Energy Solutions for Vancouver Island

Environmental Impacts of Solar PV Power

Although Solar Photovoltaic (PV) is considered to be a renewable or clean energy technology, it does have environmental impacts which are comparable to other energy generation technologies. The whole life cycle of an energy generation technology must be examined from the production of materials and manufacturing to operation and decommissioning.

Even though the environmental impacts of solar PV are generally less than that of fossil fuels, it is important to understand these impacts as solar PV technology becomes increasingly widespread. This is a summary of the various environmental impacts that solar PV technology can effect.

Types of Solar Cells

The most common types of solar cell that are in use are monocrystalline silicon, polycrystalline silicon and thin films. These types of solar cells all have different manufacturing processes and therefore have different amount of energy and environmental impacts in their production.

- ***Monocrystalline solar cells*** are the most efficient of the common types of solar cell but also tend to be the most expensive. They are made by creating a single crystal of silicon which sliced into thin wafers. Although silicon is one of the most abundant elements on Earth the manufacturing process for creating pure silicon crystals uses a lot of energy. Cells are cut from a single crystal of silicon. Efficiency ranges between 15%-20% [4].
- ***Polycrystalline solar cells*** are less expensive to manufacture and not as efficient. The manufacturing process is simpler than monocrystalline and there is less waste. Efficiency ranges between 13%-16% [4].
- ***Thin film solar cells*** are among the cheapest types of solar cells but are less efficient. The most common types of thin film cell are cadmium telluride (CdTe), Copper Indium Gallium Diselenide (CIGS) and amorphous silicon (aSi) they are not typically used in residential applications due to the lower efficiencies but are used in solar farms. The manufacturing process for these types of cells uses toxic chemicals and can be harder to recycle. Efficiency ranges between 7-13% [4].

There are other types of solar cells that have higher efficiencies but these make up a small percentage of the market which are used for specialist applications (e.g. satellites) or are still in a pre-commercial stage of research.

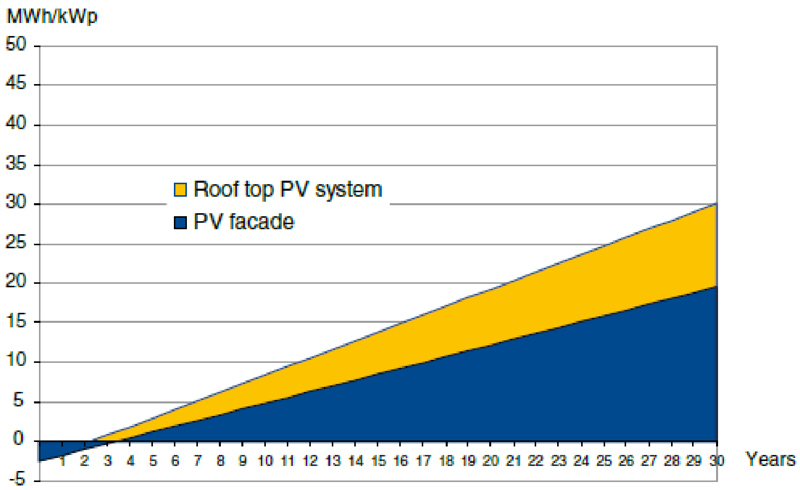
Other components that are also used in a solar PV installation are known the ***Balance of System*** components that allow the modules to be connected to the grid, this includes wiring, switches, inverters, battery system components and also any racking or structures used in the installation. Each of these components also has an environmental impact from its manufacture and must also be considered as part of the solar PV system.

Energy Payback Time

Energy Payback Time is defined as the period of time required for a renewable energy system to generate the same amount of energy that was used to produce the system itself. This is a standard method that can be used with various energy technologies and measures all the inputs and outputs of the system. The Energy Payback Time depends on many factors including:

- Electricity mix used to manufacture PV system components
- PV system lifetime yield (which depends on the irradiation on the PV array and the system performance)
- Performance ratio of the PV system (indicator of overall system losses)
- System application type (off-grid, grid connected, etc.)
- Solar cell type and efficiency
- Other factors including manufacturing process, materials used, etc.

