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Solar Thermophotovoltaics — Getting To 80% Efficiency

October 6th, 2014 by **Anand Upadhyay**

I think we are actually fortunate to have witnessed solar photovoltaic go commercial within our lifetime. With the support of governments around the world and citizens chipping in resources, there is not much doubt that solar is going to be a huge part of our future. But PV as we know it may not last throughout — it has an inherent problem. You see, PV can only convert a small portion of the energy spectrum of sunlight to electricity.

Viking 29 runs using a thermophotovoltaic generator. (Image Source: Onlinefast)

Efficiency of Solar PV

The **Shockley-Queisser limit**, a fundamental to solar energy production, limits the efficiency of an "ideal" solar cell to around 34%. In the real world, the efficiency we get to see in commercial mono-crystalline solar cells is only about 22% at the moment. You might have heard of solar cells achieving more than 40% efficiencies, but those are **multi-junction PV cells**. For now, they are still too costly for "normal" applications — they're mostly just applicable in outer space. In fact, NASA's Mars missions **has employed** multijunction solar cells.

Going beyond Solar PV

Coming back to our earth, PV basically has a problem absorbing all the photons from the sun because they are at different energy levels. Being a semi conductor, PV can only use photons at a certain energy level. If the energy is too low, it will be wasted; if it is too high, the 'higher part' will get wasted.

Hypothetically speaking, what if one could take all the solar photons in a jar, mix it (for homogeneity), and funnel it to the PV? If the right PV panel was selected as per the average photon energy level, one would expect the efficiency to just shoot up! Theoretically speaking, if one could do this, the conversion efficiency could be a mind boggling 80% or even higher! The technology to achieve this is still under development, and it is called Solar Thermophotovoltaics (STPV).

So, What Exactly is Solar Thermophotovoltaics?

To explain in simple terms, STPV has two main elements — an absorber-emitter and a PV cell. The absorber part of the absorber-emitter absorbs solar energy from a concentrated field of reflectors. In doing so, it reaches a high temperature — in the order of 1000-1200°C. The heat collected at this high temperature is used by the emitter to produce photons which are then used by the PV cell to produce electricity.

Current Efficiency of Solar Thermophotovoltaics

The engineering which goes into STPV has a lot to do with selecting the right materials. The absorber should work in the right window of the solar spectrum and the emitter should be paired to emit photons in the region the PV cell can efficiently use.

You can appreciate how difficult the engineering is from the fact that a technology with a theoretical efficiency of 80% has not been able to cross a **threshold of 3.2%** in the real world! But a lot of developments in recent times have been keeping researchers on their toes.

Key Challenges

STPV working at a reasonable level is still somewhere in the future, as a number of important challenges need to be addressed. The materials should allow absorbing solar energy within specific wavelengths and also be able to withstand high temperatures. MIT has **recently reported** on its experience with a new class of materials called metallic dielectric photonic crystals, which exhibit both these properties.

In addition, MIT also reports that these materials can be prepared from any metal capable of withstanding high temperatures, using conventional standard manufacturing process. However, a large part of the problem is still being looked at only at the design table. The team pegs a time period of about five years for commercialization of STPV.

Future of STPV

Thermophotovoltaic systems have few, if any, moving parts, and are therefore very quiet and require low maintenance. These properties make them suitable for remote-site and portable electricity-generating applications. They can, and in fact have been used, even without solar energy (just the thermophotovoltaic part of the devices).

Most interestingly, in the real world, they have been used in a car! **Viking 29** is a two-seat sports car designed and built by the Vehicle Research Institute. It is powered by thermophotovoltaics using CNG. This brings us to the possibility of hybridization of thermophotovoltaic systems. The same "generator" can be powered using fossil fuel or solar energy as the condition might be. But why bother, the future is solar, right?

PS: I did not get into economics or cost because the projected numbers available right now would not be so relevant once the system comes up for commercialization. However, we all know that the most important metric for the market is cost per kWh of electricity produced.

