

The Role of Rate Design, Part 1: Traditional Rate Design: Volumetric, Fixed, and Demand Charges

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David Jacobs

Hello, everyone. Here's David Jacobs. I'm here to present the training course organized by the International Solar Alliance and the Clean Energy Solutions Center. And today's session, Session 8a, is going to be on rate design. Just to highlight this already at the very start, we're going to have two sessions on electricity price rate design, because this is a very complex topics, so we will have one session now, and you can click on the other session later. So, as mentioned before, this training series is organized by the International Solar Alliance and the Clean Energy Solutions Center. I am Dr. David Jacobs, with more than 15 years' experience, by now, in renewable energy policy, so I'm very glad to guide you through this webinar on rate design.

As you probably already know, this is a training course with eight different modules; this course on rate design is part of the first module, policies for distributed solar PV. And next to these two training units on rate design, I also recommend to check out some other training sessions, especially number two on the introduction to solar policies, covering net metering, net billing, net fit, _____, and auction. But also the sessions three and six, which take more of a deep-dive on compensation mechanisms for rooftop solar PV, and then again, on net billing and net metering, because all of these subjects are highly interrelated. Just to give you an overview of this training session, so, first of all, we are going to define the learning objectives for today. We will then discuss traditional rate design options, namely, volume metric fixed and demand charges, have an outlook to the second session on rate design.

There will also be quite a substantial amount of further reading for you to dig deeper into this topic. And at the very end, there will be, then, multiple-choice questions in order to have a little knowledge check for you. As said before,

there is also going to be a second session on rate design, where we're going to have a closer look at smart rate design, including time-based and locational incentives built into the rate design. We're also going to look at understanding prosumer rate design, so, two-way tariffs like net metering _____ policies. And what is also very crucial when it comes to rate design and roof-mounted solar PV is, of course, an understanding of the costs and benefits that distributed solar PV has in electricity systems and distribution networks especially.

Then we'll finalize with concluding remarks, further readings, and, again, a knowledge check. So, let's first of all take another look at the learning objectives for today's session. First of all, in order to get started on rate design, we need to understand the impact that renewable energy sources in general, and distributed generation like roof model solar PV in particular, what their impact is on power systems. So, there's going to be a little introduction on that, just as a reminder for you. In order, then, to understand the link between the ongoing discussion that we have about modifications to rate design, and government plans to increase the share of renewables and distributed generation.

Then, we take a look at the fundamental of electricity market rate design, so, how does a normal electricity bill actually look like. And finally, the last 50 per cent of the session, we'll then take a deeper dive into the what we call classic rate design options, and that is volumetric rates, fixed rate design, and also demand charges. Before we get started, I should say that we've been trying to use as little acronyms as possible for this webinar, however, when you read literature on rate design, you will stumble upon a large number of acronyms and abbreviations. And here's just a little list of them, and you should probably get familiar with them, because this is some terminology that you will always stumble upon once you deal with rate design. For instance, RTP, real-time pricing, or CPP, critical peak pricing—these are all terminologies you will get familiar with today and also in the next session, in order to get a better understanding on rate design.

So we have included this glossary for you. So, let's first have a look at which part of the market is actually regulated when we talk about rate design, and there's two fundamental differences. In fully liberalized electricity markets in the European Union, also in other parts of the world, when we talk about rate design, we're actually only just talking about a small fraction of the overall electricity bill, and that is the network cost. You can see this here in this figure. About 25 per cent of the electricity bill in the European Union are network costs, and out of this, about 80 per cent are related to the distribution network.

And when we talk about rate design, we're actually talking about this little fraction of the overall electricity price. The other price components are usually determined by market force, so demand and supply in the case of the energy component, 'cause we're talking about competitive wholesale markets. And then the other components, the levies and the taxes which are substantially high in some fully liberalized markets, are then regulated by

legislation. This is substantially different in not-yet-fully liberalized markets, in the case of vertically integrated utilities, as you see them in many developing countries but also in large parts of the United States. When we talk about rate design, we're actually talking about all components—that means generation, transmission, distribution, and then also the supply of electricity to the final customers.

