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The Investment Engineers

Solar energy: do we have a lift-off?

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Executive summary

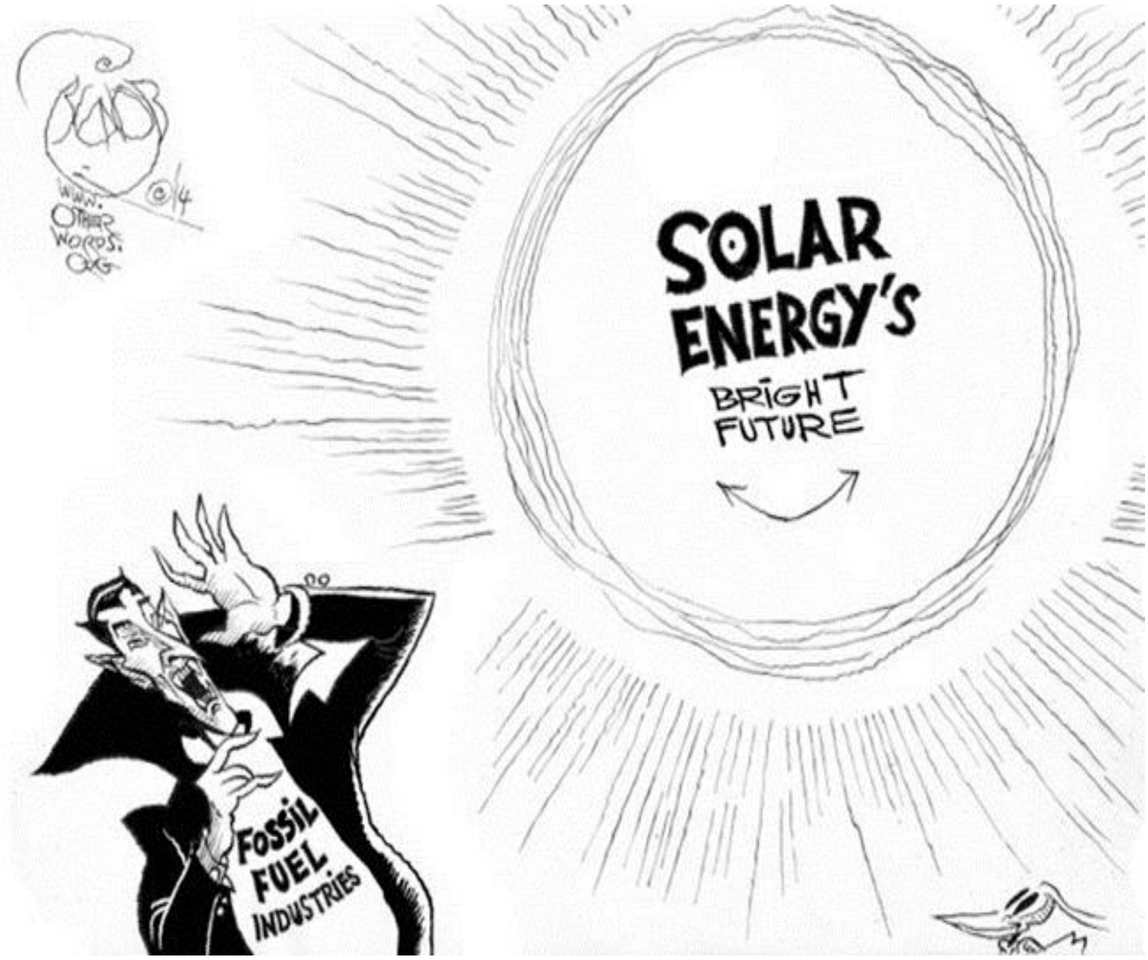
In this report we will explain why and how renewable energy will play a much bigger role in supplying our future energy.

Less than 5% of our energy is produced by sun and wind. But this is changing rapidly, as we have left the first phase of renewable subsidies and goodwill behind us. We have already reached the next phase where plain economics take over, as in windy or sunny areas it is already cheaper to produce unsubsidized solar or wind energy than burning coal or gas. Due to the rapidly declining costs of solar panels, this will become the case almost everywhere within the next decade.

Solar energy is truly abundant and only a limited amount of the surface of the earth is required to fully supply our world with solar energy. Both solar and wind energy have almost zero marginal costs and this changes the game for power production. The German grid, for instance, has a hard time handling zero marginal costs as shown by all those sunny days where German electricity had negative wholesale prices. Negative pricing makes cheap energy storage the holy grail of renewable energy. The grail will soon be found in the combination of much cheaper batteries and new stationary storage technologies.

These cheaper and better batteries will also lead to the breakthrough of electric vehicles (EVs). Next to cheaper driving, EVs might as well become the ultimate storage for the cheap solar and wind energy we are going to harvest in the next decade.

Cheap solar energy combined with cheap batteries could cause a lot of damage among companies in the energy sector, utilities and car manufacturers. Spotting future winners is much harder in such a highly deflationary environment. The most obvious winners are of course mankind and our planet Earth.


SOLAR ENERGY'S
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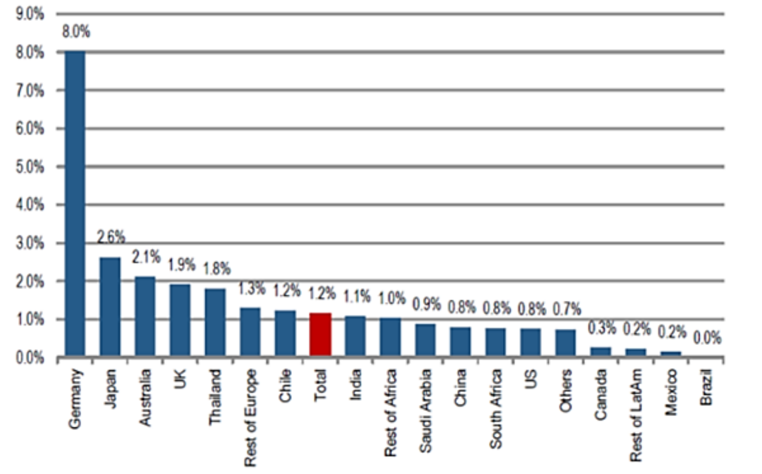
Limited current use

Solar energy has not been playing an important role in the global energy mix so far.

2014 was the first year in which solar energy reached 1% of the global energy mix. The vast majority of the current energy mix consists of fossil fuels with oil, coal and gas making up for roughly 86% of global energy consumption. Gas and coal are mostly used for electricity generation, while oil is mostly used as fuel for transportation and as feedstock for all sorts of chemical and industrial products like plastics.

