A RENEWABLE ENERGY OPTION

PHOTOVOLTAIC SOLAR POWER

THE ENERGY **OF THE SUN**

WHAT IS PHOTOVOLTAIC SOLAR POWER?

PHOTOVOLTAIC SOLAR POWER IS ENERGY FROM SUNLIGHT, COLLECTED AND CONVERTED DIRECTLY INTO ELECTRICITY BY PHOTOVOLTAIC SOLAR PANELS, ALSO CALLED "MODULES."

Cover: Ground-based photovoltaic panels

Opposite: Rooftop photovoltaic panels

The sunlight is converted into electricity in photovoltaic solar cells, using the photovoltaic effect. In a photovoltaic system, the array of cells is arranged in panels that are connected in series, in parallel or by both methods.

There are a wide range of photovoltaic technologies, all at different stages of development. Many other techniques are used to generate solar power too.

CURRENT STATE OF KNOWLEDGE

The photovoltaic industry has made considerable progress in the last decade. Its installed capacity shot from 1,790 MW to 584,000 MW between 2001 and 2019 (IRENA, 2020), an average annual increase of close to 40%. In early 2020, photovoltaic solar power accounted for about 5.75% of the world's renewable electricity output and 23% of the installed capacity for all renewable energies (IEA, 2020). With the substantial growth in photovoltaic and wind power generation in recent years, generating capacity based on renewable energy sources now accounts for 28% of the global electricity mix.

At this time, photovoltaic systems connected to power grids account for over 99% of the global solar power market. Off-grid systems, once the most common type of installation, now make up only 0.7% of the market.

In Québec, centralized photovoltaic solar power generation is in the experimental stage. Hydro-Québec is currently testing two solar generating stations in the Montérégie region with a total output of 9.5 MW (Hydro-Québec, undated). Although not very widespread, decentralized solar power generation does exist in Québec. Hydro-Québec is experimenting with a variety of photovoltaic solar power generating initiatives in both connected and off-grid systems.

PHOTOVOLTAIC SOLAR POTENTIAL

The availability of solar energy varies widely: the amount of sunshine depends on the time of day, weather and season, and it can be difficult to predict. Daily sunshine levels in Canada also vary by region. In Québec, solar energy is unavailable during peak demand periods (mornings and evenings) in the winter. As a result, photovoltaic systems have to be adapted to the wide swing in sunlight levels we experience between the summer and winter, especially in northern Québec.

This intermittent nature of solar energy poses a number of technical constraints for photovoltaic systems connected to Québec's power grid, especially when the generating capacity is significant. Ultimately, these constraints are taken into account when deciding whether to use such systems, in light of the costs involved.

In southern Québec, where most of the population is concentrated, the average annual load factor for photovoltaic systems is around 16% or 17%. That is higher than in Germany and Japan, even though they are the leaders in the global photovoltaic solar power industry.

Ground-based photovoltaic panels

OUTPUT AND COSTS

In 2020, energy conversion efficiency for photovoltaic modules used in electrical microgrids averaged 17%. The efficiency rate for multijunction cells can exceed 45% (NREL, 2020), but their production cost is still too high for large-scale use. Photovoltaic technologies have varying levels of sensitivity to temperature, and, as a result, their efficiency and output for a given level of sunshine (insolation) can vary by up to 30% between summer and winter.

The main obstacle to the growth of photovoltaic solar power remains the upfront costs. Over the last decade, an entire industry has sprung up thanks to generous incentives, especially for the development of systems connected to power grids. In recent years, however, costs have come down considerably.

In Québec, in 2020, the cost of electricity supplied by small photovoltaic systems connected to the power grid is still higher than the cost of wind power or hydropower generated in the province. However, according to certain energy cost projections (Canadian Energy Regulator, 2020), Québec customer-generators would pay the same electricity rates as Hydro-Québec's residential customers for the remainder of the decade.

ADVANTAGES AND DISADVANTAGES

- Reliable system with a long service life (about 30 years).
- Little maintenance required.
- Low operating costs.
- High site potential (buildings, parking lot sun shades, open spaces, etc.).
- No moving parts.
- Scalable design, making it possible to increase installed capacity as required.
- Panels available in different sizes and configurations.
- Output that varies depending on the time of day, weather and season and can be difficult to predict.
- Ground-mounted systems requiring considerable space.

SUSTAINABILITY

The main issues for large ground-mounted photovoltaic systems are the following:

- Visual impact: number of panels, size, color and light reflection.
- No noise.
- Obstacle to rain runoff and partial soil sealing (depending on system foundation).
- Use of large quantities of water for cooling and cleaning, and production of wastewater.
- Increased risks of soil degradation, including erosion.
- Impact on natural habitats and disruption to wildlife.
- Possible conflicts: farmland, access roads, woodlands and built environments (impact on property values).
- Use of toxic materials during manufacturing.
- Zero greenhouse gas and atmospheric contaminant emissions during operation.
- Small environmental impact over the facility's life cycle.
- Social acceptance of solar power projects is reflected in the level of public participation.

