**In July 2017, at the US National Governors Association meeting, Elon Musk told more than 30 state governors exactly how much land would be needed to power the entire country with**[**solar energy**](https://www.inverse.com/topic/solar-energy)**.**

**He was speaking a bit hypothetically of course. We all know the world isn’t that simple and the barriers to achieving that goal, even if it were set as a target, would be pretty mind boggling, not least of which would be the storage interconnections to an old and failing grid, and of course the fierce and brutal opposition that any such proposal would face from the fossil fuel industry.**

**But there’s another potential hurdle that isn’t quite so well understood, and that’s the fact that by the very nature of the way existing solar panels are constructed, there’s a physical limit to how much sunlight they can convert into electricity. That limit equates to about 30% efficiency, and in fact the most common solar panels used today actually only achieve a real-world efficiency of about 23 percent, and even that took about 40 years to achieve. The panels dear old Jimmy Carter had installed on the roof of the Whitehouse back in 1979 were barely more than about 14 percent efficient.**

**Unsurprisingly then, there’s huge global competition to discover and develop new and exciting ways to improve solar panel efficiency in an economically viable way. And one of the most promising new materials in development is something called Perovskite.**

**So, what is perovskite, and how will it help?**

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

**I mentioned that it was a new material but actually Perovskite was first discovered in the Ural Mountains in the early nineteenth century by a geologist called Lev Perovski. Perovskite in the wild is a mineral made from calcium, titanium and oxygen arranged in a crystalline cube- and diamond-like structure with titanium atoms at the corners oxygen atoms at the midpoints of the edges and a calcium atom in the centre.**

**Rather than traipsing around the world digging up the naturally occurring mineral though, scientists have developed a whole class of materials call Perovskite Structures. They have the same crystalline cube- and diamond-like shape as naturally occurring Perovskite, but they can be synthesized from a fairly wide variety of commonly available, and relatively cheap, chemicals. The scientists refer to them as ABX3 structures, with A and B acting as cations and X acting as an anion.**

**So, how can Perovskite structures help with solar panel efficiency? Well, let’s start with a quick look at how existing solar panels work.**

**The active part of a solar cell is a wafer made of a semiconductor material, typically silicon. Semi-conductors like silicon don’t normally conduct electricity well, but they can be made more conductive under certain conditions.**

**The cell has three layers. The top silicon layer contains a tiny amount of an element like phosphorous, that has more electrons than silicon, and that gives the top layer an excess of electrons that are free to move, which makes the silicon more electrically conductive. This process of adding a second element to the lattice structure of silicon is what the scientists refer to as doping. The top layer likes to collect electrons, and because electrons have a negative charge, the layer is referred to as the negative type, or N-Type layer.**

**When sunlight hits the solar cell, the very short ultraviolet wave lengths can’t penetrate the surface at all, and the very long infrared wavelengths either bounce off or actually pass right through the cell without interacting with anything.**

**But the wavelengths that contain visible light are absorbed into the middle layer of the cell where a photon of light can knock an electron off an atom of silicon. That produces a free negatively charged electron and a corresponding hole where the electron came from. Scientists refer to this hole as an Effective Positive Charge,**

**Because the top layer likes to collect electrons, the freed-up electrons jump up into that layer. The gap between the layers is called the band gap, and it’s a very important factor in the cell’s efficiency, but we’ll come back to that in a minute.**

**The bottom layer is another silicon lattice, this time doped with a different element, typically boron. Boron has fewer electrons than silicon, and that makes the silicon less conductive. The bottom layer likes to collect the Effective Positive Charge left behind by the missing electrons in the middle layer. So, the bottom layer is referred to as the positive type, or P-Type layer, and the positive charge jumps down here.**

**Stay with me here folks, there’s more..**

**The metal lines you see on solar cells are typically made of extremely thin strips of silver that are printed onto the top N-type layer.**

**The bottom P-Type layer sits on an aluminium plate, unless you live in America, in which case they sit on an aluminum plate,**

**which is, of course, not correct.**

**Nevertheless, if you connect wires to the top and bottom of the cell and run them through a battery or a device like a light then you’ve created an electrical circuit that’ll keep flowing as long as sunlight keeps hitting the panel.**