So, all of these components are then bundled together, and usually just highlighted in a few prices that are shown to the customer, for instance, fixed and variable costs. However, also, in virtually integrated markets, we're now seeing movement that the costs of the system are more and more unbundled, also to give consumers more transparency on what cost is actually associated to what part of the electricity system. And of course, the rise of prosumerism and DG—that means distributed generation _____ one reason why we see also a greater differentiation in rates, also in vertically integrated utilities. Because once we have a two-way tariff, of course, we need to know how much money I'm actually getting for inserting electricity into the grid, and how much am I paying for withdrawing electricity from the grid. So this was just a general introduction that you are aware of the fact that, yes, there are differences in what rate design actually covers in fully liberalized and vertically integrated market.

Now, as another part of the introduction to these two sessions on rate design, we want to understand the link between renewable energy _____ rate design, and there's actually two major aspects which are important for us to remember or to understand. And this is, first of all, we have an increasing share of variable renewable energy technologies—that means wind energy and also solar PV—in many electricity markets around the world, and this has an impact on the requirements on rate design. And secondly, we're also seeing an increasing share of distributor generation, because of small-scale renewable energy technologies like roof-mounted solar PV, and this also impacts rate design and puts additional requirements on how we design electricity rates in all jurisdictions around the world. So I just wanted to shortly look with you at these two aspects. We keep in mind, right from the start, why we're actually doing this exercise of redesigning rates while the share of renewables is increasing.

So let's first take a look at the impact of renewables on power systems all together, of variable renewables. As you all know, once we see an uptake of variable renewables, we will need more flexibility in the system, because the sun is shining when the sun is shining, and the wind is blowing not when the electricity is needed but when the wind is blowing. And, therefore, the other power generation technologies will have to supply flexibility on the supply side, and on the other side, we will also need more flexibility on the demand side. So that we have more electricity consumptions in terms of high output of wind and solar, and less electricity demand in times of low output of wind and solar plants. I will just show this quickly in a few graphs, which I frequently use in presentations from Agora Energiewende.

They're just showing typical weeks of power generation in Germany, in the year 2022, so, not too far away. And you can see, here, that there's a lot of variation in the output of wind and solar—wind is the blue _____ and solar are the yellow ones. And you can see that, on a Saturday and Sunday in year of 2022, you even have oversupply, so to speak, of power generation. So these are periods when, actually, it would be nice if the electricity demand would adjust to this oversupply and increase, so we would then need to have an incentives for increasing electricity demand within the system. Here, again, another month, August, where you can see there's quite sharp daily variations, so flexibility would also be needed on an hourly and daily basis.

And here, another slide, in November, you see that there will also be periods in the system where there's relatively little electricity supplied by wind and solar. This is, on the one hand, where conventional powerplants will have to step in, but a lot of the variations can also be covered by more flexibility on the demand side. So this was really just a quick memory of how future electricity systems will look like, and this, of course, has some impacts on rate design. So, first of all, we have high variations, seasonal, daily, and also hourly, so we need customers to react to price variations, which will then hopefully be built into the rate design. So we're then talking about temporal differences in the prices that you pay for the electricity.

We saw, also, that there's times of very low RE penetration. This is periods where we would like to incentivize customers to use radically less electricity. And as I mentioned in the first slide, there's also times when we have an excess of RE generation, and in these cases, we would like to incentivize customers to use more electricity, for a number of hours. So, these are the key takeaways, and also key requirements, for future electricity systems, which in many parts of the world are going to be highly reliable on variable renewable energy sources such as wind and solar [audio cuts out]. So, this was one side of the coin; the other side of the coin is dealing with more renewable energy integration in distribution networks.

Because most of _____ solar PV is connected to the distribution network, and no longer, as in the old power system, it is all large-scale powerplants are connected to the transmission network, then the electricity goes down to the distribution network, and finally it just reaches the final consumer. The new or the modern power system looks a lot different, especially on the distribution level. We will see a variety of power generation sources, PV, other distributed generation sources, storage options, and interlinkage with the transport sector, heating sector. Also, the influx of other electricity generation _____ transmission grid, and so on. So, all in all, what this picture from the International Energy Agency is showing is that things will get more complex, and we will need a lot more communication and a lot more technical solutions, in order to stabilize the grid at all times, even though we have the smarter power generation and storage units integrated in the distribution networks.

