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Understanding the Impact of Distributed Photovoltaic on Utility Revenues and Retail Electricity Rates: Case Study on Thailand

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Webinar Panelists

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Kate Contos Today's webinar is focused on the understanding the impact of distributed photovoltaic on utility revenues and retail electricity rates, case study, on Thailand. Before we begin, I'll quickly go over some webinar features. For audio you have two options. You may either listen through your computer, or over the telephone. If you choose to listen through your computer, please select the mike and speakers option in the audio pane. Doing so will eliminate the possibility of feedback and echo. If you choose to dial in by phone, please select the telephone option, and the box on the right side will display the telephone number and audio PIN you should use to dial in.

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Finally, one important note to mention before we begin our presentations is that the Clean Energy Solutions Center does not endorse or recommend specific products or services. Information provided in this webinar is featured in the Solutions Center as one of many best practice resources reviewed and selected by technical experts. Today's webinar agenda is centered around the presentations from our guest panelists—Alexandra Aznar, Dr. Sopitsuda Tongsopit, and Dr. Naim Darghouth, who have joined us to discuss the impact of distributed photovoltaics on the distribution utility revenue and retail electricity rates in Thailand. Before we jump into the presentations, I'll provide a quick overview of the Clean Energy Solutions Center, then, following the panelist presentations, we'll have a question and answer session where the panelists will address questions submitted by the audience.

At the end of the webinar, you'll be automatically prompted to fill out a brief survey as well. So, thank you in advance for taking a moment to respond. The Solutions Center was launched in 2011 under the Clean Energy Ministerial. The Clean Energy Ministerial is a high level global forum to promote policies and programs that advance clean energy technology to share lessons learned and best practices, and to encourage the transition to a global clean energy economy. 24 countries and the European Commission are members covering 90 per cent of the clean energy investment and 75 per cent of the global greenhouse gas emissions.

This webinar is provided by the Clean Energy Solutions Center, which is focused on helping government policymakers design and adopt policies and programs that support the deployment of the clean energy technologies. This is accomplished through the support in crafting and implementing policies related to energy access, no cost expert policy assistance, and peer to peer learning and training tools, such as this webinar. The Clean Energy Solutions Center is co-sponsored by the governments of Australia, Sweden, and the United States, with in-kind support from the government of Chile.

The Solutions Center provides several clean energy policy programs and several end services, including a team of over 60 global experts that can provide remote and in-person technical assistance to government and government supported institutions. No-cost virtual webinar trainings on a variety of clean energy topics. Partnership building with the development agency and regional and global organizations to deliver support and an online library containing over 5,500 clean energy policy related publications, tools, videos, and other resources. Our primary audience is made up of energy policy makes and analysts from governments and technical organizations in all countries, but we also strive to engage with private sectors, NGOs, and civil society.

The Solutions Center is an international initiative that works with more than 35 international partners across a suite of different programs. Several partners are listed above, include resource organizations like IRENA and IEA, and programs like SE4ALL and regional focused entities like ECOWAS Center for Renewable Energy and Energy Efficiency. A marquee feature the Solutions Center provides is a no-cost expert policy assistance known as an Ask an Expert. The Ask an Expert service matches policymakers with more than 60 global experts selected as authoritative leaders on specific clean energy finance and policy topics. For example, in the area of photovoltaics we are very pleased to have Hugo Luis, head of energy department for factor CO2, serving as one of our experts.

If you have a need for policy assistance in photovoltaics, or for any other clean energy sector, we encourage you to use this valuable service. Again, this assistance is provided free of charge. If you have a question for our experts, please submit it through our simple online form at cleanenergysolutions.org/expert. We also invite you to spread the word about this service to those in your networks and organizations. Now I'd like to provide brief introductions for today's panelists. First up is Alexandra Aznar who is a product leader at the National Renewable Energy Laboratory. She works on clean energy policies and provides solar technical assistance to local, state, and national level policy makers.