A SUSTAINABLE **RESSOURCE**

The Energy of the Sun

Intermittent sunshine

The amount of sunshine varies significantly depending on the time of day, weather and season, a fact that has a direct effect on solar power generation.

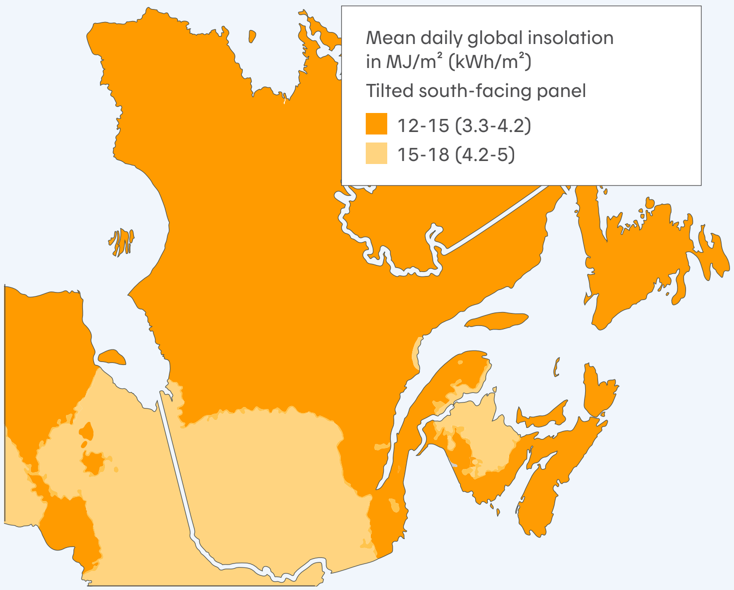
- **Day/night variation is predictable.** On a clear day, the intensity of sunlight drops from a maximum of roughly 1,000 W/m² around noon to virtually 0 W/m² once the sun has set.
- **Cloud cover is fairly unpredictable.** Clouds reduce the amount of sunshine, thus decreasing the amount of power that can be generated. The decrease can last anywhere from a few seconds (on partly cloudy days) to several days (during extended cloudy periods).
- **Seasonal fluctuation is predictable.** Around the world, day-to-day sunlight varies greatly by season. In southern Québec, the mean daily amount of sunlight climbs by 50% from December to June—and even more farther north.

Mean insolation in Québec

Insolation is the solar radiation that reaches the earth's surface, expressed in kilowatthours per square metre (kWh/m²). In other words, it is the total solar radiation (direct, indirect and diffuse) that reaches one square metre of the Earth's surface. It is a measurement of the energy value of a location.

In Québec, mean daily insolation for the most heavily populated regions is 4.2 to 5 kWh/m² (Figure 1). It is greater than in Germany and similar to Japan. Nevertheless, those two countries, along with China and the United States, are the world leaders in PV solar power output.

FIGURE 1. GEOGRAPHIC DISTRIBUTION OF MEAN DAILY INSOLATION* IN QUÉBEC



Source: Natural Resources Canada, 2013.

* Insolation: the amount of incoming direct solar radiation on a unit horizontal surface at a specific level, measured in W/m².

Mean annual insolation in Québec varies between 1,000 kWh/m² and 1,350 kWh/m², which is comparable to Ontario, but less than Tokyo and Southern California (Table 1).

TABLE 1. MEAN ANNUAL INSOLATION OF SELECTED LOCATIONS IN QUÉBEC AND AROUND THE WORLD

LOCATION	MEAN ANNUAL INSOLATION (kWh/m²)
Montréal	1,350
City of Québec	1,300
Sherbrooke	1,300
Sept-Îles	1,250
Fermont	1,100
Inukjuak	1,150
Toronto	1,400
Ottawa	1,350
Southern California	1,800
Tokyo	1,400
Bordeaux	1,350
Berlin	1,050