So, in this new world, we then talk about two-way flow of power; we also talk about advanced metering, remote-controlled units, so that the system

operator can always stabilize the network. And we, of course, also need to establish compensation mechanisms for consumers—there will be a session on net metering and self-consumption, as I mentioned before, as part of this training course. And last but not least, what we also need is that we have incentives for the right behavior of all actors within these networks. And that also means that we might not only need temporal incentives—so, for different times of the day, times of the year—but we might also need different locational incentives. Because you might have a congestion happening in one distribution network at a certain time, but not in the other.

So this is why the second session on rate design, which you can watch later, will also look at locational incentives, which can be implemented in order to make future distribution networks operate smoothly. So, this was just an introduction on the impact of renewables on power systems. Now let's take a first look at the very basics of electricity rate design. So first of all, before we even start at the electricity prices themselves, I always suggest that the most important part is that you first of all define the objectives which are related to your rate design. And here we have a large number of objectives, so as a policymaker, it would probably make sense to establish a hierarchy of these different objectives.

And then, based from these objectives that you have, you can calibrate the rate design. Sometimes, this is happening the other way around, that first _____ people start designing rates based on some macroeconomic calculations. However, I think considering the political objectives first, and the changing landscape of political objectives, is crucial for really coming to a rate design which is also accepted by all or at least most members that are part of the power system. So, rate design was relatively straightforward, let's say, until 10-20 years from now, and these objectives, I call them here traditional policy objectives related to rate design. And the most important one was to enable cost recovery, cost of service recovery, either for the network operator or for the utility, so that all customers will then benefit from reliable services from the utility or from the network operator in the future.

So that all costs which are borne by the system, all the electricity lines they had to build, for instance, all the costs need to be recovered by all, by the prices that all consumers pay together. The cost recovery is a very important objective. The other one is cost efficiency. And this is that policymakers, of course, want to create an overall efficient power system, and in order to do this, you need effective price signals to all participants of the electricity network. Because we have also seen power networks where, for instance, power generation units were overbuilt, you had too much electricity generation units installed, or too many other electricity transmission grids built, and in the end, all consumers had to pay more than they actually would've paid under a very cost-efficient system.

Another set of traditional policy objectives is the cost causation principle, so, who has been using the electricity grid, where was it used, and when was it used, and also, to what extent. So that, depending on the degree of usage, you would then have to pay your fair share for financing the overall infrastructure.

What is also very important, especially in many developing countries, is, of course, fair cost allocation among all rate payers. And here, fairness does not only mean that it should be aligned with the cost causation, but it should also be in line with the ability of different consumer groups to pay. So that should be consistent with the principle of equity and affordability, and this is why, for instance, in many developing countries, we see a lot of lifeline tariffs, they're usually called.

So that you pay a lot less for your electricity for the first couple of hundred kilowatt hours that you're using, because this is normally what all people need that are connected to the grid, and the very poor should benefit from this lifeline tariff and pay less. What is also very important, as a traditional policy objective, is to assure affordability, so this is closely connected. So, for low-income households or other specific groups of the society, there might be specific tariffs. And there is frequently, also, a cross-subsidy in developing countries, meaning that, in many cases, the commercial and the industrial sector are actually cross-subsidizing the residential sector, so that the normal populations, the residential sector, won't have to pay lower electricity prices. So these are the traditional objectives; now we're looking at some of the emerging policy objectives, which have been discussed and implemented in many jurisdictions around the world, let's say, in the last 5, 10, 15 years.

And this is, first of all, an incentive for demand side flexibility, as we have just discussed. In modern power system with higher shares of variable renewable energies, you might want to consider locational and temporal incentives, in order to increase the flexibility also from the demand side. What is also frequently included, nowadays, is incentives for energy efficiency, and also peak demand reduction. Because the peak demand is usually the most costly units in the electricity system, because they determine how much peaking capacity we need to add to the system. So there have been, frequently, incentives to reduce this peak demand, in order to also assure a cost-efficient overall system.

Many policymakers are also trying to incentivize technological innovations, be it with energy management technologies, but also with distributed renewable energy technologies such as solar PV. And what is frequently coming to the forefront of the discussion is sort of a balance between the interests, first of all, of the utility or of the network operator, and then those of prosumers—that means, people who are both producing and consuming electricity, so, households with solar PV on their rooftops, for instance. So these are a few of the emerging policy objectives. There is another very important one, and that is customer empowerment. First of all, many customers want to have more access to the data, to their own power consumption data.

