A place in the sun

Challenges and perspectives for the future of solar

Michael Liebreich, Chairman of the advisory board and founder of Bloomberg New Energy Finance, discusses solar energy with ABB Review.

ABB Review: The concept of deriving electricity from sunlight has been around since Becquerel, but only in the last decade or so has it taken a significant and growing share of the overall energy market. Is this just the beginning? What is driving the ongoing changes?

Michael Liebreich: I started New Energy Finance 11 years ago because I was convinced we were on the brink of a clean energy revolution. One of the main reasons for my confidence was that was that I have an almost religious belief in experience curves. The key clean energy technologies – wind, solar, electric vehicle batteries – are all benefitting from steep experience curves, while conventional energy is limited by resource availability and environmental limits.

Another important game changer has been the very low cost of controls and software. Even if you go back 15 or 20 years, trying to manage a solar farm – or even worse, a set of distributed solar panels on rooftops – would have been hugely expensive. You would have been writing customized communication software and renting dedicated phone lines. Now, of course, all that is Internet based and costs next to nothing.

This progress is not going to stop. Solar power is now seeing costs in the 6 to 8 cents/kWh range for good projects, before any subsidies. The cheapest we have seen is 5.84 cents/kWh on a project announced this year in Dubai. Solar electricity has moved from the era of 50 cents/kWh to 30 cents, to 20 cents, to 10 cents and now below even that.

Just to put those prices into perspective, what are the comparable prices for non-renewable sources?

Let us consider, for example, the United States. The price of electricity from natural gas there is low, around 6 cents/kWh; so at 8 cents/kWh, solar is not quite competitive without subsidies. But apply the investment tax credit and solar can come down to 5 cents/kWh. Solar can also help to manage the demand peak because it is almost ideally timed to meet the needs of air conditioning. But of course you still need to meet your nighttime demand, as well as demand when the weather is bad or during the winter.

> Experience curves have been a massive driving force in advancing clean energies.

Although we are talking about solar, it is also worth noting that wind energy is seeing unsubsidized prices in the United States at 4 cents/kWh – so cheaper even than gas-produced electricity.

This poses a real challenge for coal. If you've got a fully depreciated coal-fired power station, and you allow it to chuck out whatever pollutants it wants, then you can produce at prices of 3 or 4 cents/kWh. But as soon as you tighten that up, even if you just get rid of the SO_x and NO_x, coal can be 5 to 8 cents/kWh, and that is before you take into account any climate costs. But then, if you include the costs of asthma caused by coal dust and particulates, the cost of mercury, the cost of damage to roads from coal trucks and so on, coal is completely uncompetitive. It's a very bizarre and unstable situation that one-third of the world's energy comes from coal, and yet the writing is absolutely on the wall for the coal sector. In the developed world we are seeing a surge of coal plant retirements, and in the developing world the build rate is dropping away. By 2030 we think we will be seeing net removal of coal generating capacity, rather than additions.

Will the cost of solar power continue to fall, and if so, what are the implications?

The 6 to 8 cents/kWh of today will continue to fall to even lower levels as the industry expands – we think it will hit 4 cents/kWh between 2030 and 2040, but it could be sooner – until we exponentially approach almost free power at the point of generation.

Of course you then have to get all that cheap, clean power to the user – at the exact time it is needed. On a system level there will have to be major changes when you look at the architecture required to integrate wind and solar power. This includes demand management, interconnections and storage. We are seeing the emergence of a completely different type of electricity system, built around flexibility. Frankly it plays to the strength of ABB to build those systems.

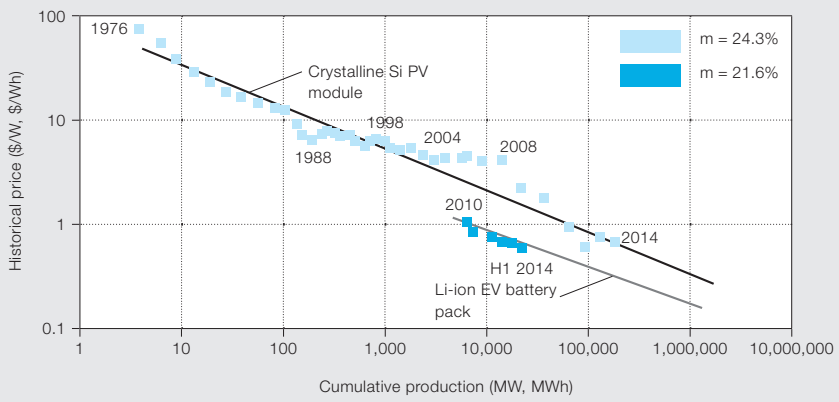
In terms of the total solar power that we can commercially harness, is there an upper limit?

