CLEAN ENERGY SOLUTIONS CENTER
ASSISTING COUNTRIES WITH CLEAN ENERGY POLICY

Introduction to Grid Parity

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David Jacobs Hello, everyone around the world. This is David Jacobs speaking from Berlin, Germany. Welcome to another webinar of the International Solar Alliance Expert Training Course. As you probably already know, this is a combined training course offered by the International Solar Alliance and the Clean Energy Solutions Center, assisting countries with clean energy policies. I am Dr. David Jacobs, founder and director of the consulting firm IET, International Energy Transition, with more than a decade in experience renewable energy policy design include NET metering and self-consumption policies.

This is a larger training course consisting of a total of eight modules. This webinar on grid parities is part of module one, where we will discuss policies for distributing. And if you haven't done so, please also check out session two, which gives you an introduction to solar policies but is also relevant to understanding grid parity in sessions six, seven and eight where you get an in-depth understanding of NET metering, NET FIT concepts and then also rate design for electricity prices. All of them are actually crucial background or crucial additions to this webinar.

As always, we start with an introduction of the learning objective. Then, move over to a more simplistic and more advanced concept of grid parity. And as always, you'll also get some further reading and a knowledge check in terms of multiple-choice questions at the end of this work.

Looking at the learning objectives, first of all, as you will learn there is a very simplistic concept of grid parity, which can be explained in less than a minute. However, in order to understand the nuances of grid parity, we need to take a closer look at some other cost competitiveness benchmarks assumed to be at different components of the retail electricity price and retail electricity market and rate design. I also wanted to highlight in a little excursion at the end of this work the death spiral argument in case you haven't heard of it. You can look forward to this little excursion and I also wanted to highlight some risks, which are related to project finance via self-consumption and how these risks also effectively slow down this market segment in also counterbalancing this death spiral argument. But more on this later.

First of all, let's take a closer look at some of the background. That means decreasing costs for solar PV and in many countries increasing retail electricity prices. But yes, this is sort of the background of the grid parity concept. Here, just a few graphs which you probably have seen already. Here, a recent graph from the IRENA Renewable Energy Costs Database showing you the development of solar PV in different markets around the world without going into any detail here, it's clear that they have been going down quite significantly over the last decade from 40, 50 up to 80% in some markets. And this is actually not only true for rooftop solar PV but this is also true for all types of solar PV projects. For residential, commercial utilities data and even large-scale utilities scale projects. Here, also an interesting graph from NREL which is depicting the evolution from 2010 to 2017 in the United States.

This just is a very generic background. What is also important to understand is that it is not just the cost of solar PV, according to IRENA, by 73% between 2010 and 2017 but also battery costs have declined rapidly, also 73% between 2010 and 2016, which is of course important for a self-consumption consumer market segment because by adding a battery to your solar PV system, you can increase the self-consumption ratio. You can increase your degree of marketing your system and, in some markets where you don't have a lot of seasonal variations, you might actually be able to go fully off grid in terms of rich effects. These are very important aspects to keep in mind when we talk about grid parity.

And this is a trend which probably is not going to stand still any time soon. There has been a lot of analysis about the past cost decline of solar PV. You've probably already heard of some learning rate assessments, learning rate theories saying that each doubling of installed solar capacity around the globe, the solar PV costs have actually gone down by 19 to 23%. Now, of course, each doubling of the solar PV capacity takes a little bit longer than it took at the earlier stages of market introduction because we're just talking about much larger volumes of solar PV, which would need to be deployed. But prices will continue to go down.

There is not so many analyses of how far prices will further develop in the future. There has been one study done by a German think tank called AGOA, a vendor where they try to analyze potential cost reductions in solar PV until 2050 looking at the different components of a solar PV system but also looking at installation costs and so on. And they were thinking in the year 2050, so 31 years from now, costs for large scale sort of PV in Southern Europe would be in the range of 2.4 to 2.1 cents per kilowatt hour. That study

I think was done in 2015 but already, in 2016, we saw prices in that range happening in some markets around the world. You probably know about the famous Saudi Arabia auctions where they managed to get results below two-cents per kilowatt hour. That was also in the United Arab Emirates, Chile, Mexico. We have seen quite low prices in recent solar PV auctions. It is unclear how low prices will get until 2030, 2040, 2050 but the trend that prices will continue to go down is not really debatable.

And at the same time, we also see an increase of retail electricity prices. This, of course, differs from one jurisdiction to the next. And also, the reason for these increases differs quite significantly. In many developing countries and emerging economies, we actually see an elimination or at least reduction of subsidies which, of course, leads to an increase of electricity prices, at least for some customer classes.