So, many jurisdictions around the world have actually established regulation that utilities need to show, either on a monthly or an annual basis, they need to show how much power has been consumed, maybe even over what period of times during what period of the days, and so on. So that's been very crucial in many countries around the world. And also, to a certain extent, customer

education can be done by more detailed rate design, because customers will then understand during what hours they have been consuming most of the electricity, and whether they could actually shift some of the electricity demand to periods with a higher supply of electricity, and so on. So that's also become a crucial component in many countries. So, therefore, they would need more timely and more granular information, and they would also need to get sufficient early strong price signals, either timely or locational, also, per customer type.

In addition to that, a very important question is always what part of the electricity system or of the network cost are actually fixed cost, and which part of the electricity system, of the network, are actually variable cost. And there's very different views about that. Usually, utilities argue that most for the costs are actually fixed; they take a short-term perspective and say, "Well, I built this power plant, and I built this transmission line, so somewhere I need to get my money back. So, these are fixed costs for me, and I have to pay for them for the next 20-30 years." However, what is very important to understand—and you can read several books about this and still learn more—is that economic theory actually suggests that, in order to come up with an efficient electricity system in the long run, we should actually consider almost all of the costs of the electricity system as variable costs.

Because when you look at it from a longer-term perspective, you will see that a powerplant, even though it might be standing there for another 20 years, it will be removed eventually and replaced with a new powerplant, or a transmission line might have to be extended or even reduced in size. So, actually, from an economic perspective, almost all of the costs of the power system are variable costs. And this is a very important discussion, as you will see in the next couple of slides, because there are some people saying we should have more fixed charges because there's a lot of fixed costs. Whereas, most economists argue that this is actually not the case; most of the costs in the power system, from a long-term perspective, are variable, and, therefore, we should also reduce fixed charges to a minimum, and, rather, rely on volumetric rates.

And what is also emerging, more and more, is the credo to apply gradualism. So, when you start changing the electricity prices, do this in a very gradual manner, step by step. Maybe you can even start with test cases in certain regions, in order to see how consumers actually react to the new rates that you're imposing. Some jurisdictions have also said that existing customers which have already adopted, for instance, roof-mounted solar PV, will not have to change their rates—this is normally called grandfathering. They will be able to remain under the existing, for instance, net metering terms that they have been offered, until they have been able to pay off the solar PV system which they have _____ or financed, in the first place, based on the assumptions that they will be able to benefit off the existing rate. So, this gradualism is very important, and keep in mind that there's usually not an abrupt uptake of distributed generation, but this is actually happening in a rather granular way.

And even when we talk about small shares of distributed solar PV and distribution networks, you probably don't even need any changes in the first years at all, and then you can start with gradually adjusting the rates. So, once again, to come back to my first major recommendation is that, first of all, you should really define these objectives and come up with a hierarchy of these objectives, and then do the rate design calibration. Because thinking about all of these different objectives which we have now gone through will actually help you very much, as a policymaker, to come up with a rate design which takes different points of view into consideration. And which is also able to solve some of the tradeoffs which we have discussed, and which are still going to discuss. So, moving on from the objectives of rate design, now let's look at how typical electricity bills actually look like.

So, in this session, now, we will look at volumetric charges, fixed, charges, take a quick look, also, at minimum bills, and then look at demand charges. And as I've already mentioned before, in the next session on rate design, we will also look at more innovative rate design, so-called smart rate design, _____ look at time-based and locational incentives which can be built into rate design. And also, rate design specifically targeting solar PV on roof-mounted systems. So, for the residential sector, we normally have two options. Either we have entirely volumetric charges, so 100 per cent of the charges are volumetric.

In some cases, you also have a small fixed charge component, which is usually implemented to recover the cost associated with the cost of metering, meter reading, billing of the utility, et cetera. So, this is what a usual residential customer bill would look like; even small-scale and commercial customers usually have this type of structure. When you look at larger-scale commercial customers and industrial customers, you normally see a three-part component electricity bill, composed of volumetric charges, so per unit of electricity consumed, fixed charges, as I mentioned before, related to metering and billing. And then also, we usually see demand charges implemented, which are usually associated with the maximum electricity demand of a certain customer over a certain period of time. And these demand charges have been implemented, traditionally, in order to reduce peak demand from each and every customer.