Following Alexandra, we will hear from Dr. Sopitsuda Tongsopit, who is an independent energy consultant with extensive experience in solar PV economics, distributed energy policy, regulation, and program design. Her research has supported government agencies, electric utilities, consumers, and private companies to make informed decisions about distributed energy options.

And our final speaker today is Dr. Naim Darghouth, who is a senior scientific and engineering associate in the electricity markets and policy group at Lawrence Berkeley National Laboratory. Naim conducts research and analysis on renewable energy policy in both US and international, including electricity rate design and its impacts on the value of residential renewable energy systems, economics of renewable energy technologies, and federal and state energy policies. And with those brief introductions, I'd like to welcome Alexandra to the webinar.

Alexandra Aznar Thanks for that introduction, Katie. My name is Alexandra Aznar, and as Katie mentioned, I work at the National Renewable Energy Laboratory. And today we're going to be looking at a case study in Thailand that explores the impacts of distributed photovoltaic deployment on utility revenue and customer tariffs. So, this engagement in Thailand is supported in part by the USAID Distributed PV Toolkit. And this is a multiyear program to assist USAID partner countries across the DPV spectrum. They want to help develop and implement pilot projects that really accelerate the DPV market. This is a multiyear program. And we take a holistic approach to our technical assistance and capacity building in USAID partner countries.

You can see in this graphic along the bottom the full landscape of distributed generation and distributed PV design issues that we touch on in this program, including rate design issues, technical issues, and policy issues. If you'd like more information about the program, you can contact me of Jeff Haeni or at USAID.

So, the USAID Distributed PV Pilot Program is working across the globe with USAID partner countries. We have ongoing projects in Columbia, Peru, and Thailand. And we have potential pilot projects right now in Mexico, India, Ghana, and Southeast Asia. We work closely with USAID missions, and in country energy institutions and stakeholders to scope, implement, and evaluate our distributed PV technical assistance. This Thailand engagement was also supported in part by the USAID Clean Power Asia program. And this is a program that aims to increase deployment in grid connected renewable energy in Asia. This is a five-year program. They focus on Cambodia, Lao PDR, Thailand, and Vietnam.

So, today's webinar will focus on distributed generation, particularly distributed PV in Thailand. So that raises the question, what do we mean by distributed generation, or distributed PV? This visual here explains the difference between centralized generation and distributed generation. So, what we mean by distributed generation are small scale generators, typically distributed photovoltaics, but there can be other resources, that are interconnected to the grid at the distribution level. So that's there on the right, the distribution level.

This slide provides just a couple more characteristics of what we mean by distributed generation. And it's important to note here that the distributed PV program works primarily on grid connected distributed generation. These are systems again tied to the distribution level of the grid. And we don't necessarily address off-grid systems. So, what's happening when a customer has distributed PV on his or her house, or business? So, in many ways, a typical distributed PV owner has three different roles—as a customer, as a self-provider, and as a power exporter. If we take a look at this graft, along the Y axis you have the energy produced, and along the X axis the customer load by hour in one day. You can see this kind of customer acts like a normal retail customer in the early hours of the morning, when it's still dark outside, and the distributed PV system is not generating electricity.

But as the day progresses, and the sun comes out, the system starts to generate electricity that is then consumed on site to feed that load. At midday, the distributed PV system may be generating so much electricity that it's more than what is needed to meet onsite demand. So, the system will then export that excess power to the grid. That's that blue box down at the mid-day point. Then as the day progresses, and it becomes evening, the customer becomes a normal retail customer again, importing electricity from the grid instead of the distributed PV system, because the system is no longer generating. So, this phenomenon I just described is really important to understand because of its implications for customers, utilities, and other rate payers. And we're going to be exploring some of those implications in this analysis.

Let's take a quick step back and look at a reason why we are seeing increased distributed PV deployment worldwide. This has to do primarily with cost. I'm sure many of you have seen different versions of this graph, which is showing trends in distributed PV system prices worldwide, from 2011 through now 2017, steep declines, and those declines are projected to continue. In later in the webinar, Dr. Tongsopit is going to talk a little bit more about these system prices in Thailand. And now I'm going to turn it over to her so she can talk a little bit more about what this increased distributed PV deployment means for utilities.