It is very early to talk about hitting a limit as we're still at a very low penetration of solar, less than 1 percent of global electricity. Additionally electricity is only a minority of overall power consumed. There is also transportation and heat, whether in homes, commercial property or industrial processes. Of course electricity as a whole is penetrating these other areas, but it still only accounts for less than one-third of total energy demand. So we are far from any sort of saturation in terms of what the system can absorb.

As the percentage of variable renewable power grows, my working hypothesis is that engineers are incredibly brilliant and there is no fundamental upper limit. If we keep on investing in storage, interconnection between systems and demand management, we can continue adding capacity. For example, everybody is very

The driver for solar investment can no longer be idealism about the environment and the tools to achieve it can no longer be subsidies.

1 Lithium-ion EV battery experience curve compared with solar PV experience curve



Sources: Bloomberg New Energy Finance Note, Maycock, Battery University, MIIT

excited about the concept of storage. They've all discovered that the sun doesn't shine at night and therefore we need batteries. Batteries will go through the same experience curve that solar has seen, but right now they are still costly ➔ 1. So is that bad news for solar?

Well, first of all, there is a lot more electricity demand during the day than during the night. You can match a huge amount of solar power to daytime demand, and in most markets that means building out solar for many more years without having to worry about nighttime. Then, before having to add day-night storage, you can shift demand around, using demand management strategies or even thermal storage. For example, you could chill your freezers and refrigerators during the day when the sun is shining and let them coast through at night.

From the ABB perspective, when looking at cost reductions, there is so much potential that can be unlocked through looking at the whole electricity delivery chain as a system rather than as a collection of individual products. ABB is in the unique position to be able to offer the entire value chain.

Where do you see the major challenges and changes to face solar power in the next decade (both technological and policy)?

The driver can no longer be green idealism and the tools to achieve it can no longer be subsidies. The motivation needs to be improved system performance, in terms of cost, pollution and resilience, and the means have to be more nuanced. The transition to a greater usage of solar electricity has to be acceptable to the pockets of consumers and of industry ➔ 2.

If you look, for example, at the German feed-in tariffs, they sent a very clear signal and were very effective in advancing solar. The problem was that they removed price signals from the electricity market, and thus removed price as a driver of competition for developers and technology providers. What happens in such situations is that people focus on lobbying and winning business through mechanisms other than price competition. And unsurprisingly, that's not an efficient way to do it. Ultimately it costs too much and something has to change. In Spain the reaction to this caused retroactive changes that stopped the market dead in its tracks. Even Germany is shifting to reverse auctions after it became clear high power costs were affecting Germany's competitiveness. Everybody is still very committed to Energiewende (Energy Transition), but the initial feed-in structures are being replaced by something more economically efficient. In the United Kingdom we are introducing a contract for difference (CFD) system requiring reverse auctions – which has already proven to bring the price down.

So government subsidy and support is good at the start-up stage, but should be reduced later?

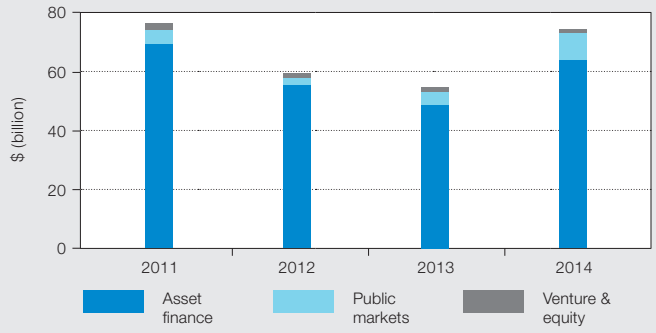
Absolutely. When solar is less than one percent of the electricity market – and I hate to say this – but if you share that extra cost over the rest of the electricity market, then it doesn't hurt much and it doesn't matter. But if solar advances to 3, 5 or even 12 percent, which is easily achievable in sunny countries, then you can no longer afford that level of waste.

As for industry, even if you are in a market with excessive subsidy levels, it's always better to be a low-cost provider: It is the only way you can really control your destiny and not be at the mercy of policy changes.

If governments should not subsidize, what role should they be playing?