The Energy Payback Time measures the complete system which includes not only the panels but the wires and electronic devices which are required to connect the panels to system whether its grid connected or off grid. In a 2015 review of 232 studies of the three main types of solar cells it was found that the energy payback time ranged between 1 and 4.1 years [5]. Wind energy has one of the lowest energy payback times of less than 1.5 years and hydroelectricity has a payback time of less than 3.6 years. For conventional energy sources like gas and coal power the payback period is between 1 and 3.9 years.



Cumulative net energy production over system lifetime for Vancouver

The above graphic is from a report by International Energy Agency [2] which analysed solar PV system energy payback and energy return in major cities around the world. Here for Vancouver it shows an energy payback time of 2.32 years for rooftop systems and could return up to 12 times the energy used to build the system over a 30 year lifecycle.

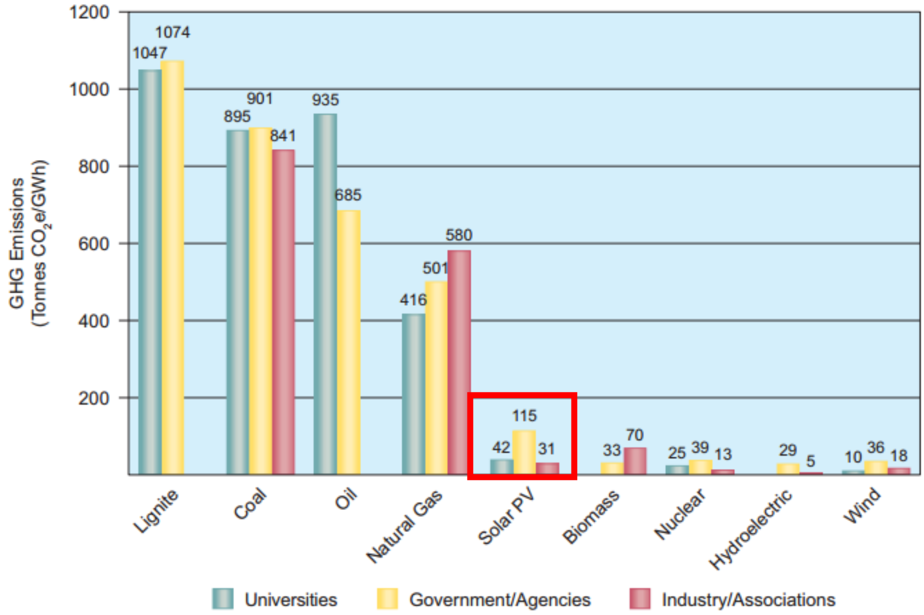
It is important to mention that, while Energy Payback Time itself does not necessarily distinguish renewable energy generation technology from traditional fossil fuel generation technology, the total lifetime Energy Return on Energy Invested of renewable sources is greater than that of conventional sources [9]. Accordingly, renewables are still a better way to generate electricity than using fossil fuels.

Greenhouse Gases Air Pollutants and Emissions

Solar PV does not emit any greenhouse gases (GHGs) or air pollutants during normal operation. However GHGs are attributed to the extraction of materials and the production of the solar cells. The greenhouse gases produced in the manufacture of solar PV therefore depends on the electricity mix of the region that they are produced in.

Emissions are measured as a CO_2 equivalent which is a measure of the global warming potential of various greenhouse gases over a timescale. For example methane has a potential of 21 times that of CO_2 over 100 years so that 1 tonne of methane is equivalent to 21 tonnes of CO2. All greenhouse gases are reported as a CO_2 equivalent.

Solar PV like other renewable energy sources is a low emitter of GHGs across its lifecycle. Below is a chart showing the GHG emissions from various studies across a range of energy sources including fossil fuels, nuclear and renewables [3].



Heavy Metals and Chemicals

Solar PV cells do not produce any toxic chemicals during operation. There are small quantities of chemicals used in the manufacture of the cells, most of which are not seen to pose a great risk [1]. These are discussed more below.