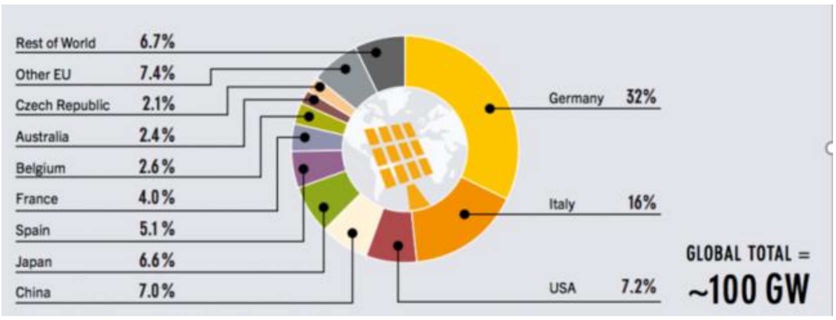
Figure 1 | Solar penetration per country in 2014



Source: Credit Suisse research

Germany in the lead | There are major differences in the energy mix for the various countries across the globe. As an example, the use of hydro-energy depends on the availability of mountains and rivers. Germany has historically been one of the first countries to embrace solar energy through a large subsidies-based scheme that started already in the 1990s. Of all the solar installed capacity 32% was on German grounds in 2012. On average, 8% of the 2012 energy use of the Germans was produced by solar. Combined with wind power, both Germany and Denmark have over 20% of their energy needs generated by renewables. These statistics are from 2012 though. The renewables market is rapidly changing as countries like the US and China are about to take over Germany's leading position.

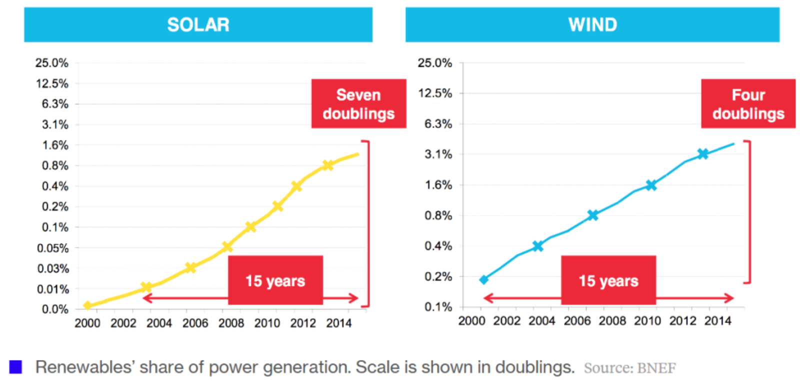
Figure 2 | Solar global capacity per country, 2012



Source: BP data

Exponential growth | Although coming from a small base, solar energy has been growing rapidly. Since 2000, solar energy's weight in the energy mix has doubled seven times. For wind power there have been four doublings, increasing the wind contribution to 3% of the energy mix in 2015. This exponential growth can be fully explained by the continuous price declines and the improved efficiency of solar panels and wind turbines.

Figure 3 | Solar and wind energy show exponential growth



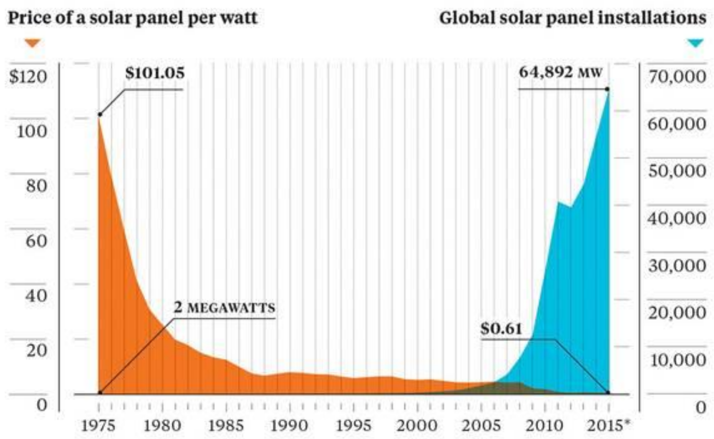
Source: BNEF

Lower costs

The costs of producing solar panels have been on a path of decline ever since the first panel was launched in the 1970s.

Solar panel costs declined from roughly USD 100 in the 1970s to USD0.60 today for a single-watt solar panel. Since 2005, the decline in solar panel prices has coincided with stellar growth in installed capacity.

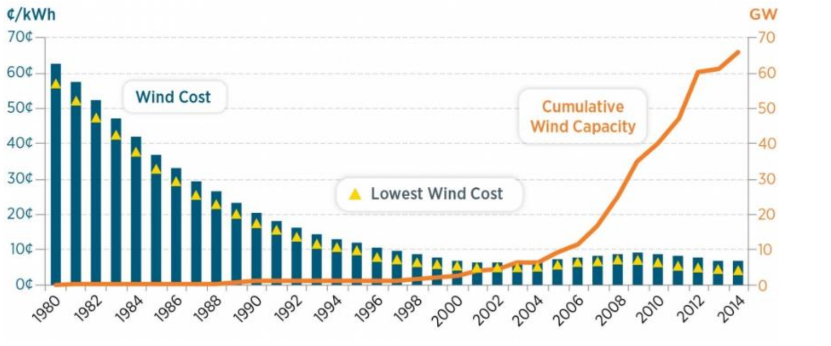
Figure 4 | Solar panel prices and installations



Source: Earth Policy Institute/ Bloomberg

Moore's law applicable to solar | This path of price decline in solar has strong familiarity with the decline in the price of semiconductors or computer chips. This is not strange as both are technologies that are based on making either small lines in silicon (computer chips) or small slices of silicon (solar cells). Simply said the more lines one can make in the silicon the better the computer chip and the thinner the silicon slice, the better the solar panel. The path of price declines in computer chips can be explained by what is called Moore's law. Gordon Moore is one of the founders of Intel and predicted in 1965 that the capacity of computer chips would double every year due to miniaturization technology. He later adjusted this to a doubling each two years. So roughly speaking computer chips double in capacity every two years for the same price or halve in price for the same capacity. The same analogy holds true for solar panels.