We also see the necessity of grid expansion, grid reinforcement as we move to its renewable energy based power systems. Those are frequently the best resource areas for solar PV and wind energy are in regions where the grid has not reached so far so the grid needs to be expanded and then also upgraded to transport the power from the solar and wind hotspots to the actual load centers. And also, carbon pricing is starting to play a more and more significant role, especially on the wholesale electricity market, of course, which will then trickle down to the wholesale electricity price. Even though this has not been substantial price increases, this will probably one-off the major cost drivers in the midterm future.

What we also see in some markets – especially emerging economies – is also higher capital costs for some fuel-based power generations that the finance expenditures, FINEX, capital costs is actually increasing since there is less and less investors willing and taking the risk for investing in the technology when no one knows how long they will actually be running in the world of climate emergency. And there's also in some markets, for instance in some European countries like Spain and Germany, the legacy cost of renewable energy support mechanisms since these countries have started to promote sort of maybe since a relatively early stage at cost of 40, 50 cents per kilowatt hour. These contracts, these long-term contracts signed for 20 years or longer, are still running for at least another 10 years. These costs, which are resulting from this long-term power purchase agreements signed in the early 2000s will still be part of the electricity prices if the costs have not been covered in any other way. There's a large variety of reasons and in most countries around the world, we actually see a decrease in electricity price.

Cost decline in solar PV combined with a cost increase, with an increase of the retail electricity prices is the backbone of the concept of grid parity, as you can see in the next graphic here. You see the over simplistic in brackets concept of grid parity where you see the retail electricity price, which is going up over time, and the PV electricity cost, LCOE, coming down over time. Once these two lines meet, we actually have the famous point of grid parity, where the LCOE of solar PV equals the retail electricity price. Some people actually say that this is actually not the point where customers will invest in solar PV on their rooftop. They we will probably wait a little bit longer because they also have some IRR expectations, some rates of returns, they want to achieve with a solar PV system even though for the residential sector these are still minor. A more sophisticated concept of grid parity already takes into account, this says, "We probably don't see a lot of investment in rooftop solar PV straightaway once we reach grid parity but maybe a couple of months, a couple of years later once we reach a situation where producing solar PV on my rooftop would also give me some rates of return on my investment. It is delayed by a little bit.

This is still a relatively simplistic concept of grid parity and it is my pleasure to walk you through some of the more nitty gritty elements of grid parity in the next 14 minutes or so. Let's, first of all, take a look at some of the more simplistic claims related to grid parity. For instance, you will solve probably some media coverage in your local newspaper that says, "Once we reach grid parity, solar PV no longer needs any subsidies," or, "Solar PV will be cost competitive once we reach grid parity or socket parity, as it is also called." You might also have heard an argument saying, "Grid parity is the final nail in the coffin of centralized electricity markets and utility businesses and the victory of distributed generation," or, "After reaching grid parity, everyone will produce electricity on its own and no longer buy any electricity from the utility." It is now my task to challenge some of these statements and to walk you through some of the more detailed nuances of grid parity.

First of all, grid parity or socket parity as it is also called is not the only benchmark for solar cost competitiveness. Actually, you have to look at different market segments for solar PV and different market types which also exist around the world to understand the different cost competitive benchmarks for solar PV. And I've tried to depict this here in this simple table where you can see that grid parity or retail parity, as you can also call it, is actually relevant for a very specific market segment. And this is distributed generation, small-scale solar PV systems on rooftops, which are now only subject to be half-meter regulation. However, for all other types of solar PV systems, largescale systems which are not subject to self-consumption or which will be sold on wholesale electricity markets or otherwise, are subject to other cost competitive benchmarks

We also have the concept of LCOE parity, which is most relevant for markets where you have integrated least-cost electricity planning points, like in South Africa, where you use a certain model to come up with the least-cost electricity system including various power generation sources. And here, the LCOE of different technologies of course plays an important role. We already have a lot of markets around the world where solar PV has actually reached LCOE parity where it is now actually the cheapest technology when it comes to new power generation additions to the system.

A similar and related concept is contact cost competitive benchmark. Avoided costs. Avoided utility costs, normally, which is normally relevant in monopolistic markets with a certain degree of power producers, which are allowed to participate. The utility in these monopolistic markets normally is looking at their own avoided costs, either avoided pure costs or avoided total power generation costs. And this is also a cost competitive benchmark which solar PV would need to reach.