Sopitsuda Tongsopit Thank you, Alex. So, I'm _____ _____ Sopitsuda Tongsopit from USAID Clean Power Asia. And my presentation will be focused on the context for our case study, and also the results from the qualitative analysis parts. Many of the participants may already be familiar with this diagram called utility death spiral. Can everyone see my screen? Not right now?

Kate Contos No, I apologize. We're not able to see your screen. Oh, there we go. Now we can see it. Yes. Thank you so much.

Sopitsuda Tongsopit So, distributed PV is becoming increasingly popular around the word. And therefore, utilities around the world are becoming increasingly concerned about the use of DPV for self-generation and self-consumption. This diagram called Utility Death Spiral happens—could happen in places that _____ utility rates encourage the adoption of distributed PV. The use of DPV by customers would then allow the utility customers to reduce their energy charges, and as more _____ customers go solar, the utilities lose their revenue, and would also have to recover their fixed costs from a smaller base of customers. These would then drive the retail _____ prices up. Which would cause the more customers to go solar. And the cycle continues. Causing the so-called utility death spiral.

What I'd like to emphasize here is that the presence and expense of utility revenue and rate impacts merely depends upon the _____ framework, particularly the expense, the retail tariff design, and the compensation mechanic _____ DPV. When we talk about utility revenue losses, we can think about these as the costs that are imposed on the utilities, and ultimately the rate carriers. However, it's good to keep things in perspective, that distributed PV can provide both cost and benefits to the electricity system. And listed here are categories of costs and benefits when DPV systems are deployed.

In our case study, we quantified the revenue losses, but we also take into account certain benefits that DPV can provide, particularly the _____ energy that the utility would otherwise have to supply from central generation.

Coming to Thailand's case study, Thailand is a country that is located in Southeast Asia. It's total generation capacity is around 57 gigawatts. And we have over 3,000 megawatts of solar PV, but most of this solar PV capacity is utility scale, whereas distribute PV capacity takes up less than 200 MW currently, around 0.3 per cent of the total installed capacity. But distributed PV is becoming increasingly popular in Thailand. Thanks to the declining costs of solar PV system, and also _____ _____ business and _____ _____ models that are happening in the Thai market. The most important driving force seems to be the _____ _____ cost of DPV _____ _____ in Thailand and is already competitive with the retail electricity prices. Especially for commercial and industrial customers.

So, we're seeing a trend now that factories and buildings are trying to install rooftop solar systems in order to generate their own electricity and have electricity _____ _____ _____. And then last year in 2016, the Thai government launched a national distributed PV pilot that allowed utility customers to install and connect their DPV system to the grid. However, if the system generates more electricity than the customer consumes, there'll be excess electricity that goes back to the grid, and that _____ _____ electricity

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was not compensated during the pilot project. After the launch of the pilot, the government has been studying a new compensation scheme to compensate—to support distributed PV and also to compensate for injected electricity. And electric power utilities in Thailand have expressed concerns on the potential massive revenue decline that could happen with more DPV deployment.

I'd like to talk a bit about Thailand Power Industry Structure, in order to introduce the players that we used in our analysis. As with all power systems in the world, we have generation, transmission, and distribution. And end use customers. Distribution utilities in Thailand are MEA and PEA. There are only two of them. Each one is serving as the default retailer in that service area. And these two distribution utilities purchase power mainly from the wholesale power supplier, called EGAT. And for the end use sector, we're seeing a trend of increasing decentralization of power supplies. Industries that generate power for their own use, mostly from natural gas, but also from distributed solar PV. So, this leads to our analysis questions in the next slide.

In our study, we asked how would the deployment of DPV impact the revenue of distribution utilities and electricity tariffs under existing ratemaking regulations in Thailand? We choose to measure the impact on DPV deployment under two distribution utilities only. Mainly the MEA and PEA. And we looked at the short-term impact up to 2020 of 3,000 MW of DPV deployment. This corresponds to around 2.5 per cent of projected sales in 2020. This amount, 3,000 MW, is relatively ambitious given that today PV penetration in Thailand is only in the hundreds.

