**Every now and then, a technology comes along that, at first sight, looks completely crazy, but which, on closer inspection, starts to make quite an awful lot of sense.**

**And that’s kind of how it is with Thermophotovoltaic or TPV technology. Now, to avoid any confusion, I’m NOT talking about the Photovoltaic Thermal or PVT panels we looked at a couple of weeks ago. No, the idea with TPV is to plunge photovoltaic cells into a superheated material at about two thousand four hundred degrees Celsius and instead of simply being instantly vapourised as you might logically think, the cells would actually start producing electricity with an efficiency of at least forty percent.**

**Completely bonkers right?**

**Well, maybe not. In fact, once the details of the overall system are revealed, it really does begin to look like something that could provide very long duration, utility scale energy storage at a fraction of the cost of current lithium-ion battery technology.**

**So, lets dive in and take a look.**

**Hello and welcome to Just Have a Think**

**Thermophotovoltaics, or TPVs, are not a new concept. The basic idea is that they convert predominantly infra-red wavelengths of light coming from a heat source into electricity using essentially the same process found in normal solar PV cells that you put on your roof. The challenge, until recently, has been getting them to a level of efficiency that starts to compete with existing combined cycle gas turbines, which are generally thought to be the most efficient heat engines currently available.**

**The first part of the problem is finding a way to efficiently heat a material to a high enough temperature to produce light at just the right intensity and wavelength. The second hurdle is how to avoid the whole TPV cell vaporisation thing I mentioned earlier. Ironically that means somehow keeping the cells cool while they’re inserted into a white-hot environment. Sounds like a bit of a contradiction in terms, doesn’t it? But that’s exactly what a team from MIT have been working on in recent years, and they’ve just published details of their breakthrough technology in this paper.**

**To get the inside track on how the whole system works in practice, I got in touch with one of the paper’s main authors, Asegun Henry, who is a Mechanical Engineer and Associate Professor at MIT.**

**Professor Henry explained that the big advantage of TPV cells is that they can facilitate very large, utility scale, energy storage at very low cost compared to existing technologies.**

**Here’s how it works.**

**The system uses excess electricity generation from renewable energy sources to power up a very large heating element, which in turn heats tin into a molten state that can then be pumped around a closed loop system.**

**Now, here’s where the MIT folks were able to make their first major breakthrough, before we even get to the TPV technology. You see, if you asked most engineers to pump molten metal around a system at very high temperatures, they’d tell you it was impossible, mainly because there would be no way of effectively sealing the various components in the loop at those sorts of temperatures. So, the MIT team developed a carbon-based sealing solution that overcomes this problem. This video capture shows the laboratory set up pumping molten tin at 1400 degrees Celsius. The team has now demonstrated the ability to pump at temperatures in excess of 2000 degrees Celsius. The methodology was so ground-breaking that it merited an entire scientific paper in its own right, which I’ll link down in the description section below.**

**The super-hot liquid metal travels through a network of pipes into a sealed and insulated warehouse-size building containing massive blocks of graphite. The super-hot pipes radiate heat into the graphite blocks, and the whole building is filled with argon gas, which keeps the environment as inert as possible and prevents the carbon and the tin from oxidising.**

**Once that heat is transferred into the graphite blocks, they stay hot for a very long time indeed, not just as a result of the good quality insulation, although that obviously does play a role, but mainly as a result of the laws of nature which, as Professor Henry explained, dictate that the bigger the blocks are, the smaller the losses will be. That’s because the rate at which heat is able to leak out of the blocks is proportional to their surface area, whereas the amount of energy stored in the blocks is proportional to their volume. A small object has a large ratio of surface area to volume. That’s why the cup of coffee on your desk only takes about an hour to cool down to room temperature. But very large objects have a much smaller surface area to volume ratio. The graphite blocks in this system cover an area the size of half a football field, which means they will literally take months to cool down.**

**So now we’ve got a very large-scale thermal energy storage facility that can be located, for example, on the site of a decommissioned gas peaker plant. Decommissioning expensive, highly inefficient, and massively polluting gas peaker plants is all the rage these days, so there’ll be no shortage of locations where this technology can be utilised.**

**Anyway, I digress. So… here’s where the TPV technology comes in.**

**Whenever there’s a power demand from the grid, the heat from the graphite blocks is transferred to a second warehouse type building, also filled with argon, containing an array of large hollow rectangular carbon-based chambers lined with a tungsten foil. The tungsten foil glows white hot as it heats up, exactly like the filament in an incandescent light bulb. The TPV cells sit inside the chambers, which the MIT team refer to as the ‘power block’, and, depending on how much electricity they’re required to produce at any given time, the cells can be raised up and down inside the block, exposing more or less of their surface to the light. We’ll come back to how that works in a second but, first of all, why don’t the cells just vaporise on contact with 2000 degrees of heat, like we said earlier? Well, if we take a closer look, we can see that the cells are mounted onto four sides of a heat sink, which is essentially a block of metal with channels of water flowing through it. The water is continually drawing heat away from the cells, and as long it flows quickly enough, it’ll always stay liquid and not change phase into steam.**