More

Tags: solar thermophotovoltaic, stpv

About the Author

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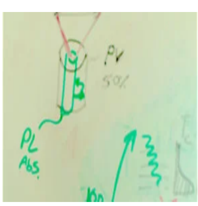

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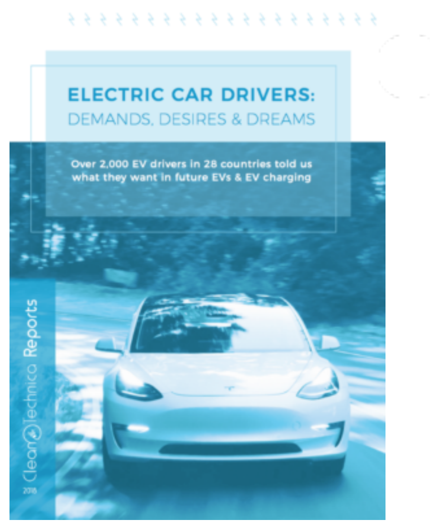

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Marion Meads • 4 years ago

I really thought they have achieved 80% solar radiation to electric energy efficiency. But no, they haven't even crossed 3.2% yet, what a bummer, it may take decades before a series of breakthroughs can happen. Meanwhile, my solar water heater achieves over 95% efficiency in converting solar radiation into heat, a feat that was achieved by many others several decades ago.

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Anand Upadhyay → Marion Meads • 4 years ago

Haha.. full points for sarcasm there. Now I hope you meant that your SWH converts 95% of "captured" solar radiation to heat. Otherwise solar to heat efficiency would not be more than 80% under operating conditions. And that in fact is the challenge here. To get 80% solar to electricity (not just heat). Personally I (would like to) believe that the team at MIT would be able to develop a commercial product within a decade.

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Marion Meads → Anand Upadhyay • 4 years ago

The key word is operating which you meant useful range of operation. You can theoretically convert 95% of intercepted solar radiation into heat energy. Use water that is a lot colder than air to start with, and you will have net black body radiation and sensible heat transfer even without the sun. It doesn't matter if the operating temperature is useful or not, as long as you achieved over 95% conversion efficiency.

All intercepted solar radiation that is not reflected nor reradiated (Stefan-Boltzmanm black body radiation) back will be converted ultimately into heat. Minimize these two factors.

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GCO → Marion Meads • 4 years ago

> my solar water heater achieves over 95% efficiency

Oh really? That's miraculous. And decades ago? Please, enlighten us: what system(s) are you talking about?

Mine has a 2.3 m^2 collector and receives 4.7 kW·h/m^2/day of sunlight on average, or ~4 MW·h/year.
The system's output (OG-300 rating) is 1.85 MW·h/year -- **46%** efficiency.

While I trust that a more elaborate installation could reach 60 or 70%, we're still very far from your crazy-looking claims.

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Gabor Pap • 4 years ago

I am all for technological advances, but efficiency is not the only measure that matters for any technology. Simplicity and the efficiency of the manufacturing process counts a lot too. You can have an 80% efficient converter but if it is so complex to manufacture that it costs 10 times as much as a 16% efficient one than which one do you think will be adopted?
Plants only convert 1% of solar energy, does it mean we stopped growing them because they are so inefficient...

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Anand Upadhyay → Gabor Pap • 4 years ago

Good point Gabor. And as you read, simple or rather I should say, already existing manufacturing techniques can be used for STPV. To add to this

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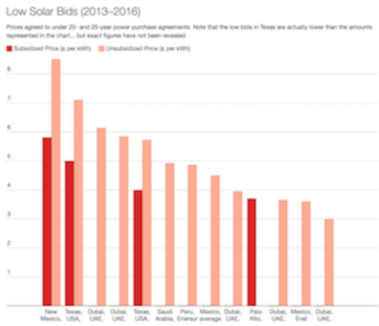

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