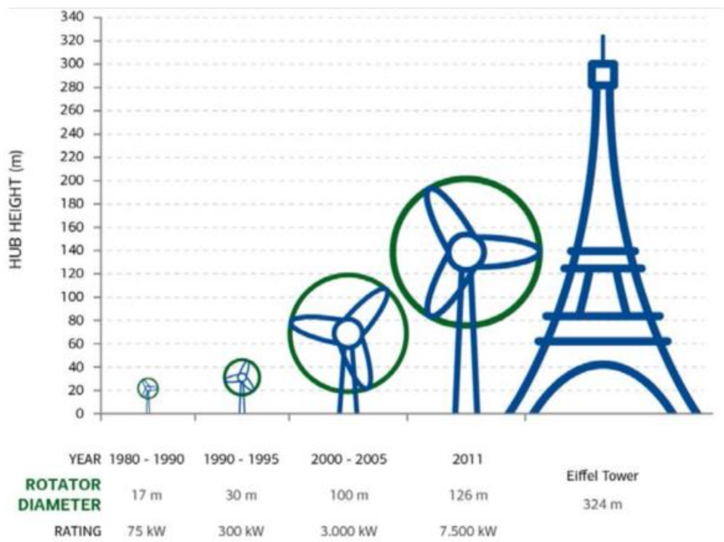
Figure 5 | Wind costs and capacity



Source: Energy.gov

Decline in wind power costs | Wind power prices have also declined on a remarkably steep path in the last decades, albeit less steep than solar power. Contrary to solar, wind power is an ancient old mechanical technology. Due to major efficiency enhancements in wind turbines, such as size and new locations at sea, the price of wind power still declined. Figure 6 shows that today's wind mills have much larger size and capacity than older ones. In fact, offshore wind mills are able to generate 100X more power versus 30 years ago. This has made wind power prices decline by roughly 40% over the last five years. In comparison, solar power has declined by roughly 75% over the same period.

Figure 6 | Wind turbines 100x the power vs. 30 years ago



Source: New Climate Economy, European Wind Energy Association, Merrill Lynch Research

Future price developments

Most experts predict a continuation of the price declines in both solar and wind power, although at slower rates than in the recent past.

Three drivers of future solar panel cost declines | For how long the exponential price decline in solar panels will continue depends on three major drivers:

1. Future advancements in solar technology and miniaturization
2. The scale effect
3. The development of integrated solar cells

With the latest technology solar panels are able to turn roughly 17% of the sunlight into energy. This compares to 10% at the beginning of this century. According to semi-conductors and miniaturization experts it will be technically possible to increase this to at least 30%. So Moore's law for solar has some way to go.

Competition is fierce | The scale effect on top of this will also lower the cost-per-unit substantially. Competition in the manufacturing of solar panels is very brutal. To illustrate, even industrial giant General Electric, the largest maker of wind turbines, could not take the heat of this fierce competition and sold its solar panels business to First Solar. Today the largest solar panel and components producers are of Chinese origin and are willing to make upfront investments in large manufacturing sites to become the cheapest producers. They just take the overcapacity and potentially lower prices for solar panels for granted. These lower prices trigger more demand that after time fills up the overcapacity.

Solar no longer only in panels | The last driver of lower prices for solar panels will come from solar cells that will be integrated into other products. Roofing tiles with integrated solar cells are logical examples. Although the first companies are already offering this today, it is expected to be mass-produced within the next 10 years. Another example is asphalt with integrated solar panels. One brand of solar asphalt is Wattway and is offered by Colas, the largest European roadbuilder. According to their website 1 km of Wattway road is enough to provide streetlights for 5000 inhabitants and has the same endurance as normal asphalt.

Figure 7 | St. Paul's Church in Devon & Wattway road

Source: solarcentury.com & wattwaybycolas.com

Cooling solar improves the yield | One of the reasons why only a limited amount of the sunlight that hits a solar panel is converted to usable energy is because the warmer the solar panel gets, the less efficient it becomes. Or in other words, cooling solar cells will increase their efficiency. This can increase their efficiency by roughly 6-8%. This makes the combination of wind and solar energy an ideal one. Putting solar cells on turbine blades will increase the overall energy output of the windmill and will also increase the efficiency of the solar cell. The combination of aquaculture and floating solar parks also seems a perfect one. According to Japanese fish farmers partially covering water with floating solar cells will lower the growth of algae and increase the yield of fish farming. On top of that and more relevant here, it will also increase the energy output of the solar cells by cooling them.

Figure 8 | Solarwind turbine & Kyocera TCL Solar project

Source: blueenergyusa.com & greenmediatech.com

Price forecasts by experts show further declines, although at slower rates | Based on further continuation of the decline in price of solar and wind energy, Bloomberg New Energy Finance predicts that these two technologies will become the cheapest ways of producing electricity in many countries during the 2020s and in most of the world in the 2030s. They see onshore wind costs falling by 41% and solar PV costs falling by 60% by 2040. Also Deutsche Bank, CLSA and Tony Sheba from Stanford University predict the price decline in solar to continue. Goldman Sachs expect that between 2015 and 2020 wind and solar will add more energy supply than US shale did between 2010 and 2015.

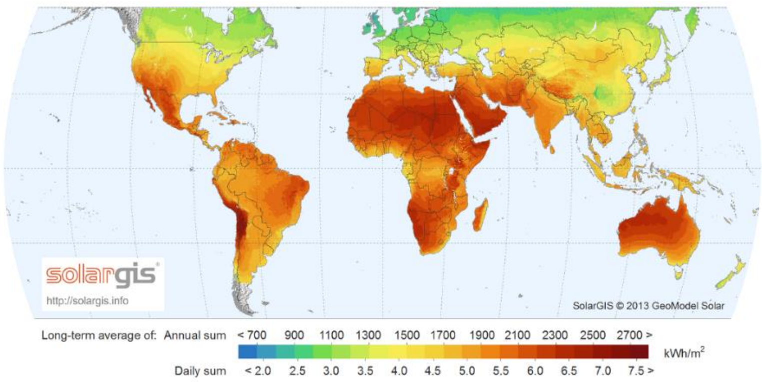
In general it is clear that the costs of solar panels will continue to decline due to technology improvements and scale effects in the decade to come. It is, however, unrealistic to assume that the path of exponential decline will continue at the same rate.

Competitive sources

In order for solar and wind energy to take a bigger part of the energy pie they need to become more cost-competitive versus other energy sources and stop being dependent on subsidies and goodwill.

Solar irradiance | The costs of a kilowatt (kW) of solar energy depends on two things. The first one is the price of installed solar panels. The second one is related to the yield of these panels. As described before, the price of solar panels has been declining and is expected to continue to do so in the nearby future. The yield depends on the location of the panels or the solar irradiance. Roughly speaking, the closer you get the equator, the higher the yield of solar panels and the higher the solar irradiance.

Figure 9 | Solar irradiance

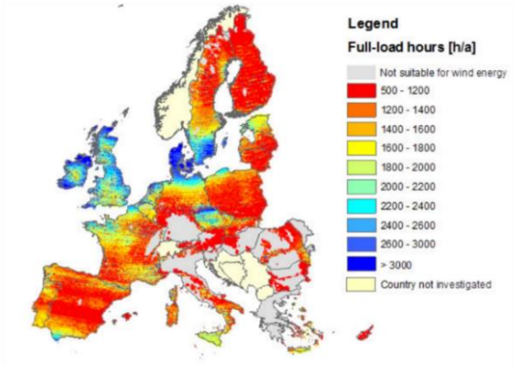


Source: solargris.info

Figure 9 shows that the solar irradiance is the best in Africa, the Middle East and Australia. Also the west coast of the USA and most parts of Latin America have high solar irradiance and would the most logical areas for solar energy investments.