Through extensive consultation with stakeholders, including the utilities, policymakers, and the regulators, we were able to uncover three important findings. The first finding is that Thailand's current regulatory paradigm already allows for 100 per

cent of all net costs associated with DPV deployment to be passed through to the customer via the tariff increases. And this means that DPV deployment would cause no direct medium or long-term net revenue impact on the distribution utilities. And this happens because retail tariffs in Thailand are based on expected future sales, and so the distribution utilities can fully recover their cost with increasing DPV levels.

For this reason, we can say that Thailand's regulatory structure is already well suited to support DPV deployment, while protecting distribution utility revenues. But these conditions will happen if and only if increases in deployment of DPV are properly planned and accounted for in rate cases. Furthermore, we found that when DPV electricity is self-consumed by the user, it will result in short term utility revenue loss, followed by rate increase after the rate case. And for the variable component of the rate structure that we'll talk about later, analysis showed it can easily increase or decrease, depending on the compensation price of the injected electricity.

What we discussed in terms of qualitative finding can be represented by the equations in the next two slides. I'm trying to be not exhaustive with these equations, and I will only point out to the concepts, and you can look at more details in our full reports. The retail electricity in tariff in Thailand consists of two main components. Mainly the base rate, the fixed component, shown here as TB, and the variable component, shown here as FT. The fixed component is calculated in each rate case. Every three to five years. Whereas the variable component, FT, changes every four months. The fifth component here is calculated from forecasted revenue requirement, RR, divided by the expected sales, ES. RR is in turn a function of all the costs that the utility is expected to incur during the rate period, including the capital cost of investment, operation and maintenance costs, and a base variable cost component.

After the base tariff is approved in each rate case, any divergence from the base variable cost here will be reflected and adjusted by the variable component, FT. The key point here is that ratemaking in Thailand is forward-looking, with retail tariff being based on expectation of future sales, and expectation of future expenditures over the rate period. And this will have important implications on how DPV deployment is addressed in the ratemaking process.

So, what happened when more and more customers deployed DPV in the utility system? All of the components in the retail tariff equation would have to be adjusted to take into account DPV. Now, recall that there are these three components in the rate equation. So, the revenue requirement, or RR, will need to be adjusted by adding the additional cost and subtracting additional benefits that are associated with DPV increases, and we'll talk about these cost and benefits in a few moments. The expected sales are ES, would have to be modified by subtracting the self-consumption that is caused by distributed PV from it. And finally, the third component, the FT, has to be modified by adding the cost and benefits associated with injected electricity. And this is because if there's any payment of injected electricity from DPV, that cost would directly be passed through into the FT.

So, this leads to the full modified retail tariff equation, which we verify with the stakeholder in Thailand, and we can conclude then that with DPV there will be fewer units of electricity sold, cost and benefits associated with increasing DPV deployment, and it's possible to take into account the impact of DPV in advance, in order to ensure full cost recovery through the retail tariff.

Now, before we move onto the quantitative analysis part of the study, I'd like to go over the cost and benefits that were taken into account in our study. The costs included in the analysis included the utility revenue losses due to self-consumption, and the costs of purchasing PV grid injection. The benefits we included—avoided wholesale electricity purchases—[audio drops]—and benefits that are excluded are shown here in this table. And based on international experiences with DPV, these are unlikely to be significant, especially in the context of Thailand, distribution upgrade cost is unlikely, because grid codes is already limiting the high penetration on individual distribution _____. With this, I'd like to give the microphone to Dr. Naim

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Darghouth, who will be discussing the quantitative analysis part of the study, and policy implications. Naim?