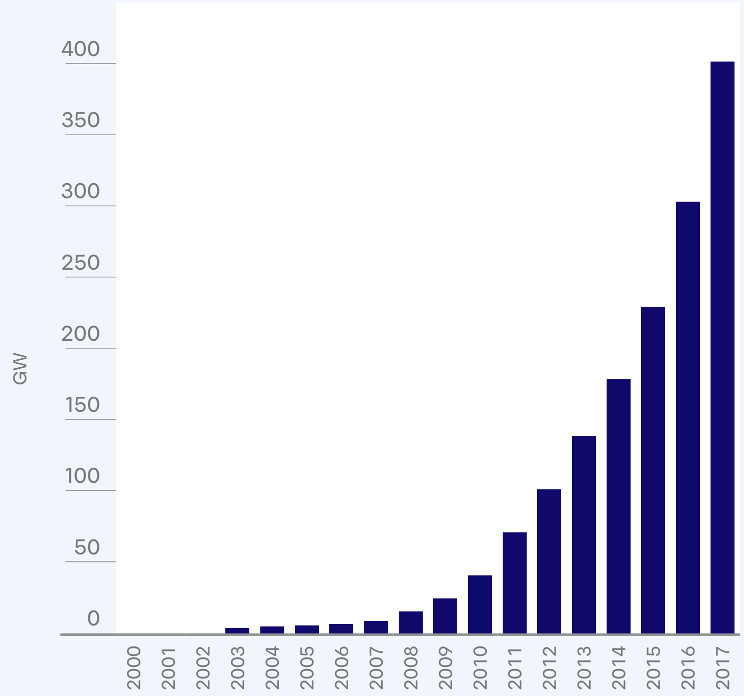
Source: Global Solar Atlas, 2016 (online).

Solar Power Generation

Around the world

Globally, solar power generation has been growing considerably over the past 15 years or so. Although it is difficult to quantify with any certainty, it is estimated that installed capacity rose from 1.8 GW to over 400 GW between 2001 and 2017, an average increase of close to 38% (Figure 2)

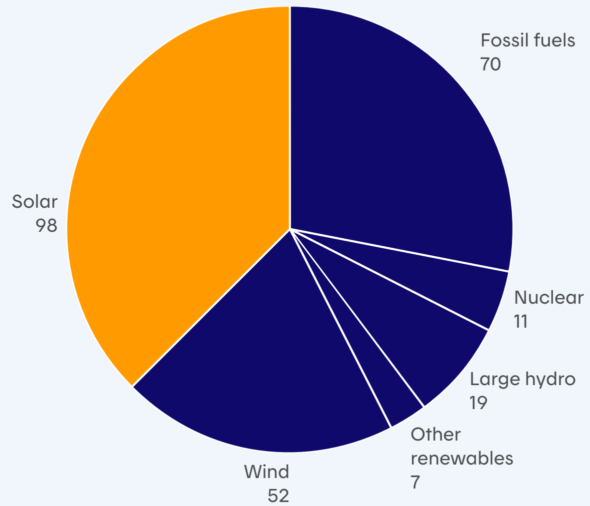
FIGURE 2. EVOLUTION OF TOTAL INSTALLED PV (GW)



Source: International Energy Agency, 2018. *Snapshot of Global Photovoltaic Markets*.

Solar also experienced the greatest growth of all power generation methods in 2017: 98 GW, compared with 52 GW for wind power and 70 GW for power generated using fossil fuels. (See Figure 3.) Solar power alone accounted for 38% of the increase in global installed capacity in 2017. This growth can be explained primarily by the contribution of China, where solar power brought online in 2017 accounted for almost 54% of the world total.

FIGURE 3. NET POWER GENERATING CAPACITY ADDED IN 2017 BY MAIN TECHNOLOGY (GW)



Source: Frankfurt School-UNEP Centre/BNEF. 2018. *Global Trends in Renewable Energy Investment 2018.*

Solar power therefore plays an important role in the development of the power industry. Overall, nearly 500 TWh were generated in 2017 by PV systems installed and commissioned that same year, which represents over 2.1% of the planet's electricity demand. In some countries, the PV contribution to electricity demand was even higher: 10.3% in Honduras, 8.7% in Italy, 7.6% in Greece, 7.0% in Germany and 5.7% in Japan.

According to data on installed solar capacity as at December 31, 2017,[1] China led with 131 GW, trailed by the U.S.A. (51 GW), Japan (49 GW) and Germany (42 GW) (Table 2 on next page). Next, and much farther behind, came Italy (19.7 GW), India (18 GW) and the United Kingdom (13 GW). For all other solar-generating countries, the figure was below 10 GW: 8.0 GW in France, 7.2 GW in Australia, 5.6 GW in Spain and South Korea, and 2.9 GW in Canada, to name but a few. Most Canadian facilities (99%) are concentrated in Ontario, because of policies implemented there in recent years.

1. Actual output data may vary, due to differences in irradiance between countries and the characteristics of the PV power stations considered.