Wind yields and maintenance costs | For wind energy similar maps came be drawn based on yearly wind yield. Figure 10 shows one for Europe. Especially the coastal areas of the Netherlands, Great Britain, Ireland, Sweden and all of Denmark have high wind yield and are filled with wind parks. It is interesting to note that at least in Europe the countries which do not seem to have enough solar irradiance seem to be blessed with potentially enough wind power.

Figure 10 | Wind yields in Europe

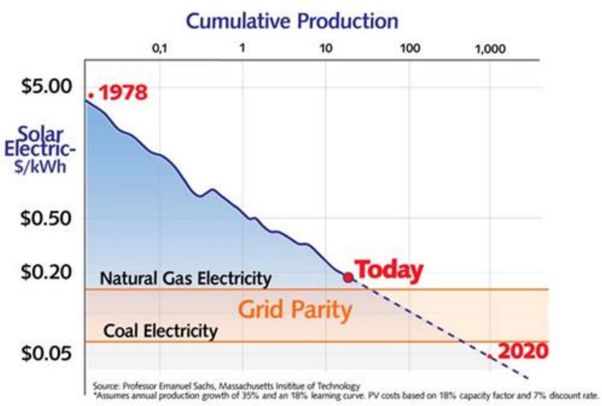


Source: European Wind Energy Association

Contrary to solar energy the cost of wind power is not just the initial cost of installing the windmill. As harvesting wind energy is done mechanically with rotating parts, also the maintenance and repair costs should be taken into account. Especially in offshore wind parks these costs can sometimes be substantial. According to Barclays Investment Bank research the lifetime servicing costs for wind could amount to 35-40% of the initial turbine costs.

Renewables vs. fossil fuels | As solar power is mostly used for electricity generation it is best to compare solar with coal or natural gas-based electricity prices. According to the Massachusetts Institute of Technology the 2015 global price of solar was on average almost at par with the price of natural gas-based electricity. On a global scale it is still USD 0.15 away from the cheapest and dirtiest way of producing electricity, namely burning coal. On their estimates, this point will be reached in 2020.

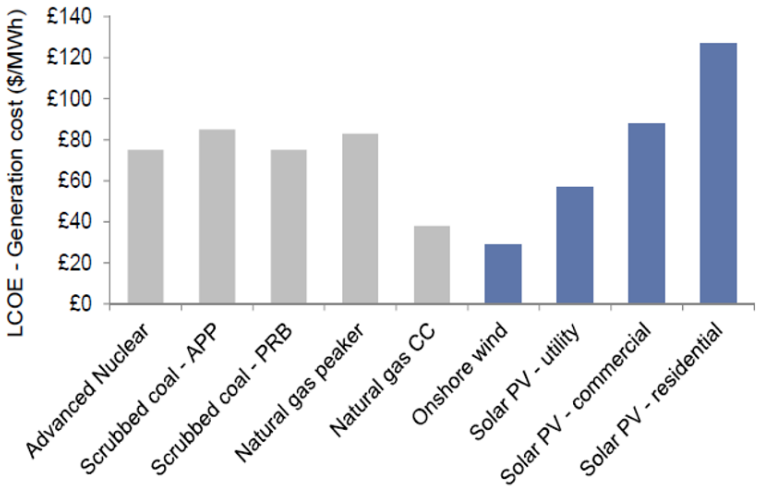
Figure 11 | Solar energy almost at grid parity in 2014



Source: Massachusetts Institute of Technology

Also Goldman Sachs draws similar conclusions for the US. Due to the presence of US shale gas, natural gas-based electricity is still cheaper today than utility-scale solar parks. However, onshore wind is in the current environment of subsidies the cheapest way to produce electricity in US. The data in figure 12 compares new build generation costs. In practice a new build solar park needs to compete with an existing old coal-fired power plant. So based on this data if an existing power plant has reached the end of its lifespan it will most likely be replaced by a solar or onshore wind park.

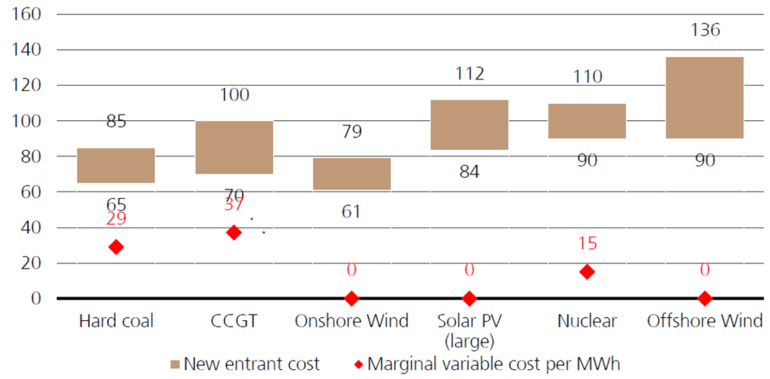
Figure 12 | US 2015 comparison of new build generation costs



Source: Goldman Sachs Global Investment Research

Investment bank UBS has calculated that in Europe for a new-build electricity plant, nuclear energy is now less competitive than onshore wind and solar. Despite the current historically low commodity prices, onshore wind prices are now even lower than for coal and gas-fired (CCGT) power stations. UBS expects that solar photovoltaic (PV) costs are heading in the same direction. So also in Europe the replacements of old power stations will be most likely be done with cheaper renewables.

Figure 13 | European 2015 comparison of new build generation costs



Source: UBS Investment Research

Solar most beneficial for off the grid | The data in figures 12 and 13 above are all based on utility scale power plants connected to the grid. Both solar and wind have the advantage that they can be used off-the-grid by local communities. The most commonly used off-the-grid way of producing electricity is by diesel generators. Such generation is widely used in most parts of Africa, but also the state of Hawaii or other remote islands depend on generators fueled with imported diesel. It is therefore not strange that Hawaii was the first state in the United States to reach for photovoltaic solar energy. Its tropical location provides abundant sun energy and Hawaii has targets to reach 40% renewable energy by 2030 and 100% by 2045. In 2015, 6% of all electricity produced in Hawaii was solar-based with 10% of the rooftops having solar panels.

Also in India, solar energy is on the agenda to replace diesel-generated electricity. The Modi government has set a target of reaching 100 GW installed capacity by 2022. This would make solar the fastest-growing energy source in this fast growing country.

