is, the parity with the cost of electricity generated using fossil fuels.

In many places worldwide, electricity production through photovoltaic route has reached grid parity. A photovoltaic cell converts sunlight directly into electricity. Water requirement for cleaning is still a challenge for these technologies. Due to modularity of the photovoltaic technologies, it can be integrated into roofs and facades of buildings and infrastructure objects such as noise barriers, railways, and roads, making it extremely suitable for use in urban and industrial areas. Since 1995, the cumulative installed capacity has increased by about 30 % per year on average. Energy payback period for photovoltaic technologies is

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about 1.5–2 years. Life-cycle greenhouse gas emissions from photovoltaic power plants are about 30–80 g of carbon dioxide-equivalent per kWh of electricity produced. It may be noted that life-cycle greenhouse gas emissions from fossil fuel power plants are 400–1000 g of carbon dioxide-equivalent per kWh of electricity produced.

Another big problem with solar energy is its intermittent, variable, and unpredictable nature. Due to this variability, there is a mismatch between the conversion of solar energy and the energy demand. This mismatch calls for storage of energy and thus the overall cost of the system increases. Although for low-temperature solar thermal technologies, this is not a significant challenge, the mismatch between generation and demand poses a serious technical challenge for solar plants for electrical power generation. Most grid-connected solar power plants without storage run as incidental load plants; the electrical energy generated are evacuated immediately. Without

storage, it cannot completely eliminate the requirement of fossil fuel-based dispatchable power plants. Unpredictability of the solar radiation and hence the power generation also restricts the maximum share it can have. Technological innovations can definitely help us in solving these challenges.

With the Paris Agreement, there is a hope for the next generation. The renewable energy in general and solar energy in particular, will play a significant role in our energy mix. With reduction of other pollutants, there is a hope that the atmosphere will be better for breathing. If these hopes are the front wheels of the bicycle, their technical challenges are the rear wheel. Researchers of the present generation will find solution to chain the two wheels together to take the bicycle forward. Following Sukanta Bhattacharya (1926–1947), a Bengali poet, we should all “*take the solemn pledge of making this world a better place for the to-be born*”.