**The efficiency of a silicon solar cell drops off a lot if there are defects or blemishes in the material. So, the cells have to be subjected to extremely high temperatures to get the defects out. And of course, that’s very energy hungry and expensive. And for reasons that are a bit outside the scope of this video, the photons hitting the electrons in the middle silicon layer need a bit of extra help from things called phonons to provide enough energy to free the electrons and help them jump up to the top conductive layer.**

**Getting randomly hit by a photon AND a phonon is much less likely than just getting hit by one or the other on its own, so to increase the chances of that happening the middle layer has to be made relatively thick, which again adds significantly to the cost of manufacture.**

**Then there’s that band gap I mentioned earlier. The gap is measured in units called electron volts. Back in 1961, two very smart boffins called William Shockley and Hans Joachim Queisser did some clever physics stuff to establish that silicon has a bandgap of 1.1 electron Volts and they calculated that this physically limited the amount of sunlight that a silicon cell could convert to electricity to an absolute maximum of about 32 percent.**

**That’s now known as the Shockley-Queisser Limit and it’s a fundamental function of all photovoltaic cells containing a single P-type layer and a single N-type layer, which is sometimes referred to as a single junction cell.**

**The best modern commercial silicon solar cells are about 24% efficient, with losses coming from a bit of light reflection off the front of the cell and a bit of light blockage from the silver wires on the cell surface.**

**So, perovskites then...?**

**Well, for a start off, unlike silicon solar cells, perovskites don’t need that extra phonon to liberate the electrons from their middle layer, which means they can be manufactured as very thin films using a technique known as solutions processing. Perovskite structures are also much more tolerant to defects than silicon. That eliminates the need for the high cost high energy machinery that silicon cell production requires, and it also means about 20 times less material is needed for each cell, which in turn means a smaller environmental footprint from production.**

**Perovskite cells don’t use rare earths or any supply-limited materials, and they can be made into traditional rigid solar panels or flexible panels for more diverse markets like the leisure industry.**

**And return on investment can be measured in months rather years.**

**One fly in the ointment is that the currently favoured metal for the central part of the ABX3 perovskite lattice is lead, which is of course a heavy toxic metal substance, so obviously not ideal on the face of it. But as this Article from Solar Panel World points out**

**“The amount of lead used is miniscule – on average about 2 milligrams per Watt. For comparison, a common automobile battery contains 20 pounds or 9 million milligrams of lead on average.**

**Largely as a RESULT of the automotive industry, the lead recycling stream is already the largest and most complete of any material in the world. Even at a recycling rate based on 1 terawatt’s worth of panels, Perovskite Solar Cell recycling would still only represent one-tenth of 1 percent of all the lead recycled globally. And alternatives like tin are already being actively developed for use in perovskite structures.**

 **There have been other operational obstacles to overcome though. Scientists have experimented with all sorts of combinations of materials in the crystalline ABX3 perovskite structure to improve stability and minimise degradation from the sunlight itself and from exposure to oxygen and moisture. But again, according to the findings of the Solar Power World report,**

**“both light-induced and environmental degradation parameters have exceeded 1,000-hour accelerated life cycle testing, which is the photovoltaic industry standard for new technologies, with some going as far as 10,000 hours.”**

**Researchers have been developing perovskite structures in laboratories for about a decade now and in that time, they’ve increased cell efficiency from about 2 percent to around 25 percent today which is already better than the best commercially available silicon panels.**

**Ultimately though, Perovskite cells are still constrained by that Shockley Queisser limit, which is determined by the band gap.**

**But yet another advantage that perovskite has over silicon is that perovskite band gaps can be increased or decreased depending on the materials used in the ABX3 structure. That brings in the possibility of creating multi-junction cells with different band gaps in each junction. And that can increase the overall efficiency significantly above the Shockley Queisser limit.**

**In a 2018 interview, Professor Henry Snaith of Oxford University explained it like this.**

 **A very narrow bandgap material would absorb all the light over the solar spectrum, so you’d generate a very high current, but you wouldn’t generate much potential difference across the gap, otherwise known as voltage.**