What is more interesting for fully liberalized electricity markets is this so-called wholesale parity or this so-called generation parity, which is a benchmark that solar PV has not yet reached in many markets around the world 'cause here, we really look in at the fuel cost and operational maintenance cost of fossil fuel based power generation which is generally setting the price in fully liberalized power markets. In combination with the carbon market, we now see situations where solar PV is actually already below form the range of wholesale parity also in some markets with little interconnections. Very good solar resources, for instance, in Spain or Australia, we see some projects, largescale projects which are fully financed on the wholesale electricity market alone. However, this is not yet the case in all markets around the world.

To tell you all of this just to say, just to make clear that retail parity or grid parity is really just one of the four important cost competitiveness benchmarks and the argument that solar PV no longer needs any subsidy once we reach grid parity is simply not true. It might be true for certain market segments, yes, but certainly not true for solar PV as a whole. And this is just showing you graphically again in the yellow line, you see the evolution of the LCOE. You have solar PV approximately over time so you see that by the year 2010, 2011 we were entering the area of retail electricity competitiveness, grid parity and then five, six years later in 2015, 2016 we also entered the area of LCOE grid parity. And now, as time has gone by – which is not really well indicated by this graph – we are also getting into the range of wholesale parity.

Looking forward, some of the constraints of the grid parity concept, we have to of course keep in mind that not all solar PV is deployed on rooftops. And this links back to what we had just discussed before. There is not so much data available, actually, in markets around the world where solar PV systems are located. This is an estimate of a recent European Union paper indicating that residential solar PV is actually becoming a major source of lead power generation. Well, we currently have it at about 20 gigawatts of stored capacity in the European Union. In the residential sector, that would probably increase to more than 30 gigawatts by 2030, which is a significant share of the market. But it is still just one share of the market and not of the full picture.

As I mentioned before, there is very little data availability on wattage shares of solar PV that has been deployed in the residential and the rooftop segment. We once did a study for the International Energy Agency RHD project where we came up with an estimate that about 25 to 35% of total solar PV worldwide has been installed in the residential sector. This, also, to keep in mind the concept of grid parity which is linked to solar PV and self-consumption is only effecting a smaller share of the overall solar PV market segment.

This is just to indicate that, of course, the fact where most of the solar will be deployed on rooftops or freestanding really also depends on market design here at points. You see that in the US and in Germany due to the market design, you saw most of the solar PV deployed in non-residential sectors. Larger scale, utility-scale projects. Also in France. However, in Australia where most of the policies were actually centered around self-consumption rooftop projects, you saw that more than 80% of market share was actually residential. You can't really judge this, all countries at once in the area if you look at the policy design of any countries to get a better idea of the market share of rooftop solar PV.

Actually, in a lot of developing countries, the develop-ability is even worse because a lot of the projects, a lot of the solar PV rooftop projects are not registered because either there is no registration process in place. Or the NET metering of the turf regulation is too complex so that customers simply decide to put solar PV on their rooftop without telling anyone. And so, there were estimates in the Philippines, for instance, where ______ chose the estimate that about 80% of the new solar PV rooftop systems were not registered. They were not in any statistics and also in South Africa, it is estimated that in many municipalities, about 85, 90% of the solar PV systems are not in any statistics because people just put it on their rooftop, connect it as a local install and no one knows about it except for maybe utility or somebody sees a drop in electricity demand from this specific customer.

This just, as some general background, another very important aspect that you have to keep in mind when trying to understand the concept of grid parity is that the full retail electricity price is not the most appropriate competitiveness benchmark when you look at solar PV consumption from rooftop solar PV. And I just wanted to highlight this a little bit in the next session, you learn more about this in the session on NET metering. This is NET metering 1.0 where you actually see that you have a bidirectional meter which is measuring at the same time. But the outdoor, obviously, solar PV system which goes to the grid if it is not self-consumed within the house but also the electricity that you purchase from the utility grid. And you see, since you have a bidirectional meter, not a smart meter, it can only either run forward or it can run backward.

What this essentially means that for each and every kilowatt hour that you export to the grid you get the same amount of money as you pay to the utility so you get, essentially, the retail electricity price that you're paying to the utility. This is what we now term usually NET metering 1.0. However, in many jurisdictions, this has now changed because utility was frequently saying, "Hey, it's not fair that I have to pay this prosumer exactly the amount of money that he pays or the electricity he's buying for me because the electricity that he's buying from me includes a lot of different components." And this is what I wanted to look at with you right now. This is the typical composition of the residential retail electricity price, where you see about 60% of the total costs related to generation in terms of actual power generation, whether it be from power or solar or from wind, et cetera. And then, about 20% related to distribution grid maintenance, upgrade, et cetera. And then, another 20% going into the costs for the transmission grid.

