"Resources, Energy, Environment, Social Infrastructure" Field

Achievement : developing high-efficiency silicon photovoltaic devices

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Predicted Growth of Solar Power

In order to realize our dreams of achieving a decarbonized society, there needs to be a shift towards the use of electrical power generated by renewable sources that do not emit carbon dioxide, a contributing factor to global warming. Renewables include solar, wind, and geothermal power, but in the past, introducing such sources was difficult due to the increased costs when compared to fossil fuel-fired plants and hydroelectric power.

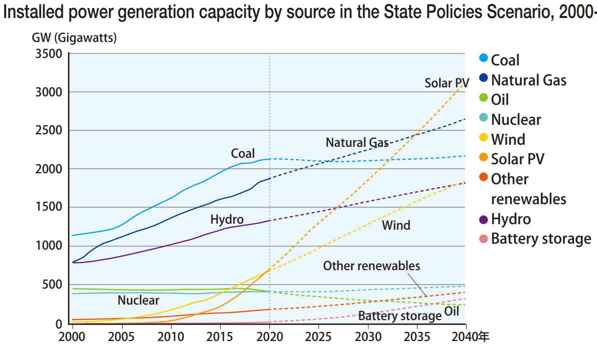
In the mid-2010s, solar power costs dropped below those of fossil fuel power, and thus began the era of solar power plants being able to be built cheaper than fossil fuel plants. Solar power generation is expected to undergo rapid expansion in the future (see below graph). Behind this paradigm shift is the ability of photovoltaic devices (commonly known as solar cells) to convert solar energy to electric power at high rates of efficiency, and the reduction in power generation costs that have allowed for the construction of large-scale solar power plants. Prof. Green has been working on improving conversion efficiency of crystalline silicon photovoltaic devices since the 1970s, and he has achieved many successes over that time.

The mechanisms behind solar photovoltaic devices and solar power generation

There are many types of devices that generate power from sunlight, but crystalline silicon (a type of semiconductor) is said to be found in approximately 95% of photovoltaic devices in use around the world. The majority of those are p-n junction solar cells, which have p-type silicon is placed adjacent to n-type silicon. When struck by photons from the sun, the energy causes the release of a negatively-charged electron and a positively-charged "hole," whereby the electron moves into the n-type silicon and the hole moves into the p-type silicon. That charge then flows out the electrodes (or contacts) as electrical power.

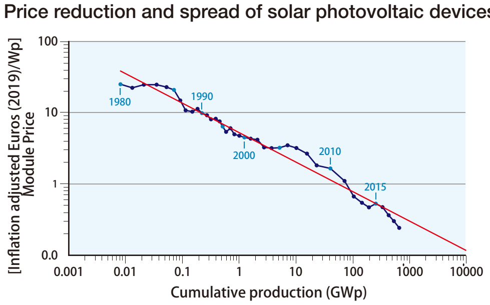
A high power conversion efficiency can be obtained if every electron-hole pair that is generated can be extracted as power, but in practice, energy is lost when the electrons and holes recombine. (see below figure.)

Installed power generation capacity by source in the State Policies Scenario, 2000-2040



Source: IEA World Energy Outlook 2019

Price reduction and spread of solar photovoltaic devices



Up until 2000, improvements in conversion efficiency were a major factor in the reduced cost of solar photovoltaic devices, but in the 2000s, the increased size of power plants also began to contribute to lower prices. Prof. Green has contributed to both, having been involved in both technological development and the cultivation of individuals who are involved in the evolution and expansion of solar power generation. (Source: Photovoltaics Report, Fraunhofer Institute for Solar Energy Systems, ISE with support of PSE Projects GmbH, 16 September 2020)

PERC solar cells and Prof. Green's role in improving solar cell efficiency

The first efficient p-n-junction crystalline silicon solar cell was demonstrated by Daryl. M. Chapin, Calvin S. Fuller, and Gerald L. Pearson at Bell Labs in 1954. From 1972 to 1974, Joseph Lindmayer, James F. Allison, Joseph G. Haynos and colleagues at COMSAT Laboratories improved power conversion efficiency to nearly 17%. However, there were no further improvements in power conversion efficiency for nearly a decade.

In 1975, Prof. Green then provided fresh insight into the processes determining the recombination of electrons and holes excited by sunlight and suggested much higher conversion efficiency of 25% was experimentally feasible. In 1983, he and his team realized a record efficiency of 18%. This was the first in a series of 18 certified efficiency records by his team, achieving 24.7% efficiency in 1999 (reaching his target of 25.0% by recalibration in 2008).