TABLE 2. ANNUAL AND CUMULATIVE INSTALLED PV POWER, DECEMBER 2017

COUNTRY	ANNUAL INSTALLED CAPACITY (GW)	CUMULATIVE INSTALLED CAPACITY (GW)
China	53.00	131.00
India	9.10	18.00
U.S.A.	7.40	51.00
Japan	7.00	49.00
Turkey	2.60	3.40
Germany	1.80	42.00
Australia	1.30	7.20
South Korea	1.20	5.60
Brazil	0.99	1.10
UK	0.95	13.00
France	0.88	8.00
Netherlands	0.85	2.90
Chile	0.67	1.80
Italy	0.41	19.70
Belgium	0.28	3.80
Switzerland	0.26	1.90
Thailand	0.22	2.70
Canada	0.21	2.90
Austria	0.15	1.25
Mexico	0.15	0.54
Sweden	0.09	0.30
Israel	0.06	1.10
Denmark	0.06	0.91
Portugal	0.06	0.58
Malaysia	0.05	0.39
Finland	0.02	0.06
Spain	0.15	5.60
Norway	0.02	0.05
South Africa	0.01	1.80

In Québec

Although not very widespread, decentralized solar power generation (grid-connected individuals and companies) actually does exist in Québec. In June 2018, there were 515 solar customer-generators signed up for Hydro-Québec's net metering option, and that does not include unconnected self-generators (cottages or off-grid systems).

Conventional utility-scale generation (solar farms connected to Hydro-Québec's transmission system) is gradually taking shape. The Québec government's energy policy action plan includes a solar power development project. So Hydro-Québec will be able to propose a diversified portfolio of projects that will vary with evolving needs and take into account the energy context.

Solar Power Generation Method

Photovoltaic solar power

- **Autonomous photovoltaic device** – Used to supply electricity to low-power systems for applications such as optical signaling, battery recharging and satellite powering.
- **Building-integrated systems, whether connected to a power system or not** – Used to provide electricity for buildings. Customer-generators can meet their own power needs and sell any surplus.
- **Grid-connected power stations or farms** – Used to supply the grid by directly injecting power generated by hundreds of PV panels.

Passive solar – The building's orientation and its window placement and size, along with floors made of materials that provide thermal mass, thermal walls and electrochromic windows, are designed to take maximum advantage of incoming solar energy to assist in heating and cooling.

Solar thermal – A heat transfer fluid and glazed, unglazed or vacuum tube collectors or other collector materials convert sunlight into heat. Frequent applications include water heaters and pool heaters.

Concentrating solar power (CSP) stations – A concentrator, or solar collector, uses reflectors in a variety of shapes (flat plates, cylindrical or parabolic dishes) to focus direct radiation onto a receiver surface at the focal point and heat a fluid to a high temperature. Depending on the degree of concentration, focal point temperatures can reach anywhere from 350°C to over 1,000°C. That heat is used to drive a steam turbine and generate electricity. This technology is most often used in desert regions.

Power Stations and Systems

Components

A photovoltaic solar power plant consists of two subsets of components: PV equipment and basic equipment common to other kinds of generating stations (Figure 4 on next page).

These are the main photovoltaic components:

- Solar panels – Consist of dozens of PV cells arranged in glass-covered panels, which convert sunlight into electricity. A solar power plant consists of many interconnected panels that generate the voltage required, depending on the inverters selected.
- Inverters – Convert the direct current (DC) produced by the panels to alternating current (AC) so it can be fed into the grid.
- Mounting structures – Support the panels. With fixed structures, the panels are always at the same angle to the horizon. With pivoting platforms, the angle can be changed, either manually or automatically, using a mechanical system to track the position of the sun (east-west or north-south).

This equipment is found in most generating stations and is needed for solar power generation, as well:

- Low-voltage collector system and switchyard, which includes a control and protection system, metering system and system to transform low voltage to high voltage to be fed into the grid.

Smaller than a solar farm, a decentralized, distributed or home PV system consists of an array of cells arranged in panels that are connected in series, in parallel or by both methods (Figure 5). More precisely, the system consists of the following components:

- One or more PV panels
- An inverter to convert the direct current (DC) produced by the panels to alternating current (AC) so it can be used in the home
- One meter to measure output and another to measure the amount of electricity used from both the public and decentralized systems.