What you see in a lot of countries, as well, is another cost component, which is becoming more and more component when designing self-consumption policies based on grid parity in many markets around the world. And this is taxes and levies. For instance, in many developing countries, you have taxes and levies which are used to, for instance, finance lifeline tariffs, very low-cost tariffs for low-income households. What you also see in many jurisdictions is levies and taxes which are used to finance, for instance, renewable energy support programs. This part of the retail electricity price is becoming more and more important.

And now, the question really is for any self-consumption policy, how much does the utility actually have to pay the prosumer for any access that is fed into the electricity grid? Should we follow the NET metering 1.0 approach where you pay them the exact same money that they pay for the retail electricity price or should it just be fractional? There's some people arguing, for instance, that only the 40% that we see which are related to power generation should be paid to the prosumer because the other cost components, they would need to participate in refinancing. For instance, the taxes and levies normally policy makers argue should be paid by all customers and not only by customers which purchase electricity but also from the customers who produce electricity on their rooftops, the prosumers. This part of the retail electricity price, this 20% up here, is normally excluded and prosumers would also need to pay this amount of money for each and every kilowatt hour which they consume based on solar PV, which is coming from their rooftop.

Then, a more difficult question is related to the cost for the transmission and distribution grid. And this really depends on your market structure but also on the electricity grid infrastructure and so on. In some countries or in some jurisdictions, it is evident that by installing distributed solar PV on your rooftop, you can actually reduce the cost or transmission upgrades, distribution network upgrades. And therefore, some of these costs should also not be charged on prosumers. However, there's also other countries where policy makers argue, "Well, actually, since we start to have more and more prosumers within our distribution networks, we need to pay quite a lot of upgrade costs in the distribution network and, therefore, some of these costs would also need to be paid by the prosumer."

Same for the transmission grid and, in some countries, it is clear that transmission upgrades can actually be reduced. Costs can be reduced by having solar PV next to the load centers in the cities in the industrial areas. However, there might also be cases where you might still need a lot of transmission because you have variations, seasonal variations, for instance, where you still need to purchase most of the electricity or you still need to transport most of the electricity over long distances, for instance, in the winter period where you have less sunshine. And it doesn't have any effect on the cost of transmission or distribution upgrades at all.

This is very country specific. Therefore, you also see very different solutions to what amount of money should be paid to prosumers. You had some countries where policy makers decided to pay prosumers price for the electricity, which is actually above the retail electricity price. We, for instance, saw this under the general FIT legislation in Europe in the 2000s. But also in Australia in 2008, 2009. Then, we entered the phase of NET metering 1.0 where any excess electricity was remunerated exactly at the retail adjusted price.

And in the last, well, five, six years, different concepts have emerged with alternative remuneration levels for excess electricity. First of all, the whole value of solar approach which has been followed in some jurisdictions of the United States where you actually look at the different values of solar PV and cost of solar PV in a very particular electricity market. And then, you'll try to quantify all of these costs and benefits of solar PV. And then, you come up with a value that you would be willing to pay for each and every kilowatt hour that is fed into the grid.

Some jurisdictions also took more simplistic approaches when they said, "Hey, we're only going to pay you what it costs in the fuel costs of our utility or we only pay a wholesale electricity price for any excess electricity that you feed into the grid." And some of the more restrictive polices even said, "Hey, any excess electricity that you feed into the grid actually has to be given to the grid or given to the utility for free and you are not getting any compensation for this." This is just to show you the variety of different values of distributed solar PV, which have been attributed to solar in different markets around the world.

What is relatively clear, maybe four major takeaways when you look at NET metering 1.0 and the concept of grid parity. In the first step, I always recommend that policy makers should assess the value of solar PV within the very specific jurisdiction by looking, for instance, at the effect that solar PV has on distribution network upgrades, transmission network upgrades. Also, what kind of ancillary services solar PV provides to the electricity systems, stabilizing it and so on.