Recent announcements | The first examples of solar winning from fossil fuels can already be found in the press. In the US electricity enabled by fossil fuels trades at roughly 7-7.5 cents per kilowatt-hour (kWh), but just outside LA a new solar plant currently in the works will sell electricity for USD 3.6 cents per kWh. Elsewhere, in Dubai, a solar bid worth a record-breaking USD 2.99 cents per kWh was accepted. Based on this record low price the Dubai Electricity and Water Authority (DEWA) revealed plans to build a massive solar power concentrated array that would generate 1,000 MW (or 1 GW). This is almost twice as much as the current record holder, the Noor-Ouarzazate solar complex in Morocco.

Figure 14 | Forbes headlines

JUN 29, 2016 @ 01:46 AM 16,897 VIEWS

Watch Out, Coal! Dubai Announces Plans Lowest Cost Solar Plant

Mark L. Clifford
CONTRIBUTOR
I write about green technology and business innovation in Asia.
FULL BIO

King Coal is taking a lot of blows recently. But at least it could usually count on being the cheapest alternative. Now even that's called into question.

The latest battering to coal's standing came when Dubai announced June 27 that it would build a massive 800-megawatt solar plant that will produce electricity at an average cost of 2.99 cents a kilowatt hour, substantially below what even coal-fired power plants charge.

Source: Forbes.com

Experts' outlook shines bright for solar | With these new and cheap projects coming to market the International Energy Agency (IEA) has changed its forecast at the beginning of 2016 and now expects 50% of the energy market to be supplied by renewables by 2050 versus less than 10% today.

Deutsche Bank expects that in 2016 it will be cheaper to produce solar energy than fossil based electricity in 47 states of the US. In 2017 this will be the case in 80% of the world. Bloomberg New Energy Finance sees 2025 as the turning point. From 2025 onwards Bloomberg expects all of the growth in the energy market to come from solar and wind energy. From here onwards they see solar power growing sixfold to become the cheapest energy resource. UBS Investment bank is even more optimistic and expects wind and solar to be the cheapest power generation technologies across the world by 2020.

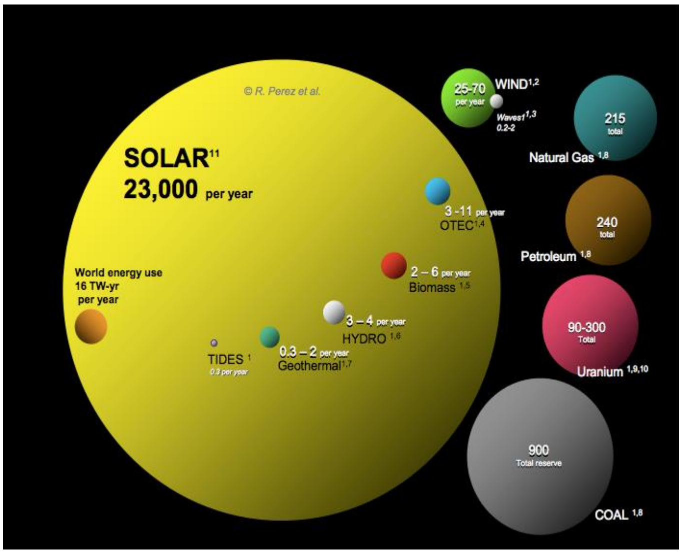
Overall, it is clear that on new build basis renewables have become very competitive and will become the logical choice for replacing old power stations when they have reached the end of their lifespan. Closing down well-functioning power stations and replace them with solar or wind parks, still looks uneconomical at the current prices. In developed markets the roll-out of renewable energy will therefore be slower than in emerging markets where there is no large installed base of power stations.

How big can solar get?

As only a small amount of our current energy use is covered by solar energy, one could wonder how much solar can potentially grow. Will it be possible to cover 50% or even 100% of our energy needs?

The sun itself is no game stopper. As shown in figure 15, roughly 23,000 Terawatts (TW) of sun power reach earth every year. Our annual consumption is 16 TW. Or rephrased differently: if we would be able to store all the energy of the sun that reaches the earth on one day, we would have enough energy for the next four years. This is as close as you can get to the true meaning of the words 'abundant energy'.

Figure 15 | The sun's almost unlimited power



Source: cleantechnica.com

Earth filled with panels? | So if the energy of the sun is abundant, the next question becomes: is it realistic that we will be able to harvest this source? This question can be answered with a clear yes. With the current (limited) efficiency rate of solar cells, we only need 0.8% of the global land surface area to be able to harvest the energy we need. As 29% of the planet's surface area is covered by land, we would only need 0.25% of the total planetary surface area including oceans to be able to supply the world with 100% solar energy. In comparison, more than 33% of the land surface is desert and deserted and would potentially be suited for solar parks. Roughly 3% of the land surface is covered by urban areas, so covering most rooftops and roads on our planet would also get us there.

Continuing the current growth path | Is it however realistic to assume we will be able to reach 100% solar energy coverage? Wouldn't it take ages to reach this? Again a clear answer: no it wouldn't.

As written before, the International Energy Agency sees 2050 as the year in which more than 50% of energy will be renewable. However, if we continue to grow solar energy as we have been doing we will get there much sooner. The global solar installed capacity has grown from 1.4GW in 2000 to 141 GW in 2013. This represents a compound annual growth rate of 43%. Should solar continue to grow at this exponential trajectory, the solar capacity installed base will be 57 TW by 2030 versus roughly 16 TW of global demand today. So if we continue to grow solar as we have been doing in the past, more than 100% of our energy demand will be covered be solar power by the end of the next decade.

Politics

There are many ways politics are trying to influence the usage and acceptance of renewable energy. In this chapter we touch upon three: subsidies, global agreements and local initiatives.

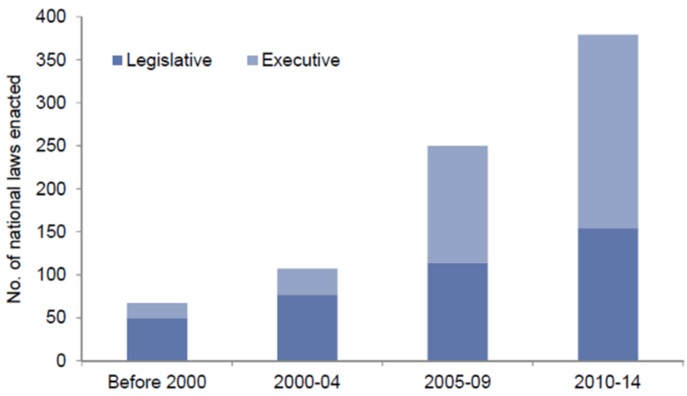
Subsidies to kick-start adoption | The biggest influence politics can have on solar and wind energy is through subsidies. There are roughly two sorts of subsidies widely used. The first subsidy is to reduce the price of solar panels or wind mills by lowering or eliminating VAT and/or other taxes. The second type of subsidy is through the pricing of the energy itself. Some countries like Germany and China allow wind and solar energy producers to be paid a high fixed price by the grid operator. Other countries, like the Netherlands and some US states, allow consumer net metering. This net metering allows consumers to use solar power generated during the day at night. There is both monthly net metering and annual net metering, which allows for solar power generated in July to be used in December.

