Some Research Challenges in Solar Energy

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Physics as we know it?

Forms of energy: kinetic energy, potential energy, thermal energy, chemical energy, nuclear energy … and so on.

But, the more you think about it, the more pervasive and mysterious ‘energy’ seems!

RADIATED energy

vis-à-vis matter and the four fundamental ‘forces’ of nature.

A fundamental law:
Conservation of energy (or mass-energy).

In the light of this law, what does it really mean to say that a form of energy is ‘renewable’?

Radiated solar energy:
Sun a *black body* at ~ 6000^o K.

Massless quanta of radiated energy: photons.

Earliest form of life: molecules which could ‘tap into’ this virtually limitless source of energy.

Solar energy is the primary life-sustaining form of energy on earth.

Seen in a long term perspective, mankind would have made liberal use of fossil fuels only for about two centuries.

Earth receives more solar energy in an hour than mankind uses in a year. But it is distributed and fluctuates over time. Clear mid-day: ~ 800 watts/m^2.

Uses of energy:

Commerce and industry,
Transport,
Domestic use,
Agriculture, etc.

Most of the time we use energy without being conscious of it.

Solar thermal energy:

Domestic hot water systems
Solar cookers
Process heat
Power generation

Concentrator, collector, heat transfer medium, thermal storage, steam turbine

Key issue: system cost

Bajri na rotla. Can a simple system be provided for under Rupees 2000?