And then, in a second step, you actually adjust the provisions and payment for excess electricity to this value of solar PV. What you see in many markets around the world is also that prosumers are forced into time of use tariffs to also incentivize some more electricity friendly behavior of these customers. And what is also becoming more and more evident is that prosumer would also need to pay some non-bypass-able charges, these other taxes and levies that we just discussed a couple minutes ago. That they would also need to pay them because these taxes or levies are not only implemented to pay some overall cost of the electricity system where it would not be fair to say only normal customers need to pay them and prosumers are kind of exempt. This was a little excursion from NET metering 2.0, 1.0 in terms of, with regards to the concept of grid parity.

What is also very important to keep in mind is that grid parity differs from one customer class to the next, and this is also frequently overlooked. That there is a fear that all of a sudden, all of the customers in a country will move away from buying electricity from the utility and everyone at the same time will start deploying solar PV on their rooftops. This is normally not the case because the electricity prices that different customers need to pay are significantly different.

In most markets around the world, we have these types of customers. We have low-income residential customers, which normally only have to pay so-called lifeline tariff, a very low electricity price. Especially in developing countries. Then, we have residential, commercial and industrial customers. And then, we frequently – especially in developed countries or so-called developed countries – we also have industrial customers, which are energy-intensive industries and they are normally benefitting, to a certain extent, NET by purchasing large amounts of electricity. And they also get very cheap prices or they are, in fact, subsidized by the electricity system design because, well, in all of the cases, they're actually a subject to international competition.

When we look at these now and the typical rates they have to pay, we also understand that grid parity does not happen to all of them at once. Looking at example electricity prices in developing countries, we actually see frequently cross-subsidization from the industrial and the commercial sector to the residential sector. You see on the very left, the lifeline turf. Let's say it's three cents per kilowatt hour. Then, it's slightly higher in normal residential tariff. This is also normally the planning point rate tariffs. That goes up with increase monthly within a household. If you want to learn more about this, please check out the sessions on rate design. And then, we have normally relatively high or even quite high commercial and industrial electricity prices, which are often used to subsidize the residential and the low-income households.

If you then say, "Hey, our LCOE of solar PV is around 14, 15 cents per kilowatt hour," you quite easily see that especially for commercial and industrial sector, self-consumption makes sense. We have already reached grid parity here, for these customer classes a long time ago. And this also reflects the reality in many developing countries that especially the commercial sector which is normally comes from a very high electricity prices. For instance, hotels or any other commercial activities. Big malls. They are very interested in deploying solar PV on their rooftop because, for them, the savings can be gained. And with very short payment theory, maybe it's just two, three, four years.

Industrial sector, of course, a little bit more different because their electricity amount usually exceeds the roof space they have available so they are normally looking at different ways of procuring solar PV, large scale solar PV in terms of copper PVAs. But that's a different story. It looks very much different when you compare developing countries with so-called developed world where, for instance, in Europe we have normally customer classes which are the same but which face very almost opposite electricity prices.

We normally have the residential and the commercial sectors subsidizing the industrial and energy-intensive sector. And therefore, when you also look at an LCOE of solar PV in the range of 15 cents, maybe it's only 10 cents a day but the story is more or less the same. You see that, yes, for the residential and for the commercial sector, it makes a lot of sense to invest in rooftop solar PV because grid parity has been reached a long time ago. However, for industrial customers and especially for energy intensive industries, this is not a relative cost competitiveness benchmarks because they're actually getting cheaper electricity by buying it directly from the electricity wholesale market.

What is also very important to note is that different customer classes also have different expectations when it comes to monetization periods and also rates of return. Some analysis also on behalf of the IARATD program show that for the residential sector in the developed countries will frequently see relatively long payback periods up to 15 years fine for people living in their house because they know that they're probably going to still be living there for another 20, 30 years. They don't really mind having this long period and payback periods.

Already in the commercial sector, this is significantly lower because business doesn't really know what will happen in the next 10 years. Normally, four and five years is the timespan which they can foresee to a certain extent so they're normally looking at payback periods of, well, four, five, six, seven, maximum eight years. But anything longer than this is actually out of scope for them. And this is even shorter when you look at some of the expectations in developing countries. That's due to additional regulatory risks and multi-ability risks. We are actually looking at payback periods of less than five years in order to make self-consumption a reliable prospect.

And as I mentioned before, there's also differences regarding IRR expectations. In the residential sector in so-called developed country, we normally have relatively low IRR expectations because when you look at IRR expectations, you also look at alternative investment opportunities. But since you no longer already getting a lot of money in the US and Europe when you leave your money in your bank account because interest rates are so low, actually also your expectations on any other alternative investment are not very high. And you also have to keep in mind that solar PV on residential rooftops are frequently not IRR driven. In many cases, the value of the property is much more important but you also have other motivations that showing a neighbor that you're an environmentally friendly guy. That your new status symbol is not a lascivious garage but rather a solar PV system on your rooftop. And this might also be a motivating factor for people.