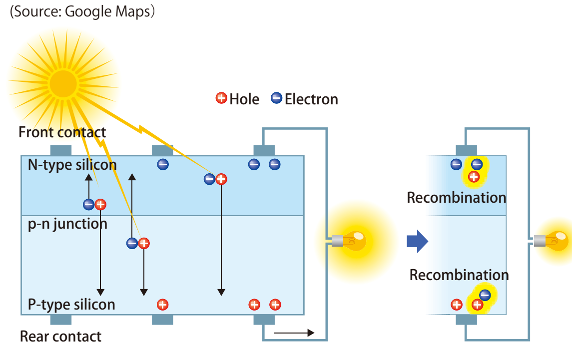
The PERC cell that he invented included measures for not only reducing recombination along the top region of the cell (the "emitter") but also along the rear of the cell as well. This PERC structure now dominates the photovoltaic device market.

Building a more secure society with solar power generation

The decades-old notion, that renewable energy is important for global environmental protection but is too expensive, has completely changed, as the society-wide adoption of photovoltaics has made solar power cheaper than fossil fuel power. This change is encouraging companies to enter the sustainable energy market and is driving a policy push for renewable energy,

Source : Google Earth

Noor Abu Dhabi PV Power Plant, a gigawatt-level solar power plant in Abu Dhabi. This power plant is installed with the p-n junction crystalline silicon PERC cells invented by Prof. Green. PERC devices are considered environmentally friendly because they can generate between 10 and 30 times the amount of energy required to produce the devices, depending on location and technologies used. (Source: Google Maps)

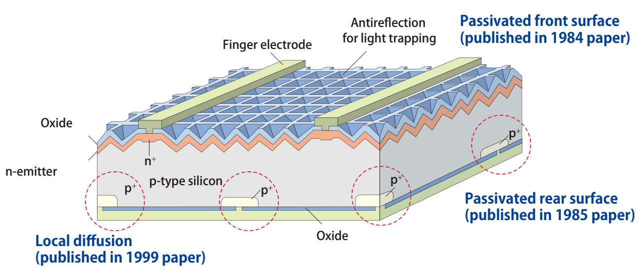


which in turn is accelerating the global movement towards a low-carbon/decarbonized economy. Nowadays, solar cells are recognized as a major solution to the challenges of sustainable energy and global warming, and various types of new solar cells are being actively researched and developed. Against this background, the time has come to recognize the achievements of Prof. Green, who developed a high-efficiency silicon solar cell that has provided an actual solution to global issues, along the way fostering many engineers and entrepreneurs who have transformed the industry.

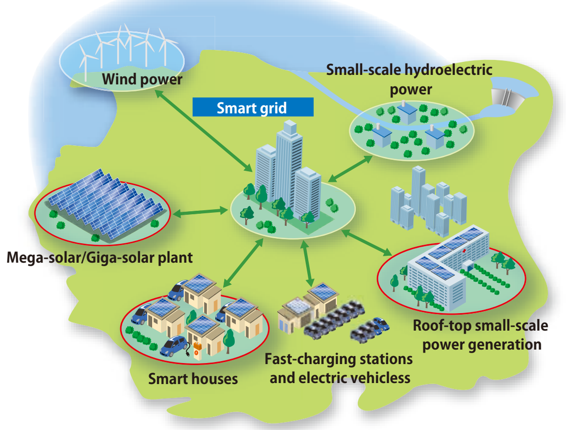
Solar power is a clean energy source not only because it emits no carbon dioxide when producing power, but also because solar power produces more energy than the energy used to manufacture and dispose of solar cells. Moreover, solar power can be flexibly adapted to meet various needs, from large-scale megawatt and gigawatt level power plants to small-scale residential generation using roof-top solar arrays. Distributed electric power generation through small-scale facilities can help reduce the severity and scale of damage caused during natural disasters. When solar power and other renewables become the backbone of our electric power generation infrastructure, we will have attained the ability to produce electricity in a more sustainable way.

History of improvements in power generation efficiency

1954	Bell Labs invents the first efficient crystalline silicon solar cell
1973	COMSAT Labs achieves 17% efficiency, an achievement that remains unbroken for nearly a decade
1975	Prof. Green proposes new concept suggesting potential 1.5 times increase in efficiency using advanced recombination suppression
1983	Prof. Green achieves 18% efficiency, which is achieved through passivation of the silicon-electrode interface and current extraction through the local tunnel junction
1983	Prof. Green invents PERC, which harnesses passivation on front and rear surfaces
1999	Prof. Green achieves 24.7% efficiency
2008	Prof. Green's solar cells certified at 25.0% efficiency



Prof. Green's high efficiency solar photovoltaic device (based on diagram in his 1999 paper) is now the mainstream device in the Si-PV market. The blue text denotes technologies developed by Prof. Green.



Large and small-scale solar power plants can be distributed throughout a region and can be tailored to match the natural and urban environments of the area. Other types of renewable energy power plants can also be constructed, and if the entire system is connected by a smart grid, it can redistribute power as needed and ensure continued power supply in the case of disaster .