Because, as I mentioned before, these peak demand units, if they coincide with the system electricity peak demand, then they could lead to some substantial additional cost for the electricity system all together, and make the overall system less cost-efficient. So, traditionally, demand charges have been implemented for large-scale electricity consumers—that means industrial consumers and large-scale commercial consumers. Now, looking at all these parameters one by one, now, let's start with volumetric rates. So, volumetric rates is really the most basic type of rate design; we're talking, here, about prices that are charged for each and every unit of electricity, so for each and every kilowatt hour of electricity that is consumed. And we already had this discussion about fixed costs, and variable costs, and the electricity system.

I just wanted to highlight, on this slide, that also other industries where you have higher fixed cost—for instance, the airline industry where you, of course, have the airplanes which you have to buy in advance, the hotel industry where you first of all have to build the building and then have customers—many of these industries are actually working on purely volumetric basis. Because, well, once you start an airline company, you don't have a set of customers which pay you a certain fixed charge. But you will actually have to recover all of your costs—that means, the variable cost and also the fixed cost—via volumetric charges that you put on your final consumer. So, it is not something very unusual, from an economic perspective, that even in industries where you have short-term fixed costs, all of the costs, the variable ones and the fixed ones, are recovered on a purely volumetric basis. When we talk about volumetric rates, actually, the most common design of volumetric rates are the inclining block rate structures.

I've already mentioned this before, that for the first couple of hundred kilowatt hours, especially in many developing countries, you normally pay less per unit of electricity. And then, once you reach a certain threshold—for instance, here in the graph, it starts at 350 kilowatt hours—you see that the price actually goes up. And then, at 600 kilowatt hours, it goes up another step. So, depending on each and every household's electricity demand, the prices for each unit of electricity will increase the more you use. And this is very beneficial for low-usage, low-income households, because they will usually just fall into the first block here.

And they don't have to pay the higher prices for the higher blocks, because these are normally paid by households which are wealthier and have more electric appliances, and, therefore, also consume more electricity. And thus, they pay more and they also contribute more to refinancing the overall fix costs of the systems. What is also interesting to note, since we are here on a training for solar PV, is that, of course, with inclining block rates, you also have an implicit incentive for self-consumption based on roof-mounted solar PV. Because once you self-consume a certain share of electricity, you can reduce your electricity demand, and, therefore, you cut off, normally, the highest block of electricity payments that you have. And this is then, normally, your benchmark when you compare the _____ of the PV system on your rooftop with the retail electricity price that you have to pay under an inclining block rate structure.

You have an incentive because you always want to cut off the _____ block, which is normally, in frequent cases, also coinciding on a timely basis with peak electricity generation from solar PV. So, you are able to erase this block from your electricity bill, and maybe you can even fall into a lower overall category of rate payment. Here is just one example, here from China, from the province of Zhejiang. You can see that this is a province where there's no fixed costs, the whole electricity price is merely based on a volumetric basis. And you can see here, also, from this graph, that for the first 230 kilowatt hours of consumption per month, you pay a relatively low price. And as soon as you get over 400 kilowatt hours, then all of a sudden your electricity price gets a lot higher, almost twice as high.

What should be noted is, as well, that this inclining block rate structure might also help you to reduce peak load to a certain extent, because you will avoid to pay these very high electricity prices for higher shares of electricity that you're using. And, of course, it also provides an implicit incentives for energy efficiency. So, to sum up the advantages of electricity market rates based on volumetric rates, we just have a few of them. First of all, they're very simple to understand, which is important in many countries around the world. So, you just have to see the overall units of electricity that you have consumed, then multiply it with one or maybe two timed variable rates, and then you can quite easily understand where the total electricity price comes from.

They are affordable for low-income households, which usually consume less electricity. Also, from a fairness perspective, they are usually better than other rate design options such as fixed charges, because the distribution grid costs are primarily driven by peak demand, and if you have an implicit incentives for this, this, of course, helps to reduce overall costs. And what you should also note is that, in many countries, low-income households live in multi-houses building, and, therefore, their electricity peak demand is normally not affecting overall system electricity demand. I've already mentioned that they also provide an implicit incentives for energy efficiency, and also create incentives for prosumers. So, I could just stop with the webinar at this point, and say, okay, we have so many advantages of volumetric charges.