FIGURE 4. DIAGRAM OF PV SOLAR POWER PLANT

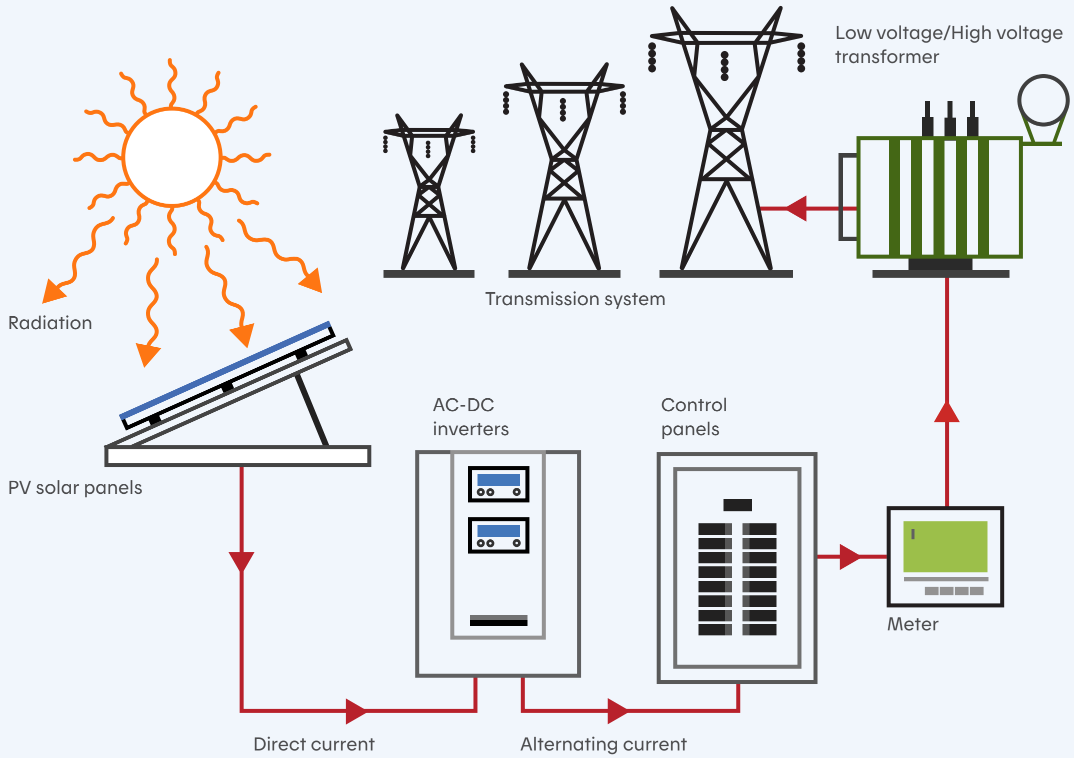
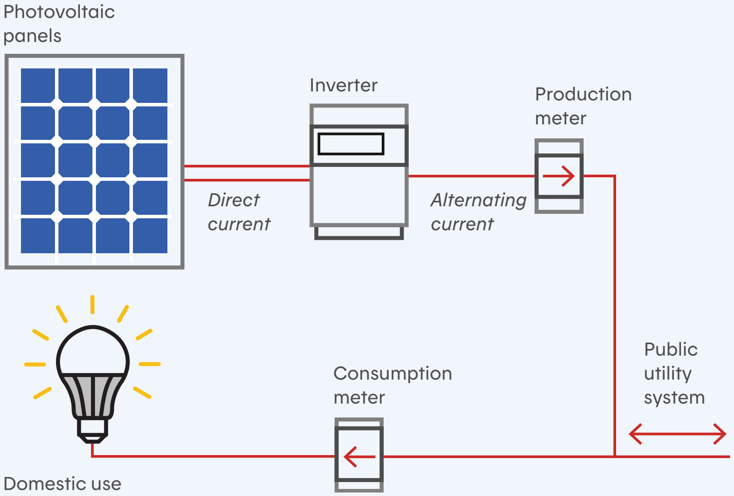


FIGURE 5. DIAGRAM OF DECENTRALIZED PV SYSTEM COMPONENTS



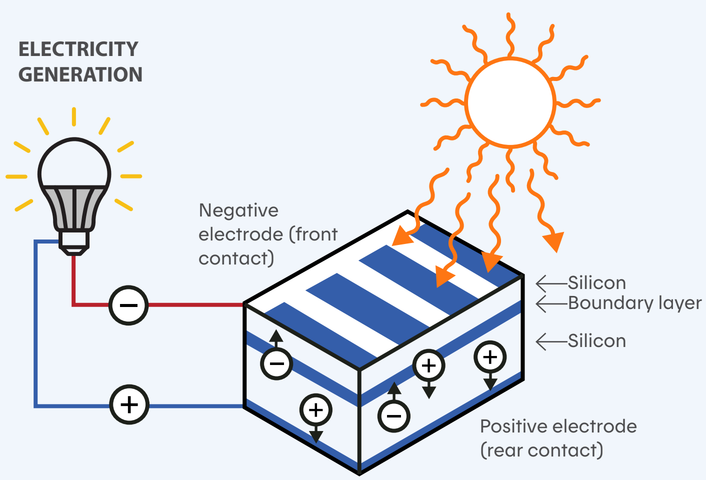
Types of photovoltaic cells

PV cells use the photovoltaic effect to convert sunlight directly into electricity (Figure 6).