Naim Darghouth Great, thank you so much, Job. Let me show my screen here. All right. Great. I hope everyone can see that. I think so. I'm going to be talking today about the quantitative analysis. So first representing really a framework to understand these impacts from revenue tariff in Thailand. And then going through the methodology, some of the data, and the results, finishing up with conclusions and implications really for both the Thai context, and more generally in global implications. So, Job so far has gone through a fair amount of detail on the rate making process in Thailand, and how PV can impact rates, as well as utility revenue impacts, which really are close to nothing, if nothing at all.

So here I'm going to go through the high-level framework that structures our analysis. And hopefully by going through this framework, you'll all have a better understanding of how PV can be expected to impact rates in the short term. So that's before the next time rates are reset through a rate case. And in the medium term, which is in the let's say five to ten years, and we look at 2020. So even less than that. So, we've subdivided the framework into four sections. DPV market conditions that drive deployment, the operation of distributed PV, and the quantification of both short term and medium-term impacts. Now I'm going to go through each of these separately in the coming few slides. Keep in mind we have divided each of these components as those that affect the DPV owner, the distribution utility, and the rate payers, as you can see here on the legend, at the bottom left.

So, the first part of the framework is one that we don't explicitly model in the analysis, but is important to understand. These are the drivers to distributed solar adoption. So, starting with distributed PV policy design, which may include incentives as well as PV compensation schemes, such as net metering or net billing or even feed-in tariffs. And these distributed PV policies will impact both distributed PV pricing, so directly through subsidies, and indirectly through market mechanisms. And both DPV pricing as well as distributed PV policy design are both going to impact the customer economics and distributed solar. So, including the payback period, and the rate of return for an individual customer's PV investment. How attractive the PV investment is to individual customers is really going to determine how many people are going to be actually adopting solar, leading to the absolute deployment level of distributed PV.

In our analysis, we assume a predetermined level of distributed PV deployment, focusing on the three-gigawatt target by 2020. So even though these dynamics are present, our starting point for our analysis is that DPV deployment is at that three-gigawatt level. That assumes that the DPV quality and pricing are appropriate to enable reaching this goal.

So, there are two kinds of solar generation for distributed behind the meter PV. Self-consumed distributed PV, and grid injection. And Alexandra has kind of introduced this concept earlier on. Because solar is behind the meter, solar generation is first self-consumed, if the load is sufficient. This

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effectively reduces the customers' net load. But if the PV generation is greater than the customer's load at any point, the excess generation is injected into the grid. So, we see in this figure here to the right a stylized version of the one that Alexandra presented earlier, where the green shaded area represents self-consumed distributed PV generation, and the yellow represents grid injection from the solar generation. And each of these components are going to have impacts on the utility sales and costs which we're going to look at here in the next slide.

So self-consumed DPV generation is equivalent to a reduction in the customers' net load, since it's all happened behind the meter. And a reduction to customer load means that utility is really selling less, it's effectively a cost to the utility. But it also means the utility doesn't need to purchase that self-consumed electricity from the wholesale electricity provider. In Thailand's case, it's EGAT, which is a financial benefit to the distribution utility. The DPV generation injected into the grid is purchased by the distribution utility at the pre-established cell rate. And this is of course a cost to the utility, but similarly to the self-consumed electricity, this also avoids the purchase of that injected electricity from the wholesale electricity provider. So, we separate out these two, mostly for accounting reasons, as we're going to see here in the next slide.

So, this is pulling all of these together. The cost of the reduced sales will be—so these costs here are going to be greater than the benefit, as the retail rate which is the cost, is going to be always higher than the energy purchase costs for the utility. Definitely in this case, in actually most cases, and the difference between the two is going to be fully recovered through electricity tariffs. So, the net effect of self-consumed DPV generation is going to be an increase to the electricity tariffs in the next rate case. For the DPV injected electricity, any differences between the sell rate and the EGAT purchase price, so the wholesale purchase price, the difference here between these benefits and costs are going to lead to a change to the automatic tariff adjustment, FT. This is what Job was presenting in an earlier slide.