The idea behind these subsidies is of course to make solar energy costs compatible with fossil fuels. In theory, once they are compatible, according to the previous chapters somewhere in the next decade, these subsidies can be removed. In practice, however, it takes governments a while to remove subsidies. We had to wait until May 2016 for the G7 nations to set a deadline for ending most fossil fuel subsidies, stating government support for coal, oil and gas should end by 2025. The IEA's latest estimates indicate that fossil fuel consumption subsidies worldwide amounted to USD 493 billion in 2014, with subsidies to oil products representing over half of this amount. Those fossil fuel subsidies were over four times the value of subsidies flowing to renewable energy.

COP21 | The 2015 United Nations Climate Change Conference, COP 21 or CMP 11, was held in Paris and was the first climate conference after Kyoto 1997 where an agreement was reached between all participating 196 countries. According to COP21, all countries need to pursue all possible efforts to limit global warming to less than 2 °C compared with pre-industrial levels. The agreement calls for zero net greenhouse gas emissions to be reached during the second half of this century. Although the positive mindset is there, COP21 still needs be ratified by local parliaments. Although this seems trivial, this is something where the Kyoto agreement went wrong as the US simply never ratified and Canada withdrew from the protocol. However, hopes are high as in September 2016 both China and the US officially ratified.

It is clear that the fight against emissions has become a global one after COP21. The number of national laws or regulations to reduce emissions and stimulate renewables has increased steadily over the last decade. It is expected that this will continue thanks to COP21.

Figure 16 | Number of rules and regulations on emissions steadily increases



Source: Goldman Sachs Global Investment Research

Local initiatives | Next to subsidies and COP21, there have been many different political initiatives to increase the use of renewable energy, at both country level and regional, city or community level. One well known example is the Carbon Neutral Cities Alliance, which is a group of cities that have agreed to lower their emissions by at least 80% by 2050. Among the participants are New York, San Francisco, Berlin, London and Sydney. The first US city that proudly announced that they have been supplied with 100% carbon-neutral electricity is Palo Alto in the middle of Silicon Valley.

US no longer lagging | In general, the US has been lagging behind Europe and Japan in introducing renewable energy sources. Due to different leadership and more competitive prices for renewable energy, the US has been catching up lost ground by introducing new solar and wind pricing schemes, signing and ratifying the COP21 treaty and recently agreeing to the North American Climate, Energy, and Environment Partnership. This partnership was announced by Prime Minister Justin Trudeau of Canada, US President Barack Obama, and Mexican President Enrique Peña Nieto on June 29, 2016 and among others contains the goal for North America to achieve 50% clean power generation by 2025.

With the US on board it is clear that politics, regulation and goodwill will continue to be an important driving force behind renewables acceptance and penetration.

Effect on energy markets

Zero marginal costs of renewable energy change the game on energy markets.

Zero marginal costs | For many years, the price of electricity has been based on the sum of the fixed costs to own and operate a power plant and the variable costs of labor and the feedstock. The marginal costs of fossil-fueled electricity are only the costs of the feedstock, in most cases gas or coal. In theory, these marginal costs are the absolute minimum prices of electricity in times of distressed markets. If the market price for energy would go below the marginal cost for a certain power station, the owner of this station would simply shut down production to avoid losing money.

The marginal costs for producing solar or wind power, however, are (almost) zero. It just takes more sunlight and or more wind to produce an additional unit of power. Due to these zero marginal costs, the total costs of electricity will go down the more renewable energy is used in the energy mix. Interestingly enough, the lower the cost of electricity the lower the costs of solar panels, as one of the biggest input costs for producing solar panels is electricity. In many ways, zero marginal costs change the game on the energy markets.

Negative electricity prices, a new phenomenon | To illustrate lower electricity prices, we simply have to go back to Sunday, May 8 2016. On that day Germany hit a new high in renewable energy generation. Thanks to sunny and windy conditions, at one point around 1 pm, the country's solar, wind, hydro and biomass plants were supplying 87% of the power consumed. Power prices actually went negative for several hours, meaning commercial customers and neighboring countries like the Netherlands were being paid to consume electricity from the German network.

Besides renewables, Germany's other sources of electricity production are nuclear, coal and some gas-fired power stations. Gas-fired power stations can adjust their output almost immediately, however for a coal-fired power station it takes between 1 and 5 days to adjust or stop production. Shutting down a nuclear plant takes at least a month. On that Sunday, Germany was unable to adjust power production at such short notice and was forced to charge negative prices to offload energy from its grid. It is widely expected that more days with negative prices will follow the more renewable energy is generated. As written before, zero marginal costs change the game on energy markets.

Unlimited install base | Due to the unreliable character of solar and wind energy, one can also argue that the link between demand and supply in the electricity market can become less tight. Today, the total installed capacity to generate energy is estimated by IEA to be roughly 30% higher than consumption. This spare capacity is used to supply peak demand, as back-up for maintenance and repairs and for future growth, mostly in China. If solar and wind power energy increase their share in the total energy mix, the amount of spare capacity simply needs to increase. In the most extreme situation, when all consumers of energy will also become producers of energy, the backup generation capacity could be as high as 100%. This will lower the price of energy in the daytime substantially.

Take for instance the example of roof top solar energy in California, one of the best places to generate solar energy. According to Brick and Thernstrom in the Electricity Journal, the difference in solar output between January and June is a factor of three in Sacramento. So the same solar panel will generate three times the electricity in a typical June than in a typical January. In order to make sure enough energy is produced to fulfil the needs of the homeowner in January, he will overbuild his solar system relative to his needs in June. So in other words, the unreliability of solar energy could lead to higher solar installed capacity, which will lead again to lower electricity prices. Zero marginal costs really change the game.

There will however be no need for such large backup generation capacity if we are able to store the renewable energy locally and use it when electricity prices are higher. This makes storage the holy grail for further penetration of solar and wind energy.

Storage: the holy grail

The combination of unreliable renewable energy and its zero marginal cost clearly shows the need for temporary electricity storage. Or rephrased: it shows that large profits can be made if cheap and reliable storage is available, making storage the holy grail for renewable energy.