 **A very wide band gap semiconductor generates a lot of voltage but only absorbs a small fraction of the sunlight. A semi-conductor with a band gap of 3 electron-volts for example, would only absorb the ultraviolet part of the spectrum, but ideally you want to absorb all of the available energy at all wavelengths, from ultra violet to infrared. So, the optimal compromise band gap for a single absorber material is somewhere between 1 and 1 and a half electron volts, and that gives you a maximum of somewhere around 30 to 32 percent efficiency.**

**But if you have multiple absorbers with different band gaps on top of each other you can significantly exceed the Shockley Queisser limit. The simplest way is to put a perovskite cell on top of silicon. Silicon-perovskite tandems have already reached 29.1 percent efficiency, which is much higher than the 23 percent for a single junction perovskite cell and higher even than the all-time world record for crystalline silicon using a very advanced technology, which is 26.7 percent.**

**But Professor Snaith reckons it doesn’t stop at tandem cells. He’s confident that with a triple junction cell they can push towards 40% efficiency. And that could be two perovskites on a silicon cell OR an all perovskite combination.**

**So, perovskite solar cells really do look like they offer the prize of an ultra-adaptable, ultra-thin, flexible, cheap, high performance solar cell, which could accelerate the move away from fossil fuels and perhaps a bit closer to Elon’s 100 square mile analogy.**

**There are already several companies all over the world that are racing to capture this potentially enormous market, including Oxford PV, a spin off from Oxford University, co-founded by Professor Snaith himself.**

**I’ll leave the last word though to the author of the Solar World Power article - Dave Buemi of Prescient Energy Consulting, who reminds us that**

**“To meet 20% of all global energy for the U.N.’s emissions reduction scenario, the solar industry would need to install between 300 and 500 GW annually over the next 30 years. Current global PV module manufacturing at 100 GW per year already presents an enormous supply chain challenge.”**

**“Perovskite solar with its unique simplified manufacturing attributes, raw material, performance and small environmental footprint makes it highly scalable — quickly. Depending on the business model, perovskite modules can be manufactured in facilities that cost 50% less than other solar factories and use less material. The supply chain to support manufacturing is also small, allowing for factories to be sited close to end markets.**

**The Perovskite Solar Cell industry is in a state where its lab developments already exceed prior solar panel commercialization launch points. The challenge is how quickly the simplified manufacturing can scale-up for a given production method to enter high-volume production.**

**Leave your thoughts in the comments section below, but that’s it for this week. Before I go though, I just want to let you know about a podcast that I was invited to take part in recently with climate activist Marc Buckley. Marc is an Advocate for the United Nations Sustainable Development Goals, a member of the World Economic Forum Expert Network, and an award-winning Global Food Reformist. He was also one of the very first people to be trained by Al Gore as part of the Climate Reality Project. The podcast was posted last Tuesday the 4th August 2020 on all social media and also on YouTube. Hopefully all the links should be appearing on screen now, and of course I’ll also leave them as clickable links in the description box below this video. It was a very enjoyable deep dive into climate change, sustainable living and the socio-economic and political challenges we face in our world today, so check it out if you can.**

**A big thank you as well to our supporters over at Patreon who keep the channel going and also keep it fully independent, and a special shout out the folks who’ve joined in the last couple of weeks with pledges of ten dollars or more a month.**

**They are**

**Ho Kai Tong**

**Razvan T**

**Dr. ISO**

**Vinicius Zachary**

**And of course, a big thank you to everyone else who’s joined since last time too.**

**You can also get involved in influencing the direction and content of the channel and chat with other like-minded climate and sustainable energy advocates by visiting**

[**www.patreon.com/justhaveathink**](http://www.patreon.com/justhaveathink)

**and you can support the channel absolutely for free by subscribing and hitting that like button, so we get noticed by YouTube’s search algorithm and get the message to more people each week.**

**Dead easy to do that of course. Just click down there somewhere or on that icon there.**

**And don’t forget to hit the bell icon as well so you get notified of new content.**

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

**See you next week.**