Sun Shine on Solar Energy Future

Friday 4 March

Summary :

"Without major changes in how we produce and use energy, we face significant risks to our common energy security and the future of the environment" Nobuo Tanaka, director of the International Energy Agency (IEA) Ministerial Meeting on Clean Energy, Washington, July 19, 2010.

The Energy problem

Fossil fuels are still widely used in the world today and this can cause two main problems: their rarities will create geopolitical tensions in the world and high emissions of CO_2 they generate contribute heavily to global warming. The availability of reserves is a major source of concern. At current rates of consumption, oil will be the first fossil fuel which we should dispense, there would be between forty and sixty years of reserves. Natural gas could, in turn, be exploited for another seventy years.

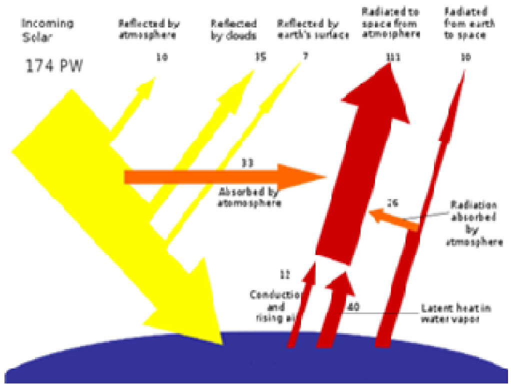
The growth solicits since the beginning of the industrial age an increasing demand for energy. According to the International Energy Agency (IEA), global energy demand could increase by more than 50% by 2030. It is estimated that by 2030 fossil fuels would still represent nearly 80% of our consumption. Fossil energy resources are limited and may not meet the growing needs of the population. However, they are sufficient for their burning triggers a dangerous climate disruption to the planet.

The IEA has estimated that without transition of fossil fuels to clean energy, emissions of carbon dioxide, considered responsible for global warming, will double by 2050.

Sustainability

In establishing the **Brundtland Commission**, in 1983 the United Nations General Assembly recognized that environmental problems were global in nature and determined that it was in the common interest of all nations to establish policies for sustainable development. In this commission sustainable development has been defined as the "development that meets the needs of the present without compromising the ability of future generations to meet their own needs."

Major shift energy is crucial for the sustainability of our planet.This shift included the use of Renewable Energy in our production including solar.



Solar Energy

The solar energy source is even larger than the traditional fossil fuels, in theory it can easily supply the world's energy needs. The radiation incident on earth is more than $1.7*10^{17}$ W and irradiance at surface is about 1.0 kW/m². It means that capturing less than 0.02% of this solar energy would be enough to provide the current energy needs.

Nonetheless converting sunlight in electricity still be a green niche, mostly because of its cost and its low efficiency. The basic cost problem with solar energy are, high capital cost, the need to store or transport energy long distances and the maintenance cost. A photovoltaic system will cost between £5,000 and £8,000 for a 1kW system whereas the electricity cost in UK is about 7p/kWh. The efficiency of photovoltaic system is the other problem. The conversion efficiency of a PV cell is the proportion of sunlight energy that the cell converts to electrical energy. Today's PV devices convert 7%-17% of light energy into electric energy.

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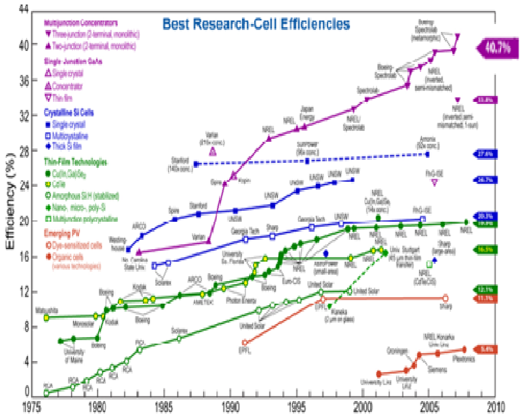
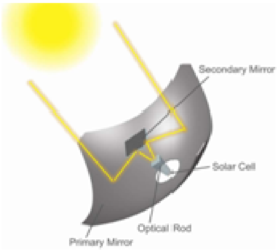
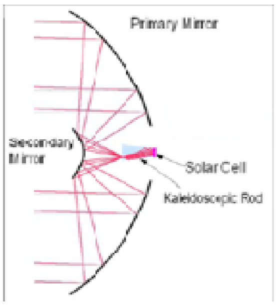
- Sustainability
- Solar Energy
- Concentrator PhotoCPV Advantages
- voltaic technology
- Victor Valley Collage CPV Power Plant
- Energy Output calculation