There are three types of PV cells:

- **Crystalline silicon** – Thin slices cut from a silicon crystal (in the case of monocrystalline silicon), a block of silicon crystals (polycrystalline silicon) or ribbon silicon. Their manufacture requires a significant amount of energy and raw materials.
- **Thin-film** – Thin layers of a photosensitive material laid on a substrate of glass, stainless steel or plastic. The main materials used are amorphous silicon, cadmium telluride (CdTe), and copper indium diselenide (CIS) or copper indium gallium selenium (CIGS). Their manufacture makes a lesser use of energy and raw materials. Multijunction cells, which are made of several thin layers, are the most efficient.

FIGURE 6. PHOTOVOLTAIC EFFECT



The photovoltaic effect is the direct conversion of photons (sunlight) into electric current by means of a semiconducting material.

- **Organic cells** – Created by depositing a thin layer of an organic semiconductor on a thin plastic substrate, something like light, flexible camera film. There are three types of organic solar cells: those based on organic crystal semiconductors, those based on organic polymer semiconductors, and hybrids. Their manufacture requires very little in the way of energy and raw material.

Almost all cells on the market are either crystalline silicon (first generation) or thin-film (second generation), but crystalline silicon cells dominate thanks to their commercial availability, relatively high efficiency and low cost. Silicon-based cells accounted for about 94% of global PV cell production in 2016 and 93% in 2015. Over the past decade, the mean efficiency of crystalline silicon solar panels has risen by some 12%, to between 17% and 20%. In the lab, they may be up to 24.4% efficient.

At the same time, the supply of thin-film cells has been considerably consolidated in recent years, and it seems to be on the increase. This type of cell offers some advantages in certain operating conditions and is increasingly competitive. For that reason, these cells are likely to continue to play an important role in the range of products offered.

Organic PV cells (third generation) are still in the R&D stage. In 2017, they were estimated to be about 12% efficient.

Hybrid perovskite cells, while still in development, are considered to be highly promising. They are similar to thin-film cells, but are made of methylammonium lead iodides. Efficiencies of about 22% have been achieved in the lab.

Multijunction PV cells are more than 40% efficient, but the manufacturing costs are too high for utility-scale production. They may, however, be used with an **optical concentrator**. An optical concentrator uses a lens or mirrors to focus sunlight on photovoltaic cells placed inside a collector. In this way, the same amount of power is generated with fewer cells.

It is worth noting that all PV cells on the market are more effective in cooler temperatures. So with equal insolation, a PV system may be up to 30% more efficient in winter than in summer.

Grid

Photovoltaic systems may or may not be connected to a power grid.

Grid-connected systems

- Systems connected to a building that uses electricity
- Systems integrated into a structure that is connected to a power grid or another electrical system (e.g., a roof over a public walkway or a sound barrier)
- Systems composed of an array of cells arranged in ground-mounted panels connected in series, in parallel or by both methods. These systems can cover thousands or tens of thousands of square metres. Such generating systems feed power into power grids.

Off-grid systems

- Artificial satellites, portable electronics, small devices like calculators and watches, road signs, highway emergency telephones, parking permit dispensers, telecommunications links, shipping and air traffic beacons and isolated sites (electrification)

Capacity factor and production profile

The capacity factor of a photovoltaic installation is the ratio of its annual electrical energy output to its maximum possible electrical energy output over that period. This factor varies from one region to another, depending on the amount of sunlight. For instance, it is about 15% in Canada and 25% to 30% in the sunniest parts of the United States.

The production profile usually shows a peak in the middle of the day and a monthly increase in summer. In Québec, unlike California, for instance, the solar capacity factor doesn't match the demand profile.

Efficiency

The efficiency of photovoltaic systems depends primarily on insolation (amount of sunlight available on the ground) and the conversion efficiency of the technology being used.

Insolation is affected mainly by the sun's position (distance and inclination) and cloud cover, or cloudiness, which depends on the season. The reflectance of the surrounding surface, or albedo, also affects insolation. The greater the reflectance, the more indirect sunlight is captured by PV panels. For example, snow is one of the most highly reflective surfaces.

A PV system's efficiency also depends on atmospheric conditions, including temperature, humidity, precipitation and pollution levels. So with equal insolation, a PV system is more efficient in a cool environment (low ambient temperature, wind or cooling system) than hot. Accordingly, a 10°C drop in temperature translates into a 3% to 7% increase in energy output.

In given atmospheric and environmental conditions, a facility's performance will therefore depend on the technical specifications of the PV panels and their angle to the ground.

Changing costs

Solar panels

Since 1990, the mean cost of PV panels has been in constant decline, except for a brief period in the early 2000s. The increase in costs observed between 2004 and 2008 is the result of a global shortage of crystalline silicon, which has since been replaced by a type of silicon developed specifically for the industry. Between 2009 and 2017, production of solar panels continued to increase and the price declined steadily.