Their primary role should be concerned with energy security – making sure that the system doesn't fall over – whether that's because of technical instability or because of geopolitics. After that governments must support where necessary but not beyond. They shouldn't try to force the incumbent energy providers to lead the transition to clean energy (but should let them do it if they want to). They should open up the market to new players and new business models. If you look at Germany, where solar has progressed most rapidly, the big utilities own 80 or 90 percent of gas, coal and nuclear, but only 5 to 10 percent of renewable energy. Why? Because incumbents didn't have the incentive to go in and do it. You see the same in California. The utilities are responding and trying to catch up, but they are only doing it because there is a competitive threat from new players. So governments need to ensure new players have access to the market. An example is the capacity market. If you put into place a capacity mar-

2 Investment in solar power



Source: Bloomberg New Energy Finance

Solar is better and cheaper than kerosene and can charge your phone as well as giving you light.

ket, you need to ensure you are not keeping out new players or solutions, which is very hard.

Are the main challenges facing the solar industry largely universal, or are there significant differences between countries and continents?

Solar is moving beyond its traditional core markets such as Germany, Japan and the United States and into places such as Chile, South Africa, North Africa and Thailand. Solar is now really happening all around the world. As prices are coming down, we are seeing a lot of places – especially in developing countries – that traditionally have high prices for electricity and low supply reliability. Solar is suddenly becoming very attractive and competitive in such markets. This is where the energy access piece comes in. You can easily install solar in locations that were previously off-grid. Solar is better and cheaper than kerosene and can charge your phone as well as giving you light. Solar is an enabler of rural development, especially in countries that were traditionally forced to import fossil fuels using expensive foreign currencies ➔ 3.

What are the main remaining barriers to the further spread of solar energy?

One of these is electricity subsidies. In places like India you are looking at artificially depressed electricity prices of 3, 4 or 5 cents. At that level, you can't recover the costs of building capacity. Another barrier is regulatory, protecting incumbent energy providers and their business models. A third barrier is about the physical limitations on the grid. Are we going to produce too much electricity when it's sunny and not enough when it isn't?

Where do you see the future of solar PV? In distributed rooftop installations, or in large ground-mounted PV power plants?

The answer is both. I don't think we need to prioritize one over the other.

Governments must support where necessary but not beyond.

We will get to the point that we will have a very high penetration of rooftop installations at grid parity. But will that cover all electricity demand? No. The area of solar rooftops is too small to meet all power demand. There will always be a wholesale market for electricity.

With rooftop generation growing nevertheless, we sometimes hear such terms as grid defection – meaning people will seek to become autonomous in terms of energy and remove their grid connection. Is grid defection a threat to utilities?

I'm not a big believer in grid defection. It will happen in some very niche situations such as very remote locations in the Australian Outback or libertarians who want to live by themselves. There are a number of reasons why most users will want to stay connected to the grid.

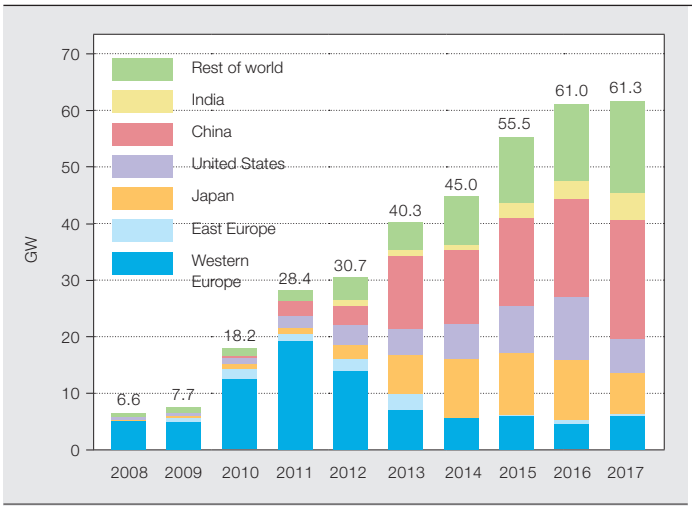
The first is, I have solar panels on my own roof, but when I put the dishwasher and kettle on at the same time, I've got to source that power from somewhere. Retaining the connection to the grid enables me to meet those peaks – as well as those days when there is no sun – more cheaply than investing in huge amounts of storage.

Second, if I have correctly sized the installation to meet my needs during the most demanding time of year, I'm going to be generating a big surplus during the rest of the year. Why not sell it? But for that I still need a wire. Third, what happens if my system fails? The grid can provide backup.