So, this change in the FT is in the short term, because this automatic tariff adjustment is abated every four months, but it's also carried through to the longer term after rates are set during the next rate case. If the sell rate is less than the wholesale purchase price, this means that the distribution utility is getting that solar electricity generation for cheaper than it would from a wholesale supplier, and the savings are going to then be passed on to the rate payers through this automatic adjustment mechanism, the FT. However, if the sell rate is higher than the wholesale purchase price, then the extra costs of purchasing that electricity is going to be passed on through the FT, to the ratepayers.

So now that we understand really the framework for the analysis, dividing it into self-consumed and consumed, and how it impacts different parts of the rates, let's look at some of our data and assumptions for the analysis, all of which, as Job mentioned earlier, were validated, and even sometimes provided by the various stakeholders that we worked with.

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So, as we mentioned before, we looked at 3 gigawatts of distributed solar, distributed between the two distribution utilities. So those are the Metropolitan Electricity Authority, and the Provincial Electricity Authority, MEA and PEA. And we needed to make some assumptions on the PV system sizes as well, since this really impacts the amount of electricity that's consumed, versus injected into the grid. So, we assume that residential PV customers can generate 80 per cent of their annual consumption. And because commercial customers tend to have large annual loads, those customers are assumed to be able to generate about 50 per cent of their annual consumption with PV. Customers were distributed across the country for the PEA distribution utility, and in Bangkok for the Metropolitan Electricity Authority.

So, we considered three core scenarios when conducting the analysis. The base scenario is a net billing arrangement. So, this allows self-consumption. But any DPV generation injected into the grid is going to be compensated at a sell rate, and we looked at three different sell rates—one, two, and three baht per kilowatt hour. Now as a reference, the average retail rate is about 3.5 baht per kilowatt hour, so each of these sell rates are lower than the retail rate. We also consider a high impact and low impact scenario, to try and bound the analysis and the results. So, the high impact scenario is a full _____ metering. So, this means that both the self-consumed and injected electricity are going to be compensated at the full retail rate. And this is really going to lead to the highest tariff impacts, since this is also the highest difference between the costs and benefits for the utility we talked about in that previous slide.

The low impact scenario is a self-consumption only case, where the DPV customers can only self-consume, and any excess electricity that's injected into the grid is not compensated at all. So, this is the lower bound to the impacts. We assume that the customer mixed among the various residential and commercial customers is proportional to the load that by each customer class. Under the high impact scenario, we assume that PV is only installed in the two rate classes with the highest PV billed savings, and again, we do this to provide the highest potential impact, bounding our analysis. So, to calculate the tariff impacts from distributed PV, we first calculated the reduced sales and revenue from self-consumption by customer class, using the load profiles provided by each of the utilities.

We also calculated the total cost of the exports using the appropriate sell rate for each scenario, as well as how much DPV generation is injected into the grid, using our assumptions for load and PV generation profiles as well as PV system size. For the benefits side, we calculated the reduced wholesale electricity purchase cost from EGAT, which is the wholesale utility in Thailand, using the peak and off-peak electricity prices charged by EGAT. So how did we do this? We needed to develop net load profiles for each customer class, using the load profiles provided by the two distribution utilities, as well as we needed to use simulated PV generation, and here we used NREL's System Advisor Model. The revenue reduction due to self-consumption is simply equal to the total bill savings for all DPV customers. We calculated the exported DPV generation for each load profile, and again

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aggregated the total cost, and benefit, from the injected PV generation for all DPV customers.

So, we considered the eight tariff classes available to the main customer segments in Thailand, including two tariffs for residential, two for small, medium, and large general services, and then we simulated this for 56 cities using PV profiles for those 56 cities, leading to a total of 448 simulations for both distribution utilities. So here are some of the customer characteristics used for the analysis. I'm not going to go through this in any detail here, and the slides will be made available afterwards. But for each customer segment, I've written out the total annual consumption of the model and DPV customer, as well as the model DPV system size for each customer class. As you see, residential PV size to reach that 80 per cent PV to load ratio is 6.4 kilowatts for the larger residential. But this goes up to 2 megawatts for the lower PV to load ratio under the largest industrial customers.