Scientists' quest to find this holy grail in energy storage has led to a spur of new ideas and technologies. Many different chemical compounds are being tested in laboratories to find more efficient batteries. In solar and wind parks tests are being conducted with hydrogen-powered fuel cells, mechanical flywheels and compressed-air storage. Although perhaps in the distant future these technologies can become the holy grail in energy storage it is realistic to assume that two technologies have such grail-potential today. Both pumped-hydro storage and lithium-ion batteries are well proven and therefore the most used storage technologies today.

PSH: the most efficient storage option today | The most-used storage today is pumped storage hydroelectricity (PSH) that produces electrical power through the use of the gravitational force of falling or flowing water. Simply said, PSH uses cheap (or even negative) energy prices to pump water up the mountain into a lake and release water out of the lake to flow through a hydro generator whenever energy prices are expensive. According to Electric Power Research Institute (EPRI), PSH accounts for more than 90% of bulk storage production capacity worldwide with storage capacity at 740 tWh. Typically, the round-trip energy efficiency of PSH varies in practice between 75% and 80%. So this type of energy storage would be economically viable whenever the difference between the prices of the energy produced and consumed is more than 25%.

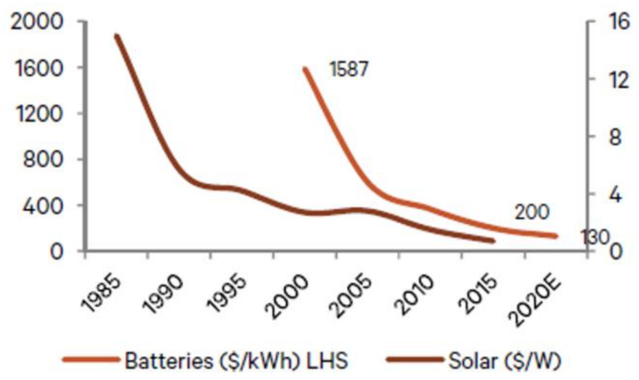
The major disadvantage of this type of energy storage is that you need a good location with both mountains and water. Given that most large solar parks currently being built are in deserts and most large wind parks are offshore, nearby PSH is not directly available.

Existing battery technologies | A more mobile solution to the storage problem is of course battery technology. Most of the rechargeable batteries today are either lead acid batteries used in normal cars (non EVs) or lithium-ion batteries mostly used in portable electronic devices like laptops and smartphones, and in modern electric vehicles (EVs). The round-trip efficiency of batteries varies between 75% and 90% depending on the chemical components used. The major disadvantage of batteries is that round-trip efficiency decreases with the age of the battery and the duration of the storage. This is something we all know from our older electronic devices and smartphones. Pumped Hydro does not have this disadvantage.

Although there is no direct need for renewable energy storage to be mobile, it would be useful if more electronic devices were able to store energy, especially if they are filled up in times when energy is abundant and at low prices. Take for instance street lights that are able to store solar energy produced in the daytime and can use it at night. But in order for this to be economically successful the prices of batteries need to decline considerably.

Most experts expect this decline to happen. In figure 17 Berenberg's forecasts are shown. They expect prices of lithium-ion batteries to be halved every five years, leading to USD 200 per kWh in 2020. Bloomberg New Energy Finance's outlook for renewables projected battery costs is a decline of 60% by 2030. The Electric Power Research Institute (EPRI) forecasts lithium-ion battery packs to drop to one-quarter of their current price by 2022.

Figure 17 | Battery costs declining by half every five years



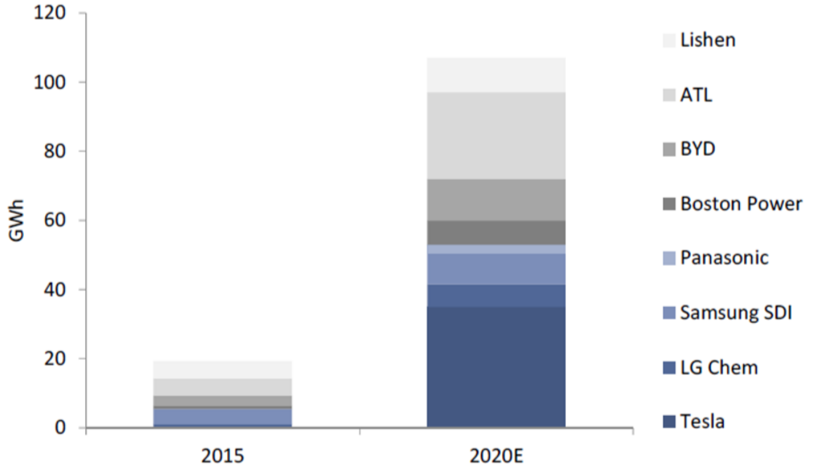
Source: Berenberg Research

Scale leads to major price declines | The major driver behind these expected price declines is the increased manufacturing scale of batteries. Figure 18 compares the current manufacturing capacity of lithium-ion batteries with the 2020 capacity that is currently being built.

The largest example of a new batteries plant is the Tesla/Panasonic Gigafactory that is currently being built in the Nevada desert. This plant will provide on its own more lithium-ion batteries in 2020 than the worldwide production of 2015. According to Tesla, it will need all of these batteries for its own production of 500,000 EVs per year. On top of this an expansion of this Gigafactory will be needed to produce the Tesla Powerwall, a battery pack that stores energy for domestic consumption for daily load shifting or back-up.

Next to Tesla/Panasonic Gigafactory, other battery suppliers are also increasing their manufacturing scale and capacity. According to Goldman Sachs, the manufacturing capacity of lithium-ion batteries will increase by more than 500% by 2020 versus 2015. Such an increase will be a major driving force behind the future price declines of batteries.

Figure 18 | New battery capacity being built



Source: Goldman Sachs Global Investment Research

Given the spur of new technologies, the huge upscaling of the manufacturing of lithium-ion batteries and the economic incentive to benefit from cheap solar and wind energy, it is realistic to assume that it is only a matter of time before the holy grail of storage will be found and exploited by mankind.

The role of EVs

The large economic incentive to store cheap solar energy combined with a huge increase in manufacturing capacity for batteries will make it possible for more and more electronic devices to have their own electricity storage on board, with the best example being cars.

Such electric devices would be able to store energy at low prices and use it whenever needed. The one with potentially the most batteries on board would be the car. At this moment, cars are still equipped with an internal combustion engine that runs on oil-based fuel. So far solar and wind energy have only been seen as alternatives for coal and gas but if electric cars (EVs) would really take off, they could also become an alternative for the oil market.

EVs no longer luxury products? | So far, EVs have been positioned and sold as luxury products for environmentally aware customers. Although most countries have large incentives on EVs, the price of a mainstream EV is not yet seen as competitive versus a regular car. The price disadvantage of EVs is mostly due to the costs and the weight of the battery pack. By halving the cost of battery packs and by lowering the weight of the batteries, the unfavorable economics might change in the near future. As discussed before, halving the costs of the battery pack seems realistic somewhere in the next decade.