Between 2010 and 2016, the cost of PV panels dropped by about 80%. In 2016, the mean retail price in China was US$0.43/W, but was among the highest in California, where it rose to US$0.61/W. In 2017, prices fell a little more: good quality panels could be sustainably made for US$0.40/W or less. Together, China and Japan produced about 70% of all the PV panels in the world in 2015 and 2016.

Conventional PV system production

Between 2010 and 2017, based on the mean weighted cost of components, the total cost of installing a utility-scale PV system dropped by 68%, with a 10% decline from 2016 to 2017.

The rapid decrease in costs in China, Japan and the United States is the chief factor making solar technology increasingly competitive. In the period from 2010 to 2017, the total costs of setting up a PV solar farm dropped by over 70% in many countries. The smallest decline in that period was in the United States (52%).

So in 2016, the price for peak power (expressed as kilowatt peak, or kWp) of utility-scale PV systems was about US$660/kWp in Germany, US$1,005/kWp in China and US$1,500/kWp in the United States and Canada.

System prices continued to decrease in 2016 and 2017 thanks to a drop in the price of panels, accessory costs and marginal costs. Prices below US$1,000/kWp for utility-scale PV systems are now common in very competitive RFPs.

Distributed PV systems (residential)

The total costs of installing a home PV system have also dropped dramatically in many countries since 2010. In Germany, Japan and the United States, costs oscillated between US$6,700/kW and US$11,100/kW in 2007. A decade later, they ranged between US$1,050/kW and US$4,550/kW, a 47% to 78% drop. Costs are still the highest in California: in the first quarter of 2017, they were US$4,550/kW, twice as high as in Germany and three times as high as in India.

What about Québec?

In 2018, installing a home PV system cost between C$2,500/kW and C$3,250/kW, or about C$3,000/kW on average.

In December of the same year, the National Energy Board (NEB) published a report on the financial viability of typical solar power projects in Canada entitled *The Economics of Solar Power in Canada*.

The competitiveness of solar power generation in a given province generally depends more on local electricity prices than on the amount of sunlight received there.

In its report, the NEB presented the average return on a residential solar power system based on the cost of electricity in Canadian provinces and territories using three scenarios: today (2018), in the near future (2023) and in a low-cost future (2028). The three scenarios are based on solar installation costs falling over time, and continuing to fall for several years to come. Consequently, the breakeven point—meaning the price at which system owners save enough on electricity to recover their costs—will also continue to fall.

However, residential solar systems are not cost-effective in Québec or Manitoba due primarily to the low price of electricity, even under the low-cost future (2028) scenario.

Nevertheless, the decision to install a residential, commercial or community system is not only motivated by the savings such a project would generate. Other reasons may also come into play, particularly environmental factors. In this case, the system's breakeven point would be lower than the figure indicated in the NEB report, although it may not be a good indicator of the savings achieved by the owner.

Sustainability Issues

The main environmental issues associated with solar power are discussed below.

Greenhouse Gas Emissions

Greenhouse gas emissions and air pollution are associated with the manufacture and installation of solar panels, but PV systems generate no GHG emissions in normal operation. Those attributable to manufacturing depend largely on the source of energy used in the region where the components are manufactured. The same applies to GHG emissions associated with system installation: they vary depending on the equipment used at this stage.

Life Cycle Assessment

In the life cycle approach, the main environmental impacts of photovoltaic solar power are estimated to be slightly greater than for hydroelectricity and other renewable energy sources. System service life, sunlight conditions and the manufacture of panels in countries where most electricity is generated by burning fossil fuels are the most important factors in the life cycle analysis for this power option.

For more information on the subject, please see these reports. (Full reports available in French only.)

- Comparing power generation options and electricity mixes
- Small-scale distributed electric power generation

Ecosystems and Biodiversity

The installation of a ground-mounted photovoltaic solar farm could have various impacts on the natural environment: erosion, small changes to vegetation cover, habitat fragmentation for certain species, etc. In arid regions, the installation of solar panels may necessitate major changes to the landscape, such as clearing vegetation, grading and compacting soil, and building access roads, which increase soil erosion by wind and water.

PV power stations in built-up areas generally have little direct impact on biodiversity. The main risk is to local wildlife, particularly any animals displaced by the erection of a fence on sometimes extensive lands. Large projects should provide for fence openings and wildlife corridors. The benefits of PV projects in arid regions include creating shade for small animals, limiting invasive species populations and reducing disturbances caused by off-road vehicles.

Like any industrial infrastructure, solar power systems and farms may have an impact on birds and insects. Bird deaths due to by photovoltaic infrastructure appear to be very limited, much fewer than those caused by any other type of infrastructure.