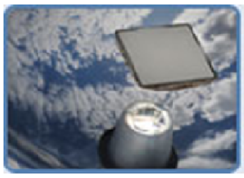
Concentrator Photovoltaic Technology (CPV)

This other solar systems convert also light energy into electricity, in the same way than conventional photovoltaic technology does. But in this system the addition of an optical system that focuses a large area of sunlight onto each photovoltaic cell permit to reduce the energy cost. Moreover the technology of the cell used permit to increase from 17% to more than 40% the efficiency of the photovoltaic cell. Finally, CPV systems have to receive direct-beam radiation to provide the concentrating benefit. So the CPV panels are installed on dual-axis trackers with a precise tracker control.



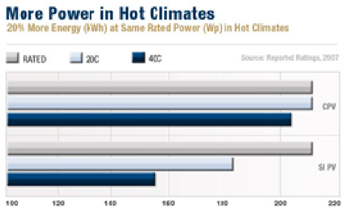


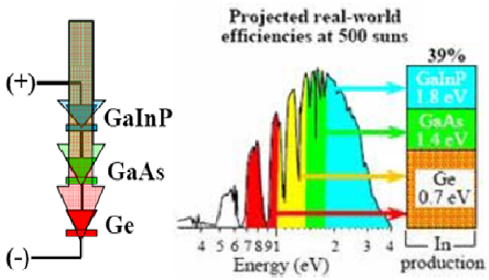


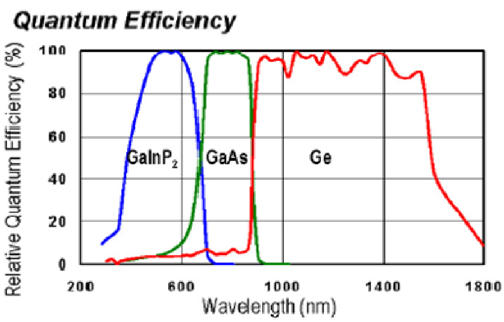


Optical System: An optical system is used to collect the sun's light, and concentrate it at 650 suns onto the PV cells. A primary mirror collect the sunlight and focuses it on a secondary mirror, by Fresnel principle, and then down the optical rod onto the solar cell. One advantage of this technique is that panels are constructed primarily of readily available and cost-effective materials such as aluminum and glass resulting in systems which are over 95-percent recyclable. The optics are in all-glass, so it doesn't need to be wash or it doesn't become yellow or have pit of plastic lenses. The glass components are immune to long-term UV degradation. This characteristic gives a good durability to the system. The optical design confers low losses and permits to increase the efficiency. Moreover this design avoids chromatic aberrations and cell mismatching.

Multi-junction solar cells: The photovoltaic cells used are multi-junctions cells, with an efficiency which approaches 40%. This high efficiency compared with the 17% of traditional silicon PV cells leads to use less solar cell material. In fact the cell size is only 1 cm². This cell has high performance at high temperature, they are less impacted by temperature degradation than silicon PV cells.







The cells are realized with an absorber material in the band gap range of around 1 eV. The cell used have low band gap tandem solar cell with optimized band gaps of 0.66 eV, 1.42 eV and 1.92 eV. It consists of InGaP, InGaAs and Ge connected by tunnel diodes jonctions. The efficiency of these cells is due to wide-band gap tunnel functions, improved hetero-interfaces and other device structure improvements. Those InGaP / GaAs / Ge triple-junction cells have the highest efficiency of photovoltaic device. It is intricate devices, with 20 active semiconductor layers which interact with one other, optically, electrically and via defect diffusion. The disadvantage with those cells is that works only with direct sunlight, so it has to be use with a tracking system.