In developed countries, the commercial sector normally has IRR expectations of 8% or higher. However, when you look at developing countries, again, you see that expectations on returns are much higher. 10 to 20%, sometimes even higher than that 'cause of the increased regulatory risk, ability risk and also more restricted access to capital on the banking side.

The next aspect which makes grid parity look a little bit more complex, grid parity differs depending on your rate structure. And here, I wanted to highlight that there's already two index sessions, two hours in depth on solar

PV and rate design so please also check them out if you want to learn more in this aspect. Here's just a few of the highlights.

When we look at a typical residential customer in many countries in many jurisdictions around the world, they are either 100% volumetric charges or you have a very small fixed charge. Volumetric charge means that all of the payment a utility operator receives from you are actually paid per kilowatt hour and not per kilowatt installs or as a fixed cost, fixed monthly cost that you would have to pay to the utility. However, this is currently changing. You see more and more utilities in the wake of self-consumption and solar PV rooftop systems that want to increase fixed charges. And as you probably know, this actually has a negative effect and it delays grid parity. And it also, some people argue, disincentives solar PV because putting a fixed charge on a solar PV owner is not fair. You would also not put a fixed charge on insulating your home and, thereby, reducing the amount of kilowatt hours you purchase from the utility. However, that's a different discussion. I don't want to go into any detail here, just that you keep in mind that by increasing fixed charges, reducing volumetric charges but also by introducing demand charges are the changes to your rate design you can actually delay grid parity quite considerably.

What is also interesting or important to keep in mind that, of course, time-of-use tariffs will also impact grid parity quite considerably. Here, is just an example from Australia where you can see that actually when you look at the peak tariffs, grid parity was already reached in 2010, 2011. However, for the off-peak tariffs, this was only, grid parity was only reached four or five years later. And of course, when you have subsidized electricity prices as we have discussed before with lifeline tariffs in developing countries, you actually see that you might not get to a point of grid parity anytime soon because these electricity prices are so l wo that it might still take a decade or more until the LCOE is less than the subsidized electricity price for low-income households, which probably requires different types of policies that you would need to put in place in order to allow low-income households with lifeline tariffs to also invest in rooftop solar PV.

As we mentioned before, please also check out session eight, A and B, two hours on rate design. This might be of some importance to come back to this session.

These were just some of the concepts that you need to, some of the aspects you need to understand when you really want to understand grid parity but I also wanted to discuss with you some of the more general barriers to rooftop PV uptake based on grid parity and self-consumptions. And here, I particularly wanted to highlight two barriers being the availability of roof space and also access to capital.

Keep in mind the availability of roof space can also be a barrier to self-consumption after grid parity has been reached. When you do the analysis in different countries, you see that grid parity has been reached already for a couple years. And when you just look at the economics of a solar PV system alone, you would expect that already 100, 200,000 households have installed solar PV on their rooftop. But then, when you look at the reality on the ground, you can actually see many countries around the world – but it's not a couple 100,000 people having installed solar PV on their rooftops – but maybe it's just a couple of hundred, a couple of thousands. And we want to understand why this is the case. And I wanted to just highlight two aspects and one of them is availability of roof space and the other is access to capital.

The availability of roof space, first of all, it would probably make sense to do an analysis in your jurisdiction, how much roof space there is actually available for solar PV. This may actually be an important component of designing the electricity system of the future because you can already see how much electricity you can supply potentially with just rooftop solar PV. What is also important to realize is roofs of low-income households in many developing countries are actually not sufficiently stable to hold a solar PV system for a period of 50 to 20 years. These are frequently, you have to take them out of the equation. Once you have analyzed the full potential of roof space in your country, you might actually look at the actual structure of the housing and see which house is actually able to hold a solar PV rooftop system for the next 20 years.

Then, another very important problem in many countries is also the landlord-tenant problem. If I'm renting my house and I do not really know for how long I live in the house, do I still have an incentive to put a rooftop solar PV system on my roof? Or is maybe the landlord willing to install it on my behalf? And I pay him a little bit and then a very low electricity price. In any landlord-tenant relationship, of course, becoming a prosumer becomes very much more complex. And it is no longer straightforward as when it's my house and I live in this house. And I consume electricity on my own.