Heavy metals such as lead and cadmium are found in PV cells. If PV cells are not recycled, these chemicals can accumulate in the natural environment via landfills by leaching into ground water and can enter the atmosphere through incinerator emissions. The majority of heavy metal emissions come indirectly from burning of fossil fuels for the generation of electricity to manufacture the cells and for use in the production of raw input materials such as tempered glass or steel used for the balance of system components.

Recycling

As most solar cells have a 20-30 year lifespan it will mean that there will be challenges in waste disposal over the next 25-30 years. The technology is improving to limit the amount of waste that goes to landfill and reduce the amount of toxic chemicals used in production.

A scheme in Europe called PV CYCLE has been developed that collects end of life solar cells and recycles them. They have managed to recycle on average 90% of silicon based PV modules and 95% of CdTe and CIGS thin film modules. In North America there are schemes operated by solar panel manufacturers such as First Solar to recycle modules.

Water Use

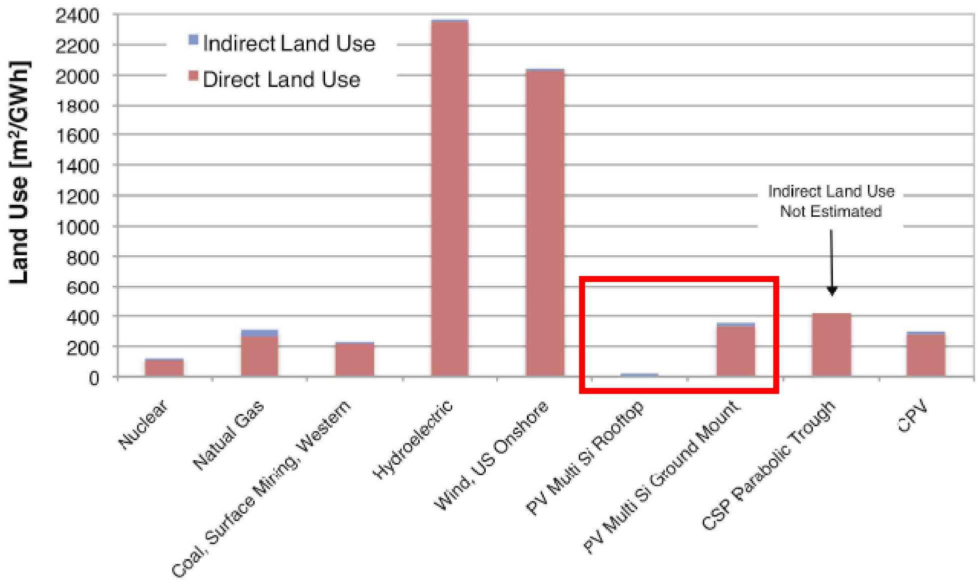
Water use for the production and operation of solar PV is relatively low compared to other energy sources such as fossil fuels, nuclear energy and hydroelectricity. The majority of water use associated with solar PV is related to the manufacturing process. This includes water used in the production of silicon wafers, glass and chemicals as well as water usage attributed to the electricity used in production. There is also a small amount of water attributed to the operation of solar PV modules which is used in the cleaning of the cells to remove dirt and debris.

Water consumed in the production of silicon based wafers is around 200L/MWh and for thin films such as CdTe it is much less at around 0.8L/MWh. Comparing this to water use rates for other process such as coal (1140L/MWh) and nuclear (1500 L/MWh) which are considerably more [6].

Landscape and Ecology

Land use for the generation of energy concerns the land used directly by the installation of equipment and indirectly from the mining of materials used in construction or for fuels.

Rooftop solar has a minimal direct impact as it is installed on land that has already been disturbed by the building on which it is installed. Ground based solar farms however have a larger impact and have comparable land use to that of non-renewable sources. However this land use is passive whereas conventional fuel sources land use is through the extraction of resources in the operational phase.



The above graphic shows how rooftop and ground mounted solar PV compare to other technologies in terms of land use [1].

References

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