What are we making all this fuss about? Why are we actually discussing other rate options? And this actually has to do with the nature of distributed solar PV, and the ability to self-consume or self-produce a certain amount of your electricity with your distributed generation unit. And I just wanted to highlight this, well, problem that is occurring, with a few very simple graphs. So, let's look at this together. So, here's a very simplistic graph that shows three different customers, Consumer A, B, and C. And how they actually contribute to the total network costs, by fully paying, by, we're assuming, here, a case where all for the rates, all of the electricity prices, are actually just based on volumetric rates.

So, they all have the same electricity consumptions, and with their volumetric rates, they are also helping to refinance the total _____ network costs. Now let's assume that Consumer C actually becomes a prosumer, so he puts up a solar PV roof system and starts to autogenerate electricity. And then, of course, he will no longer contribute in as much as before to the total network costs, because he is saving some of his electricity generation. And since he is only repaying the total network cost with volumetric rates, he can actually decrease these costs. And this means that we have a shortfall of the network operator, and he cannot recover all the money that he needs.

So what the network operator will then do in the next round of rate design is say, "Hey, I have a shortfall here, and, therefore, I will need to get more money per unit of electricity that is consumed, in order to refinance my system." So, the next round, you would then see the total network costs for each consumer going up, of course, as a portion of the overall electricity that

is taken from the grid. So the network cost for Consumer A and B will actually rise more sharply than this one of the Prosumer C, because Prosumer C is withdrawing less electricity from the centralized network than the other two consumers. And then, some utilities have spun this further, and if this continues to happen again and again and again and again, then we will have something which is called death spiral. And since the network costs will increase for less and less consumers, there will be more and more incentives to become a prosumer.

And in the end, you will only have a few consumers customers left, who will then have to pay the entire network charges. As I said before, this is a very simplistic view of it; it's really just there that you can understand the emerging problem in the most visible way. There, of course, this constitutes some of the disadvantages, then, of volumetric rates in a prosumer world. Because cost recovery for utilities or network operators is more risky, there is a common concern that there will be cross-subsidization from one prosumers to prosumers, because the non-prosumers will actually pay part of the fixed network cost of the prosumers. And there's, then, of course, the concern that prosumers might not pay their fair share in maintaining the grid infrastructure.

This is a very dramatic view. Actually, when you look at it from a real-world perspective, you have to keep in mind that the electricity that is saved, or that is no longer taken from the grid due to roof-mounted solar PV, is very, very, very, very low in most markets around the world. So, once you start seeing roof-mounted systems emerging, until this really has an overall effect on the total electricity network, that takes quite a long time. And that, of course, depends a little bit on the structure of your electricity system. So in Germany, for instance, the residential sector is only consuming 25 per cent of overall electricity, and then 75 per cent is consumed by the commercial and—well, almost half by the industrial sector alone. So, even though if there's now more than 1.5 million small-scale roof-mounted systems in Germany, the effect on the overall system cost is relatively negligible, because the commercial and industrial sector is playing a much more important part.

That might be different in some islands, for instance, where you have very little industrial and very little commercial activities. Of course, once you, in these situations, start having prosumers emerge, for instance, on hotels and in sunny Caribbean islands, then, of course, the impact on the overall system and the ability to refinance the system might emerge much quicker. So that's really, a case-by-case analysis is required, here. So, moving on from volumetric rates, now let's look at fixed charges, because these have been usually put forward as a straightforward argument by utilities. They were saying, "Okay, we have a certain amount of fixed charges," some even say, "Well, almost of our cost are fixed charges, and, therefore, we should also increase of implement a certain share of the electricity bill of residential, and, also, commercial consumers should be fixed in order for to allow us to recover the costs."

These fixed charges are usually imposed on electricity consumers as a certain amount of money per kilowatt per month, so it's a monthly fee that you have to pay. And it should be noted that there's a differentiation: in some jurisdictions, they have only been imposed on prosumers, so that means on customers who are self-consuming electricity with solar PV systems. Or in some jurisdictions, they have actually imposed on all customers to give the broader base for the utility or for the network operator to recover their costs. I mentioned these types of arguments before; this is adapted from paper from APBA, from 2015.