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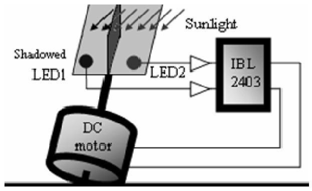
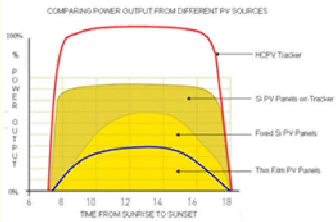
Tracking System: Concentrator photovoltaic cell has to stay in line with the sun. So the panels are integrated in advanced tracking system that continuously aligns the solar array with direct sunlight throughout the day. This tracking system specially developed for those panels provide a highly integrated and performance, with provide tracking accuracy of 0.1 degree. In order to increase safety and reliability this system has a wind and night stow position. Having a good tracking system provide an optimum cost/performance ratio with a minimum of energy consumption in eliminate unnecessary movements and a maximization of output energy produced through an optimal positioning. Moreover the possibility of centralized monitoring of an array of PV panels, with inter-connected operability by CAN protocol communication in a central computation unit makes operating and maintenance easier.



Advantages

The first advantage of concentrator photovoltaic, due to multi-junction cells, is its efficiency. More than 40% for the cells in laboratory leads to a 25% panel efficiency, which is the highest energy yield of photovoltaic systems available today.

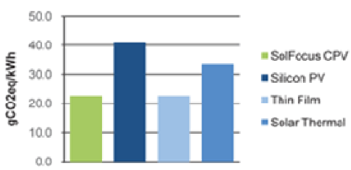


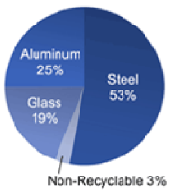
Investment required for a 100 MW/year manufacturing plant

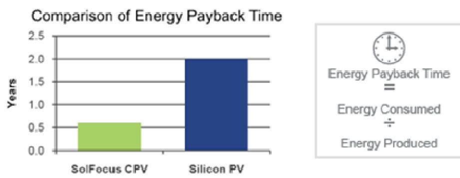
Technology	Cost (US$ million)
Crystalline silicon PV	150-300
Thin-film PV	150-300
Concentrating PV	30-50

The second advantage is its cost, thanks to the optical system and the cells efficiency, the size of the PV cells is 1/1000th of the active, expensive solar cell material compared to traditional photovoltaic panels. An inconvenient of concentrator solar is its cooling required, but it is provided by passive cooling, a reliable low cost technology.

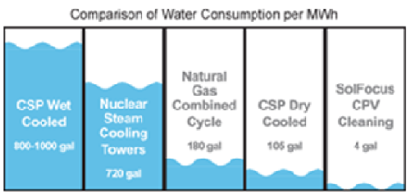
SolFocus CPV solar panels are listed by the California Energy Commision as qualified for California Solar Initiative incentives, thanks to cost-effective materials which result in a 97% recyclable system and a very low carbon footprint in manufacturing and short energy payback period.







SolFocus offers environmental benefits including next-to-no water usage reduce land use in maximizing energy production the lowest greenhouse gas intensity of any solar technology. It's the first CPV product certified to IEC 62108 standards and CEC listed.



The performance and reliability of SolFocus CPV has so much increased that a famous insurer, Munich Re, 40 million clients over more than 30 countries, has proposed a policy of insurance for its panels. According to this SolFocus is the first CPV society who provides an energetic performance guarantee of 25 years to its customers.