**That fast-flowing water then circulates through what is effectively a massive version of a car radiator where the heat energy is dissipated, allowing the cooled down water to flow back around the closed loop and back into the heat sink underneath the TPV cells.**

**So, what about those TPV cells then? Well, if we delve inside them, we find that there are two junctions with different band gaps.**

**We’ve looked at the concept of multiple junctions and band gaps in a previous video, which you can jump back to by clicking up there somewhere, so I won’t go into the minute detail of that here, suffice to say that the band gap of a material determines the wavelength of light that can interact with it to knock its electrons out of their position and send them into an electrical circuit.**

**Rather than using silicon as the light capturing material, like you find in most solar PV cells, the MIT team have opted for gallium arsenide, which is the same stuff that NASA and satellite operators use for solar panels in space. It’s a much better quality material, with far fewer defects, which is capable of coping with the high intensity of light produced by the tungsten power blocks.**

**In this case the top junction in the cell has a band gap that captures light in the visible part of the spectrum** **with wavelengths around zero point 8 microns or 800 nanometres. That’s represented by the dark blue section over here on the left-hand side of this graph. The bottom junction has a slightly modified molecular structure which enables it to capture light in the infra-red part of the spectrum, represented by the narrower, lighter blue section of the graph. Right at the base of the cell is a mirror that bounces any remaining light in the infra-red part of the spectrum back through the cell and into the tungsten material, where it’s reabsorbed to help keep the tungsten as hot as possible. The higher the peak on the graph, the greater the power output it represents. So, you can see that the power produced by the cell is derived from the visible and near infrared light, while the majority of the light simply goes through the cell and is reflected back to the tungsten emitter. That means the quality of the mirrored surface plays a big part in the efficiency of the cell. Previous research had already achieved mirror reflectivity of 98.5%. Using that methodology, plus their own technological breakthroughs, the researchers in the MIT team plan to demonstrate an overall cell efficiency close to 50%. They’ve already achieved 40% using a mirror that was only 93 % reflective, and Professor Henry explained that they have a well-defined pathway for reaching the 98% reflectivity target to eek out that extra 10 percent of overall efficiency in the cell. That’ll be getting close to the efficiency achieved by combined cycle turbines.**

**This animation gives you a rough idea of the size of a typical configuration compared to the pick-up truck in the bottom right-hand corner. Each TPV cell module will have about 1 square metre of area and will have a generating capacity of around a hundred kilowatts. So, an array of 30 by 33 modules will give an overall capacity of about 100MW. There’s enough heat in the graphite to keep the cells generating electricity for ten hours, which means a site like this size would provide 1000MWh hours of energy, or 1 GWh, if you prefer. That’s enough for tens of thousands of homes.**

**One very significant additional advantage of setting the system up with this kind of modular configuration is that everything is decoupled. In other words, each component can be modified in isolation from the other parts of the system. So, if a grid operator needed very fast charge times, they could simply increase the size of the electrical heater. If they required more storage capacity, they could just add more graphite blocks. And of course, the same principle applies to the number of TPV cells, allowing discharge capacity and rates to be fully adjustable too. That’s an extremely attractive feature for grid operators who are always looking for maximum flexibility on their systems, especially as more and more intermittent renewable power sources come online over the next couple of decades.**

**And because the electricity is being generated by a PV cell rather than a steam turbine, you get instant response times, just like a lithium-ion battery, which means this system is much better than a gas peaker plant at following the peaks and troughs of the daily demand cycle.**

**Professor Henry and his fellow mechanical engineers on the project have crunched the cost numbers, and unlike some other research projects, they’ve really considered ALL of the variables that would come into play to get to real world commercial production. Once all those elements are factored in, they reached an overall cost of less than $10 per kWh. Compare that to the fully installed cost of a typical utility-scale lithium-ion battery configuration, which can be more than $300 per kilowatt hour, and you start to see the very compelling economic advantage of the TPV system. Plus, you’ve got all that much greater flexibility that I just mentioned.**

**Unsurprisingly then, Professor Henry and his colleagues are quite keen to get cracking on ramping this thing up. A start up business called Thermal Battery Corporation has been created to get the concept from laboratory prototype to full commercial scale. They’re already working with an existing producer of gallium arsenide-based PV cells with a view to manufacturing a 1 MWh pilot system during 2022. Following that, a 50MWh commercial scale demonstrator will come online in 2026, with the first full scale 1GWh system planned for 2028. That should be pretty good timing to slot nicely into place as all those gas peaker plants I mentioned earlier get decommissioned.**

**Now, of course this technology will be entering a very competitive market place, with all sorts of energy storage solutions coming online all the time, many of which we’ve featured on this channel, so Professor Henry and his colleagues have certainly got their work cut out. But commercial partners are already being secured, and discussions are already taking place with electricity grid operators, so there’s a decent chance we could see this innovative energy storage system cropping up all over the world in the next decade or so.**

**As always, if you’ve got news or views on this particular topic, then jump down to the comments section below, and leave you thoughts there.**

**That’s it for this week though. Thanks, as always to our amazing Patreon supporters who keep this channel one hundred percent independent and completely ad free.**

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**As always, thanks very much for watching, have a great week, and remember to Just Have a Think.
See you next week**