You will also find this in the further reading sections below, where they argue that most of the costs, or half of the costs, are actually fixed cost from utilities. However, the fixed charges which are collected by residential builds are just 10 per cent, and, therefore, it should increase. But as we know from our in-depth discussion on the emerging objectives of rate design making, we have learned that a longer-term perspective should be applied when you come to the assessment to what is fixed cost and what is variable cost. So, maybe the share that we're seeing here with 10 percent fixed and 90 per cent volumetric is actually not such a bad idea. There are, of course, some very important advantages of fixed charges, and that is, simple cost recovery for the utility of a network operator.

Because as soon as you know that all of your residential consumers, or at least the prosumers, will pay a certain monthly fee as fixed charges, it's much easier for you to calculate the overall revenues that you're making in a certain building period, than just by relying on volumetric charges. They also, to a certain extent, enforce the cost causation principle, because as we've seen before, there might be cases where prosumers become—well, once they become prosumers, they contribute less to refinancing the fixed cost of an electricity system. So by implementing the fixed charges, you can counterbalance this, to a certain extent. And then, certainly, well, some people—most people will probably say that's not really an advantage, is that they actually give an advantage to customers with higher electricity demand, because most of the analyses have shown that higher fixed charges actually hit low-income households the hardest.

Whereas, they might actually lead to a reduction of the electricity prices for households with some very high electricity demand. However—and this is also already the introduction to the second section on rate design, where we look at some smarter ways of designing rates—there's quite a large number of disadvantages related to fixed charges. First of all, they reduce incentives for the overall efficiency of the electricity system, which might actually increase the electricity bill all together for everyone. And in some cases, they even led to the overbuilding the power system or overbuilding the grid infrastructure, because there's no more financial incentives for the utility to take a cautious approach, because you can just refinance the fixed costs that you're generating, with higher fixed charges. They also reduce—and this is the biggest problem from an energy transition point of view—they reduce incentives for system flexibility.

They no longer provide a price signal to the consumers, at what time and in which location they should produce less or more electricity. There's no incentives for behavioral adjustments, and also, existing price signals which might still come from the other volumetric component of the electricity price are undermined, they are overlaid by additional fixed charges. Another disadvantage is, of course, the disincentives for energy efficiency, and also, as we have discussed before, disincentives for new technologies such as roof-mounted solar PV. Because some people argue, "Actually, solar PV is just a reduction in my electricity consumption, and if I put on a more efficient air-conditioner on my rooftop, I'm not going to be penalized, either. So why is this happening in the case of solar PV?"

So that's an argument which is frequently brought forward. Then, I mentioned this briefly already, with fixed charges, most of the negative impact goes to low consumption low-income households. As you can see here, from an analysis in the United States, that by increasing the fixed charge from \$9.00 to \$25.00 per month, you can actually see the impact on different types of households, depending on the monthly kilowatt hours that they're consuming. And for the low-consumption households with just 250 kilowatt hours consumption per month, you can see, actually, an increase of the electricity price by almost 40 per cent. Whereas, a household with a large electricity consumption can actually benefit from this and have a lower electricity bill, and this is probably not in line with most objectives of most policymakers around the world.

Just a quick word on minimum bills—they have also been discussed by many policymakers around the world—it has very similar effect to fixed charges. And to cut a long story short, here's just two examples of minimum bills. Also, with the rise of prosumerism of roof-mounted solar PV, some jurisdictions have said, "Oh, maybe they will be able to reduce electricity demand to an extent that we will no longer be able to finance the network cost." And, therefore, for instance, California has increased the minimum bill from, previously, less than \$2.00, to \$4.50, and then to \$10.00. However, they also made some exemptions for low-income households, where the minimum bill is only \$5.00 per month and per customer.

And also, in Hawaii, we saw quite a drastic increase of minimum charges, which are just fixed: whatever you do, even if you consume 0 kilowatt hour of electricity in a given month, you would still have to pay this minimum bill. And this, again, was intended to give the utility of the network operator a greater certainty on how they can recover their money. However, the other objectives, the emerging policy objectives, _____ have not really been taken into consideration by implementing these design features. So, last but not least, when we talk about traditional rate design, we need to talk about demand charges. And demand charges have, historically, been applied mostly for the larger-scale commercial and the industrial sector.