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Victor Valley College Concentration Photovoltaic Power Plan

The VVC, Victorville at the northeast of Los Angeles in California, has invested $4.66 million in a 1 MW facility of high concentrator photovoltaic systems. This power plan of 122 Solfocus SF-1100S dual-axis tracking 8.4 kW CPV arrays, i.e. 3416 triple junctions cells panels of 300 W each. Construction of the plant, owned and operated by the collage, took less than three months. This power plan will contribute 30% toward the college's electricity demand in producing 2.69 million kWh/an, redistributed on the regional electrical grid.
The projected cost savings of the $4.66 million project have been estimated at $20 million over the 25 year life, and thanks to the Performance-Based Incentives of California Solar Initiative, which will provide $4 million over the next 5 years, the return on investment period is only 5 years. So this 1 MW CPV system has an installed cost of $4.66/W and will delivered electricity at 8.5 c$/kWh.

PV Inverters | PowerGate Plus 500 kW

The CPV plant will have a capacity of 1024 kWp DC. To convert direct in alternative current two 500kW SatCon inverters will be used, plus a small other one to harvest any paek energy generated. These inverters, with 97.6 % of peak efficiency, will provide 999.4 kWp AC power.

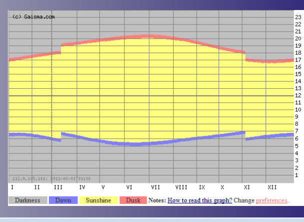
Calculation

Panel characteristics: 122*28 SF-1100 S, Vmp = 51 V, Imp = 5.9 A, Voc = 58 V, Isc = 6.8 A, Standard conditions 850 W/m², 20°C à FF = Vmp*Imp/Voc/Isc = 0.76, Pmp = 300.9 Wp in theory so it should provide Pmptotal = 300.9*122*28 = 1028 kWp. But I used in this calculation is 850 W/m². η = 0.26, Area = 1.362m²
Inverters characteristics: 2 inverters of 500 kW, η = 0.976

Insolation:
I moy = 5.16 kWh/m²/day

Time of sunshine/day:
I moy = 5.16/12.3 =420W/m²

I	7H→17H	10H
II	6H30→17H30	11H
III	6H30→18H30	12H
IV	6H→19H30	13H30
V	5H30→19H30	14H
VI	5H30→20H	14H30
VII	5H30→19H30	14H
VIII	6H→19H30	13H30
IX	6H30→19H	12H30
X	6H30→18H30	12H
XI	6H30→17H	10H30
XII	6H30→16H30	10H
Moyen		12.3H



CPV Optical & Cell Efficiencies

Input Fresnel loss	0.96
Output Fresnel loss (AR coated)	0.99
Primary mirror loss	0.93
Secondary mirror loss	0.94
Tertiary input loss (AR coated)	0.99
Tert. throughput, output mismatch.	0.99
Cell	0.33
Cumulative:	0.26

Victorville, California, United States - Solar energy and surface meteorology

Variable	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
Insolation, kWh/m²/day	2.84	3.64	5.04	6.41	7.48	7.96	7.33	6.31	5.22	4.09	3.05	2.60
Clearness, 0 - 1	0.57	0.57	0.61	0.65	0.68	0.69	0.65	0.61	0.59	0.58	0.57	0.57
Temperature, °C	5.12	7.11	11.16	15.28	20.62	24.86	28.23	27.53	23.33	16.83	9.09	4.80
Wind speed, m/s	5.21	5.20	5.14	5.06	5.23	5.21	4.76	4.35	4.63	4.65	5.15	5.22
Precipitation, mm	32	24	23	18	8	2	5	8	6	6	23	27
Wet days, d	4.6	4.4	5.1	2.9	1.2	0.6	0.7	1.2	1.7	1.7	3.1	3.8

These data were obtained from the NASA Langley Research Center Atmospheric Science Data Center; New et al. 2002
Notes: Help. Change preferences.

Overall system efficiency: η_{total} =0.26*0.976 = 0.254

Peak Power Output: $P_{poutput} = \eta_{total} * P_{input} = \eta_{total} * I_{moy} * Area * Nbr_{panels}$ = 0.254*420*1.362*3416 = 496 kWp

Energy Output over one year: E= $P_{poutput} * Sunshine_{moy} * Nbr_{day}$ = 0.496*12.3*365 = 2 226.2 MWh/year

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