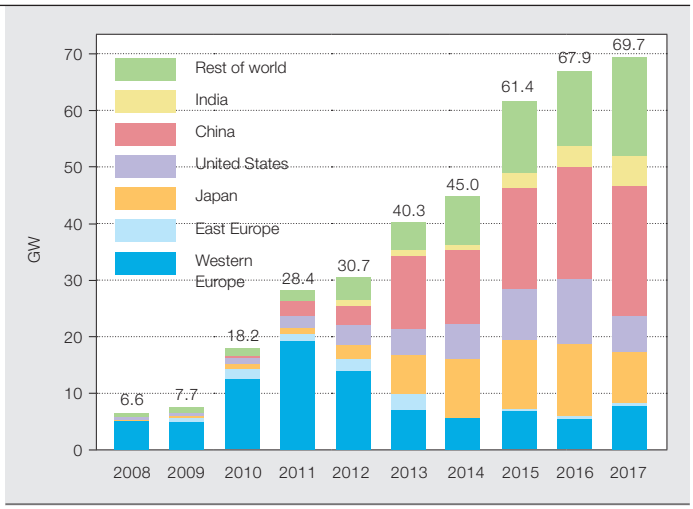
Finally, if you go off grid, your system needs to be a completely self-managed mini-grid, and that's not easy. I want my utility to help me manage it, to tell me when I need to clean my solar panels or maintain my fuel cell, and so on. So even for a well-designed system there are many services ranging from maintenance to supply security that a utility can provide. The utility can charge clients for these services, but not for bulk electricity.

So what we are going to see is load defection, meaning the user buys less power from the utility, both because of energy efficiency and because he or she self-generates power. Utilities will change their business model from charging for electricity to charging for services. If they

3 PV new build per annum



3a PV new build by year, historical and forecast to 2017 (conservative)



3b PV new build by year, historical and forecast to 2017 (optimistic)

Source: Bloomberg New Energy Finance
Note: A conservative and optimistic forecast has been developed for each country. It is unlikely that all countries will come in at the conservative or optimistic end, so for the global forecast, conservative is the sum of conservative country forecasts + 25% of the sum of optimistic-conservative forecasts. Global optimistic forecast is the sum of conservative country forecasts + 75% of the sum of optimistic-conservative forecasts.

don't do this, then yes, you'll see grid defection.

Looking beyond the scope of solar for a moment and considering other renewable energies, be they wind, hydro, biomass, geothermal or even some of the more experimental forms such as wave and tidal power, do you see these as competitors or partners of solar?

They are very much partners. We need to recognize the value of electricity in terms of when it can be delivered. Solar is fairly readily available during the day, but leaves an important supply gap in the evening, meaning you've got to look at what demand it can best meet. Hydro is dispatchable. You might even be able to use pumped storage, but even if you can't, you can collect water in a reservoir during the day and use it during the night, or during a few weeks when there's a wind lull.

Geothermal power is very interesting where you can do it. Biogas is working quite well. Tidal power is very predictable, though expensive. Wave power is at a much earlier stage of its development. I'm skeptical about the ability to drive costs down to levels anywhere close to what we see with solar and wind. You have to put an enormous amount of concrete and steel into the sea for a relatively modest power yield.

Where do you see the main strengths of ABB in serving and advancing solar energy?

It is all about ABB's extraordinary strength in engineering. So first of all we are talking about leading-edge components, ranging from photovoltaic inverters and low-voltage products to high-voltage direct current (HVDC) and communication equipment. ABB has huge technological competence at the product level.

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Secondly, I see ABB's competence at the system level. Whether you're talking about load balancing, designing a minigrid or providing other system-level services, there are relatively few players out there who are really able to deliver that. For example, startups might be very good at providing one component but will find it very difficult to provide a higher level of knowledge, reassurance and distributed services across a city, grid or multiple grids.

The third element lies in the company's reputation. One of the challenges is that the mainstream – be it the business reader of the Financial Times or the energy ministries of medium-sized countries – is not, on the whole, up-to-date about the technology and its costs. There is a knowledge lag. ABB has an exceptional role to play in reassuring policy makers and decision makers that clean energy is no longer about high-risk pioneering technology, but about robust, resilient, proven solutions.

Which is exactly what ABB Review is about and why we are producing this issue dedicated to solar.

To move on to a less mainstream topic, ABB is supporting Solar Impulse 2, a solar-powered plane attempting to fly around the world. Obviously aviation is not one of the primary fields of application of solar energy, but do you think we will ever see a commercial solar-powered flight?