Driving range and refueling time | Besides the current price, two other often heard disadvantages of EVs are the limited driving range and the time that is needed to refuel the battery. It is true that the first EVs on the market have had a limited driving range, but this changed with the introduction of the Tesla model S, which has been able to drive over 400 kilometers on a full battery. For mainstream EVs today, using a similar amount of batteries as Tesla would price them out of the market. However, with the introduction of cheaper and lighter batteries mainstream car manufacturers will follow this range extension. For most cars having a 400 kilometer range would be more than sufficient to remove the disadvantage of the longer refueling time. Refueling a Tesla battery pack takes up to 6-8 hours when using the normal electricity grid. Using the Tesla supercharger network, which is free for Tesla drivers, the battery pack can be filled up to 80% within 30 minutes.

Figure 19 | Wireless recharging buses in Torino

Source: Conductix-Wampfer

Another way to remove the refueling problem would be the roll-out of wireless charging roads. Driving such a road would recharge your EV battery while you are driving. In Torino, Italy, some city buses have been experimenting with such a system. These fully electrical buses are partly recharged every time they drive over the wireless charging point in the road. In Torino these points are located at the busiest bus stops. Especially combining solar cells and wireless recharging in the same road would make an interesting self-sustaining solution.

EVs cheaper and more efficient | Next to the disadvantages, EVs also have some clear advantages. Electrical engines are far more efficient than internal combustion engines. Electrical engines convert almost 90% of the energy into rotating wheels. For modern internal combustion engines roughly 20% of the fuel is used to drive the car; the rest becomes heat.

On top of that, EVs are far cheaper to drive and maintain. Refueling an EV in the US today is ten times cheaper than refueling a gasoline car. For Europe with its high gasoline taxes the difference is even more favorable. If electricity prices would decline further due the higher use of solar energy this difference could increase. Maintenance costs for an EV are much lower than for a gasoline car. The design of EV is quite simple. The fully electrical Nissan Leaf only contains 25 rotating parts that need regular maintenance versus over 2500 rotating parts in a comparable gasoline car. Most problems in EVs can be solved by rewriting software and, just like with a smartphone downloading a new software version, this can be done anytime, anywhere.

Figure 20 | Tesla model X chassis with two electrical motors

Source: Tesla.com

In essence an EV is nothing more than a huge plate of batteries with two or four electrical engines, a steering wheel and large tablet with software. Designing a new EV is much easier than designing a new gasoline car due to this modular build-up. This increases the speed to market and lowers the barriers to entry for new entrants. This explains for instance why newcomers like Tesla, Faraday and - according to the rumors - Apple are trying to or have already been able to launch new electric cars out of the blue.

The ultimate storage | A network of EVs can also be used as storage for cheap solar and wind energy. In Lombok, a part of the city of Utrecht, the Netherlands, they are experimenting with EVs to be used as external battery pack for solar energy produced by a local solar (roof top) park. Whenever the sun is shining and the local grid operator cannot handle the supply of energy, it charges the connected EVs. In the evening when retail consumption peaks and the sun is no longer shining the energy is withdrawn from the connected EVs. The system is called smart in a sense that it leaves enough energy in the EV to make the necessary trip the next morning. A similar initiative has been announced in Palo Alto in California.

The political push to EVs | Local politics are very much in favor of EVs, even more so than solar and wind energy. The zero emissions and the reduction in noise make EVs the preferable vehicles for congested and polluted cities. There are different ways to promote EVs. Removing local taxes or congestion charges is used often, but also switching city buses to EVs is quite popular. Banning old gasoline cars from entering the city is done as a permanent measure in German and Dutch cities but also as temporary anti-smog measure in Mexican cities. One of the most EV friendly countries today is China. From the limited amount of new license plates that are awarded in Beijing every year a large part is reserved for EVs and this part will grow in the coming years. China has already become the largest market for EVs as 45% of all EVs sold in 2015 were sold in China.

Figure 21 | Targets for electrical buses

	Targets for electric buses
China	80% of all new buses to be electric by 2020
London, UK	All electric buses passing through London's ultra low emission zone to be zero emission by 2025
Paris	Replace the entire 4,800 bus fleet with zero emission ones by 2025
Copenhagen	All zero emission busses by 2025
California	All zero emission busses by 2040

Source: Tony Seba: Clean Disruption

It is clear that cheaper batteries will not only play an important role in storing renewable energy in the future but also in speeding up the penetration of EVs. We would not be surprised if EVs and solar storage were to become different sides of the same coin.

Implications for investors

Cheap solar and wind energy combined with cheap batteries will cause a lot of damage among energy companies, utilities and car manufacturers. Spotting future winners is hard in a highly deflationary environment, but the most obvious winners are mankind and our planet Earth.

Due to their ever-declining prices solar and wind will become our main sources of energy within the next decades. It will become harder to survive for those that mine and produce the most used power sources of today. It is more than likely that coal will be the first victim as gas-fueled power stations are seen as most efficient to use as a temporary back-up for the unpredictable renewables.

Competing with the zero marginal costs of sunlight and wind will make it also very hard for today's utilities to survive. Especially if the roll-out of cheaper storage continues, the centralized utility business model will probably become extinct in the remainder of this century. On top of this, cheaper and better batteries will also lead to wider usage and penetration of EVs. This will also put large pressure on oil producers and refineries. Although most car producers today have new electric cars lined up, the lower barriers-to-entry for launching a new EV will make the car industry an extremely competitive environment in the future. So in a nutshell, the move to solar and wind energy will very likely create a large amount of victims among companies in sectors like energy, utilities and car manufacturing.

Winners are hard to identify at company specific level | Finding the winners from the move to solar energy is not as easy as it seems. The huge deflationary forces and changes in leading technology make it hard to predict the true winners already today. Similarly to the semiconductor industry at the turn of the century, the great variety of players with different scales and technologies in the solar industry makes long-term investing almost impossible.

For wind energy, however, this is no longer the case. As also pointed out by Chris Berkouwer in his article 'Wind of change' (August 2016)[1], three global winners (GE, Siemens and Vestas) dominate the wind industry. Despite the high growth of new windmills, the installed base of existing wind mills has become large enough for maintenance income to stabilize their yearly earnings.

In essence the true and most obvious winners of the move to renewable energy are mankind but above all our planet. Cheap or free energy could potentially solve mankind's water and food scarcity while lowering the emissions profile. Throughout this report, the discussion on pollution and emissions has been mostly avoided, simply because solar and wind energy in some areas no longer need the support from the environmentalists to win the battle. It is capitalism that has taken over for them.

[1] Available on www.robeco.com.

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