And as I mentioned before, in previous power systems, which were based on fossil fuels and on large-scale power generation units, as a system designer, you always want to decrease or cap peak demand to a minimum. Because the

peaking powerplants—usually gas or even diesel powerplants—are the most expensive to operate, and, therefore, one wanted, also, to give industrial and also commercial customers and incentive to reduce the peak demand. Always assuming that their peak demand would coincide with the system or with the locational peak demand, which, of course, might not be the case, but this was just the general assumption. So, what we learn in the second session is that, when you discuss these options, of course you will also have to analyze whether the customers' peak demand will coincide with the system peak demand or with the locational peak demand, in order to give the right price signal to the different customers.

So, here is just one example of how these demand charges are calculated. They're actually calculated as a unit of payment per kilowatt. So you would, for instance, look at the electricity consumption of a commercial customer, over a year period, and then identify the one hour where the electricity demand was the highest. And then you would take this hour of highest electricity demand, multiply it with the demand charge, and then you come up with a certain additional cost which the customer has to pay. So here is just one graphical illustration.

So, you look at the entire year, you look where has the maximum demand actually happened, and you take this unit, this hour, as the calculation factor that you will use to calculate the demand charge. For instance, here is a typical commercial rate with demand charges, based on a study from Lazar, from 2015. So, you see we have a fixed charge here per month, which is independent of the usage, then we have a demand charge of, let's say, \$15.00 per kilowatt, multiplied with the one hour in the month where you had the highest amount. And then you also have a volumetric charges, let's say, ten cents per kilowatt hour, which you will have to pay additionally for each unit of electricity that you consume. So, these are the three components, as mentioned earlier, that you would usually see in commercial and in industrial electricity prices.

The question, now, is whether these charges should also be implemented for small-scale commercial and residential customers, and there is a certain arguments for this. Once again, the cost causation, on principle that prosumers will likely have to pay higher demand charges if PV generation does not coincide with the peak demand. Also, from a system efficiencies perspective, you could argue that demand charges can help to reduce the peak demand, and, thus, lower, also, the total electricity system cost. However, there are some disadvantages when we talk about demand charges for the residential sector, and this is, of course, simplicity. As you have already seen from the very simplistic calculation before, having these three components of the electricity bill, or two, will make it more complex, and, therefore, also more difficult to understand, for the final consumer.

What you also don't have, normally, today, in most households, is demand control technologies. So you have them more usually available in industrial complexes, or at larger-scale commercial customers, however, they are only just emerging in the residential sector. On the point of fairness, some people

argue that demand charge is actually unfair to residential customers and small-scale business, because they might not be in line with the system peak demand. The system peak demand might not coincide with the peak demand of residential and industrial customers. This, of course, is, once again, a case-by-case analysis, depending on the country and typical peak demand periods.

And then, from a flexibility cost efficiency point of view, you might still remember the one slide I showed to you was Germany in 2020, where in some hours there will actually be an oversupply of solar PV and wind energy. And if you then have demand charges in the system, you actually are always giving any type of consumer groups the incentive to say, "Oh, try to reduce your peak electricity demand." However, in power systems with very large shares of variable renewables, we actually need to come to a situation where, in certain hours of the year, you should give industrial, commercial, and residential consumers incentive to consume more. So, traditional demand charges might actually stand in the way of this, but this only applies for power systems with very high shares of variable renewable energy technologies.

So, this was, well, the quickest possible summary of these really major design features of traditional rate making, looking at volumetric, fixed, and demand charges. In the next session, you will actually learn more about so-called smart rate design, so we will discuss time of use rates, we will discuss real-time pricing, we will discuss locational pricing, all of which, of course, need some advanced metering infrastructure. And we will also look at the cost and benefits of distributed power generation, of solar PV in particular, look at two-way rates and specific rate design, which might only be implemented for prosumers and not for all electricity customers all together.

So, after this one hour of presentation, you might have become interested in this topic, so we have put together a very substantial list of further reading. So here, first of all, is the references. Here, actually, you find the links to a lot of reading material. This is on rate design generally, and we also have two slides on specific rate design related to distributed generation and solar PV. So there's tons of material out there on rate design. We will, as I said before, discuss more of this in the next session.

Now I just want to thank you for listening, and I hope you will continue following these training sessions on solar PV policies, which are organized by the International Solar Alliance and the Clean Energy Solutions Center. So, thank you very much for listening, and hear you soon. Bye-bye.

>>Female: This concludes Module 8a, covering rate design. You may now proceed to the knowledge check questions.