Obviously solar planes are not going to be a major target market for solar technology any time soon. Solar Impulse is really an exercise in pushing the boundaries of technology and also the boundaries of human thinking by saying to people, "Look, this is possible." And it is doing a great job.

Can it ever work as a commercial offering? Solar Impulse 2 is very slow. It is taking something like 15 hours to fly across

> Every generation had to win its energy supply and we had a period where we almost forgot that.

the Gulf of Arabia, 6 days to cross the Pacific. But who knows? Maybe commercial freight flights, possibly configured as a drone or a blimp could take the entire fuel costs out of the shipping equation.

Probably a better way to use solar to power flights would be to use it to create synthetic fuel, either through direct catalysis or from solar-powered electricity. But who knows? Had you looked at telecom companies in 1975, you would never have forecast Facebook, Skype and so on. So I'll rule nothing out.

Another form of transportation in which solar has a more direct part to play is electric vehicles.

I'm very bullish about electric vehicles. As I said earlier, I am a strong believer in the experience curve. Electric-vehicle batteries are seeing the same sort of cost curve as photovoltaics. But having said that, I don't think we're going to be seeing equally rapid penetration in all segments and countries where we now see combustion vehicles. The batteries are a major cost factor and this favors adoption in the sectors seeing the highest annual mileage, but range is an issue. So someone with a long daily commute is going to be a more attractive target than someone using their car either occasionally or for long random journeys to places where you don't know if you can get your battery charged.

Let us conclude this interview with something more philosophical: One interesting consequence of solar power is that normal people are choosing to add PV panels to their own houses and offices. Electricity generation is no longer something that happens in remote locations, of which we as consumers have only a vague awareness, but has become something tangible. Do you think this is changing the way we think about and value energy?

Absolutely. We easily take energy for granted, but actually it has to be won, has to be converted, has to be delivered. Each generation has to secure its energy supply. It looks like as if are coming out of a period in which we could almost forget that fact; everything was so easy.

The new technologies are making us look afresh at how we win our energy, look afresh at our rooftops, our garbage, our insulation and so on. Energy is moving out of our deserts and ports, and into our homes and our communities. I met a chap in India who was selling solar energy to local stalls in a village market. Stallholders could for a few Rupees get an LED lightbulb and a wire back to this chap's battery, which he was recharging every day with his solar panels. The stallholders were happy and the guy had created a good business. It was a fantastic service provision and a fantastic innovation. But actually all he had done was reinvent the electric utility.

It is also accelerating because the new technologies are building on each other. This Indian entrepreneur could only create his business because of the interaction of LED and solar. If he had tried to do it with a filament lightbulb, the solar panel would have been so huge that he wouldn't have fit on his roof. The revolution of solar technology is going to drive the emergence of super-efficient appliances and vice versa. The Clean Energy Ministerial launched the Global Lighting and Energy Access Partnership prize (Global LEAP) for highly efficient appliances, and one of the first winners was a television set that runs on just 6 W. That's less than a lightbulb.

Marshall McLuhan, the philosopher who coined the phrase "the medium is the message," also said "the 'message' of any medium or technology is the change of scale or pace or pattern that it introduces into human affairs." Well, it looks like solar power and these other new technologies carry an incredibly important message for us all.

Thank you for this interview and sharing your enthusiasm with us.

This interview was conducted for ABB Review by Erika Velazquez, Alex Levran and Andreas Moglestue. For inquiries please contact erika.velazquez@ch.abb.com

Michael Liebreich

Michael Liebreich is chairman of the advisory board and founder of Bloomberg New Energy Finance, the world's leading provider of information on clean energy to investors, energy companies and governments. He leads a team of about 200 around the world, just under half of them in London, comprising journalists, researchers, analysts and sales and marketing departments. Michael founded the company as New Energy Finance in 2004, selling it to Bloomberg in 2009.

Michael is a frequent commentator in the press, on TV and on radio on issues of energy, development and economics. He serves on the UN Secretary General's High-Level Group on Sustainable Energy for All and formerly on the World Economic Forum's Global Agenda Council for the New Energy Architecture. He is a Visiting Professor at Imperial College London, Board Member of Transport for London and Chairman of a Medical Charity funding research on colorectal illness.

Michael earned his MA in engineering from Cambridge University, winning the Riccardo Prize for Thermodynamics, and an MBA from Harvard Graduate School of Business, where he was a Harkness Fellow and Baker Scholar.

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