In the case of PV panels, birds are killed by flying into structures. For concentrating solar power stations in desert areas, deaths are due to burns caused by exposure to concentrated sunlight. One of the few studies on the subject estimates that the bird mortality rate in California is about 10 deaths per installed megawatt per year, much lower than what has been observed for other types of infrastructure (buildings, thermal generating stations and so on). In that study, bird mortality was within the low range of estimated mortality for utility-scale wind farms.

The idea that aquatic birds could confuse solar panels with bodies of water appears to be unfounded. A study carried out in Germany at a solar farm next to an immense Rhine-Main-Danube canal holding basin was inconclusive in this regard.

Cleaning panels for normal operation of a PV system uses a minimal volume of water, 15 L/MWh. But much more water is needed to wash solar panels in desert regions, where dust can reduce panel efficiency. This type of cleaning is not necessary in Canada. Solar technology uses much less water than thermal power stations (1,140 L/MWh) or nuclear power stations (1,500 L/MWh), both of which require water for cooling. Concentrating solar power plants may use more water than coal- or gas-fired generating stations if they are cooled by water rather than air. This technology is not used in Canada.

Health and Quality of Life

Some compounds used in manufacturing photovoltaic systems, such as cadmium telluride, are a concern due to their toxicity. However, only small quantities are used in the manufacturing process, and they are not released into the atmosphere during system operations. In the United States, cadmium emissions associated with solar power are 150 times lower than those associated with coal-fired generation. Moreover, once PV cells have reached the end of their useful life, the metals can be recycled. However, there are few recovery sites to date.

In nonelectrified areas, the use of solar power improves quality of life. For instance, it can be used to provide lighting or access to information (radio, TV and cellular telephony), which can help improve literacy rates. In addition, the use of solar-powered devices like stoves is beneficial for human health, as opposed to burning wood or oil indoors, which pollutes the air.

Land Use

Although a photovoltaic solar farm occupies a greater area than a wind farm, its visual impact is smaller. Here's why:

- Its horizontal structure is only a few metres high, making it unobtrusive, even for nearby observers.
- Its colors are neutral, ranging from medium blue to dark gray.
- It stays still or moves only a little (if it tracks the sun). There are no moving parts to draw an observer's eye and attention.

The ground area needed for solar panels is about 2 to 3 ha (about 6 acres) per MW (DC) for fixed support structures and about double that for rotating platforms. PV systems generate the most energy per unit of surface area of all renewable sources, including wind energy, hydropower and biomass, making them an efficient use of land.

Interestingly, a photovoltaic solar farm takes up no more space than a coal-fired generating station in the United States. In fact, over the entire lifetime of a coal station (25 years), both generation and transportation take up a great deal of space, mainly because 70% of the coal used in American coal-burning power plants comes from open-pit mines.

A building-integrated PV system may have an impact on the landscape, but less so than a ground-mounted system. Rooftop panels do not require any ground of their own.

In the United States and other countries with limited land, combining solar power with other energy sources (like hydro, wind, biomass, fuel) may be worthwhile. Optimization methods for solar-wind systems are being used in several parts of the world.

As photovoltaic systems can be located on a wide range of sites—vacant lots, brownfields, adjacent to highways, railways or airports, etc.—there may be land-use conflicts between agricultural operators and solar farm operators. But a PV solar farm can be compatible with some agricultural practices, like raising sheep, beekeeping and small-scale vegetable farming.

Since 2015, over 100 floating photovoltaic (FPV) farms have been commissioned around the world, on hydropower reservoirs, industrial basins, aquaculture ponds and other bodies of water. The benefits of FPV include cheaper output per unit of land, higher output (probably thanks to the cooling effect of the water on the panels) and less water evaporation. Japan leads in the number of FPV farms because it has only limited ground space for PV systems. Others countries also stand out: China, with an installed capacity of about 400 MW, Korea and Brazil, which completed its first FPV farm in 2017.

Regional Economy

Photovoltaic solar power projects demand major investments, but can create jobs and local economic spinoffs during construction, operation and dismantling. Leveraging this source of power, which can help secure energy supply, will also spur regional development and strengthen energy security. The extra power sold to customers or local distributors is a new source of revenue, and local benefits are maximized if the owner and installer hail from the host community, if the PV system components are manufactured there and if the system maintenance, which is easy and minimal, is performed by locals. It is worth noting that PV solar power creates twice as many jobs per megawatthour as thermal power does.

Social Acceptability

Generally speaking, solar power is well accepted by host communities. In short, the environmental impacts on the landscape and wildlife, when effectively managed, are limited. However, this source of energy is still little used in Québec. Taking certain steps—such gaining a better understanding of the potential impacts of the various types of PV panels on the market—could contribute to its growth and development.

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February 2021

2020G916A-6