And what is also a frequently discussed issue is the fact that depending on the solar PV policy if it end up being NET metering or NET FIT fueling turf, do I actually make optimal usage of the roof space that is available to me or do I have an incentive via the existing NET metering regulation, for instance? Do I only optimize my self-consumption ratios so that I consume 89% of the electricity that I also produce on my rooftop and I avoid any excess electricity that I would have to feed into the grid? However, this, of course, leads to a situation where I scale down the size of my solar PV system and that might actually take full advantage of the roof space that is available to me. The roof space can be a very constraining element.

What is even more constraining is access to and cost of capital. Here, we have to differentiate those access to capital can be especially difficult for low-income households. You have to keep in mind that rooftop solar PV, that that accurately structures is not only different from that sort of largescale solar PV or largescale solar PV and frequently have 70% depth involved and normally 30% equity. However, when you look at rooftop solar PV, you frequently see that either all of the costs are just equities and are just out of the pocket of the prosumer or at least a very important fraction of the overall capital cost that is actually equity. And very little depth is normally involved.

That, of course, also depends on the disposable income, especially in developing countries. Do they actually have some money left at the end of the months which I could potentially invest in a solar PV system? And then, of course, the economics play an important part. As mentioned before, you normally have very high IRR expectations and very short-term payback periods required in developing countries in order to make any investment attractive at all.

What is frequently overlooked, as well, other additional risks for any finance space in self-consumption. When you can compare, for instance, having a solar PV on your rooftop which you can finance via feeding turf whereas this solar PV rooftop which you find via NET metering scheme, you have the risk that, for instance, your own electricity demand changes. In the residential sector, this could be because you insulate your house better. In case you heat your house with electricity or you decrease your electricity by other means. However, this is especially important for the commercial and industrial sector where any efficiency merges can lead to rather drastic decrease in electricity demands. If I want to size my electricity system on my rooftop optimally in a self-consumption world, I also have to take these future electricity demand decreases into account due to energy efficiency measures.

As mentioned in more detail in section eight that nay change to the rate design, for instance, introduction of fixed charge can undermine my investment in the self-consumption but there may be also introduction of other levies or taxes which may happen during the payback time of my solar PV system. Changes to the NET metering policy or other self-consumption regulations, changes to tax laws might also undermine my investment and also changes towards the electricity market design in the world of regulations. You see those, actually, a handful of risks that you have to face when you want to finance solar PV systems with self-consumption alone.

And therefore, we normally recommend that next to your self-consumption policy to at least have some very low payment for any excess electricity that you could potentially feed into the grid 'cause this could then be really a fallback option for any investor who says, "Okay, even though I might consume less in my own household because I put in some energy efficiency measures, even though there is fixed strategies, I still have the chance to feed all of the electricity that I've produced back into the grid. Even though I don't get a lot of money, the money that I get per kilowatt hour might actually be sufficient to get some interest in access to finance from my solar PV which is consistent."

Risk is, of course, also plays an important part when it comes to access to capital costs. Not access to capital but more capital costs. Here, just an example from an analysis in the European Union where they were actually comparing the weighted average costs of capital for different power generation technologies. Here is an example for wind but the same is actually true for solar PV so that you can see that in some of the areas in the sunny southern areas of Europe and Greece and Spain, yes. You have better solar radiation but you also have higher costs of capital, higher interest rates and also higher IRR expectations. And when you're actually combine this with an assessment of your resource qualities or your solar radiation, you can see that even though Germany has much worse solar radiation resources, the cost of capital has very low interest rates. It's actually outcompetes its other _____ and solar PC is actually cheaper to deploy in Germany than it is in Greece despite the solar radiation levels.

Last but not least, I wanted to end with a little excursion and I wanted to look with you at the concept of the so-called death spiral. And I put in brackets here don't use this terminology because it's really a little bit over exaggerated. But nonetheless, I wanted to highlight this, that it becomes clear to you what it is once you hear this argument. I tried to put this into some nice visuals, that it becomes very intuitive for you.

First of all, let's look at some of the simplistic claims, again, related to grid parity. "It is a final nail in the coffin of centralized electricity market and utility businesses. And no one will ever buy a single kilowatt hour from the utility anymore." And these very dramatic statements are also reflected in the statements or in the concept of the death spiral, which I just wanted to illustrate in a very simplistic way.

Let's look at an electricity system where the network cots of distribution and transmission network costs need to be paid by all customers. That means prosumers and also the normal customers, the non-prosumers who do not produce a kilowatt hour on their rooftop but who just buy each and every kilowatt hour from the utility. Now, when we move to a prosumer world and we have an electricity system which, where electricity customers are paying electricity mostly on volumetric charges so per kilowatt hour. We are actually entering a situation where the prosumer no longer pays the same amount of money for the total network cost as the prosumer does.