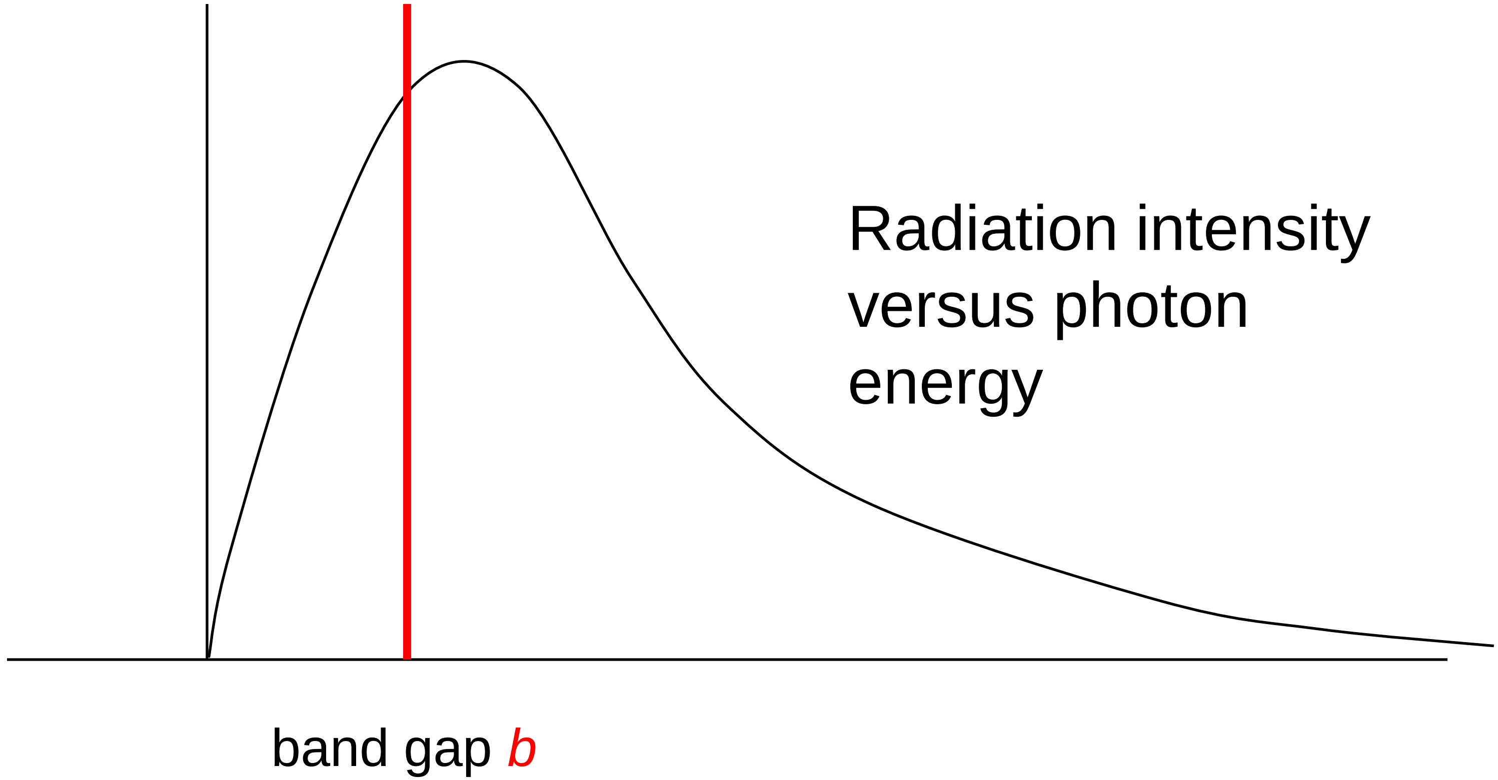
Solar photovoltaic energy

Photons cause electron transitions to higher energy states, generating electric potential.

Must be combined, collected and tapped as voltage & current.

Sample calculation:

Assume that the sun is a black body at temperature 6000 K. Assume PV material with band-gap 1.1 volt (silicon). Photons with less energy do not contribute. Photons with higher energy contribute only 1.1 eV per photon. Under these assumptions, the ideal conversion efficiency is found to be 43.8%.



$$E = \int_0^\infty e f(e)\,de$$

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Effect of radiation on semiconductor

Which material?
How thick?
How many junctions?
How to trap photons?
How to tap electrons and holes at opposite ends?
Sheet or wafer?
How to manufacture it?
What should be the effective load?

[ref] First Solar, the largest manufacturer of CdTe thin film solar cells:

“Pathway is mostly improved light transmission into existing device …
NREL Jsc demonstrates upside of 1.3% absolute …
➔Opportunities for improvements in current:
Reducing thickness of CdS
Proprietary improvements to TCO
Proprietary improvements to glass transmission”

“1,000 Pathways to >16% and beyond:
Contact engineering
Optical engineering
Grain boundary engineering
Band engineering
Dopant engineering”

Balance of system:

With or without tracking?
Concentrate or not?
With concentrator, heat generated.
Concentrators are cheaper than solar cells, but cell efficiency drops with temperature.

What is a good system design?

Energy storage:

Battery?
Hydrogen?

Molten salt?
Cement concrete?

What is a ‘fuel’?

A mix of renewable energy sources is likely to be used in the future – alongside nuclear and hydroelectric.

Physiologically, a human being needs less than 100 watts of energy to live.

Total energy needs of life in Germany today are about 60 times this figure, i.e. annual consumption per person = 52000 kWh. In India, the figure is much smaller.

Annual global energy consumption is about 10^{14} kWh, i.e. about 15000 kWh per person per annum.

In Germany, available land area per person is about 4400 m^2. Average solar energy available is about 115 W/m^2.

Assuming 20% conversion efficiency and half the land area reserved for agriculture: '… areas at and on top of existing buildings are sufficient for covering our present energy requirements by the use of solar cells ...'

Present cost of PV energy works out to about Rs 18/- per kWh.

Sample calculation.

What do we assume for:

Cost of finance?

Rate of depreciation?

Life of system?

System cost ~ Rs 300,000 per kW

Life ~ 25 years

Financing + maintenance cost 12% p.a.

Generation 2000 kWh p.a.

Cost per kWh = 18 Rs

If tax is saved against depreciation, say in the first two years → 12.6 Rs

Assume efficiency goes up from 15% to 20%, and cost comes down by a third.

Result: Electricity cost is reduced by half.

Many families may like having such a system on the roof-top, if the grid supply is not reliable.

Power generation through concentrated solar thermal energy may offer better economies of scale.

Future economy will use a mix of different forms of renewable energy. Even if the average real cost per kWh is higher than it is today, the economy will adapt.

Comments of the automobile industry expert from ARAI.

How to tackle the cycle of high production costs and low volumes?

Thank you.