Please keep in mind that this is an overly simplistic illustration. The prosumer is very happy and the non-prosumers are not too happy because they now have to pay a total share of the network costs because one of them has actually changed sides and went to the prosumer cut. This does not only make the non-prosumers angry but it also makes them become a prosumer as well because they have additional incentives because the electricity price has increased a little bit so they were reaching the level of grid parity. And this led them to a situation where more and more of the normal customers will become prosumers.

According to the theory of death spiral, everyone then will become prosumer. Everyone will just produce each and every kilowatt hour with the solar PV on their rooftop. We, of course, have learned that this is not going to be this case. But this is at least an illustration. And in the end, there will only be one guy left who will have to pay the entire network cost of the entire system on its own. And he will have to pay billions by having to face higher network costs from, in his electricity bill.

Please keep in mind that this is really a simplistic illustration on a case study here, in Germany. Looking at Germany in the year 2017, we had about 1.6

million solar PV systems started in _____. And 1.5 million of them – more than 80% – were actually installed on rooftops. Very fit for self-consumption. And the retail electricity prices – I've shown you actually somewhere else before – is actually very much higher than the LCOE of solar PVs. Three times higher. We have very, very strong incentives for maximizing self-consumption, even combining solar PV with the metric. You have very attractive returns, rate of returns and you have very short payback periods for refinancing the solar PV system.

And on top of which, we did some analysis off the total available roof space available in Germany and the total potential for up to 260 gigawatts of solar PV on German rooftops. According to the concept of the death spiral, this is actually the perfect storm. These are the perfect conditions for any death spiral. However, let's look at some of the realities.

With these 1.5 million solar PV use systems, this is only accounts for 8% of the total electricity demand and please keep in mind that the self-consumption ratio for Germany and other countries around the world is about – in the residential sector – 25, 30%. You're still purchasing 75% from your utilities. Only 2.5 terawatt hours are actually self-consumed solar PVs. This is only 6.2% of total PV generation and only 0.5% of total electricity demand within German. With this 1.5 million rooftop systems, only 0.5% of total electricity demand is actually generated via PV self-consumption.

Yes, it is true that PV self-consumption will increase in the future and when combining solar PV with battery storage, this will probably increase even further. But it will always be just a small fraction of the overall market. And this is just like in any other market development when you introduce independent power producers, for instance, a certain market share simply just goes somewhere else. This is the same in the case of solar PV and distributed generation. This will become a certain markets hare but it will not become, all of a sudden, the overall market share. And this is something very important to keep in mind.

I also have to put the disclaimer here that this is really the German case study. It might look very different when you look, for instance, at a small island like Mauritius where you don't have so much commercial and industrial electricity demand or maybe weren't aware most of the electricity demand comes from the commercial sector. And the commercial sector has a strong incentive to put solar PV on the hotels, for instance, in Mauritius so then, all of a sudden, the impact on the total energy consumptions on the total electricity system is on refinancing the entire electricity system might be felt much more immediately. We also used analysis within each and every US jurisdiction, which is every jurisdiction for the desert as it claimed, there is no death spiral where all of a sudden the utility will go bankrupt from one day to the next. It is just that a separate market share will probably go to the self-consumption sector and the system simply has to adjust to this.

Here, just a quick summary of the various aspects that we have discussed today. I hope it has become clear to you now that the concept of grid parity is not as simplistic as some of the simple claims sometimes suggest. Yes, grid parity is an important milestone for distributed solar PV generation but it is certainly not the last nail in the coffin of utility businesses. Actually, grid parity is relatively complex because you need to understand the differing cost competitiveness benchmarks of PV in order to understand different customer classes and that not all customers will move to self-consumption classes simultaneously. You need to understand rate design, the impact of fixed charges, of term abuse rates and so on. And what is also very important when you look at potential growth of the distributed generation market within your country, please also do not just look at the pure economics of self-consumption and grid parity. But also, take some of the limiting barriers into account like the ability of roof space but also the access to capital and the cost of capital.

Thank you very much for listening. As always, you get a lot of further reading here on NET metering and grid parity and solar PV. Thanks very much and we have the International Solar Alliance and the Clean Energy Solutions Center. As always, there's some final knowledge checks at the end of this. And I'm really looking forward to hearing you soon in the next webinar. Thank you.