Now, the percentage of customers on each available rate for each customer class is presented in these last two columns here. And as we see for residential customers, most are going to be on these time invariant, so these flat rates, whereas a minority will be on a time of use rate, and this—woops. This relationship flips around for the larger customers, most which are going to be on time of use rates, and fewer will be on time invariant rates.

So now let's turn to some of the results. So, the high-level result is that retail tariff impact associated with the 3 gigawatts of DPV deployment, even in our high impact scenario, is relatively small. Note that the Y axis here is in satang per kilowatt hour, where 100 satang is equal to one baht. So, the average retail rate is about 3.5 baht, as I mentioned, per kilowatt hour. Or 350 satang. The high impact scenario would lead to an increase of just about 3 satang per kilowatt hour, or less than one per cent. Now, to put this into perspective, we compare it to the median change in the FT, which historically has been driven by changes in natural gas prices. So, this is the automatic adjustment mechanisms that accounts for these fuel cost changes. And the median number here is almost 8 satang per kilowatt hour, change, within those four months. So, we do this just to put this into perspective that we do see large changes or larger changes in the rates, due to natural gas prices. Mostly, and when we compare this to the effect from solar, the impact from solar is much lower than those jumps.

So, we can separate out the tariff into the impact from the self-consumed, versus the generation, self-consumed generation versus injected PV generation. And we do this for our core scenarios, with net billing. Since the revenue reduction due to the self-consumption generation is always going to be higher than the value or benefits from that self-consumed electricity, the impacts from the self-consumed electricity seen in blue on this chart is always going to be positive. As I mentioned during the discussion of the framework, the impact of the injected PV will really depend on whether the avoided costs are higher or lower than the sell rate. For the low sell rate, of one or two baht, it's lower. And so, the tariff impact is going to be negative. As the sell rate

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gets closer to the avoided cap, costs, the impact from the injected electricity is going to be about zero.

So, I'm going to go quickly over these next two slides, just presenting again the breakup between the impact from self-consumed versus injected electricity when you have a self-consumption only, with the net impact being negative or zero, depending on the utility. Under the high impact scenario, again, we have a retail rate impact of close to 3 satang per kilowatt hour, and again comparing it to the median FT change in the last ten years, the median FT change is closer to eight. So, again, these impacts even under this high impact scenario, are minimal.

Now I wanted to go through some of the policy implications for these results. So, some are going to be specific to Thailand, of course, but a number of these are more broadly applicable to many other country contexts. So, first for policymakers the main conclusion here at least, in Thailand, is no utility revenue impacts will be—will result from these 3 gigawatts, and low retail rate impacts. And this really should address concerns about PV deployment, at least in the short term. Policymakers can also recognize that any DPV policy that's going to be adopted is going to be a balancing act between incentivizing PV adoption and reaching PV and potentially climate targets, and moderating impacts on electricity rates and utility revenues. And this kind of balancing act is going to be present in any country context.

Even though we've seen low impacts from the DPV program here in the Thai context, policymakers can really ensure these impacts are limited by employing a system wide deployment cap for distributed solar, or perhaps a retail rate impact cap to policy mechanisms that can be used in any country context. So, for regulators this work really highlights the importance mostly of data collection to accurately quantify the rate impacts from solar, perhaps from implementing a national distributed PV registration system. For utilities, this work highlights the importance of including DPV when presenting their general rate case. So again, utilities are going to present their proposed updates for rates. In Thailand it's every four years. And this will change from country to country. But it's important to make sure that the reduced sales from PV are going to be incorporated into the sales projection.

Now for Thailand, the test year for rates is a future year, and this is rather unusual. Often. It's a current or historical test year. When it's a current or historical test year, utilities aren't able to include projected PV scales into their rate case. In addition, it's going to be in the interest to work with stakeholders to collect accurate DPV data and track the DPV program administration and interconnecting costs. Again, to potentially include in their rate base to be recovered through tariffs. This is—can be done in Thailand, and it's going to be context specific for other policy contexts in other countries.

So, a few lessons learned about the process and methods in this study. So, abstracting from the results, what can we learn from the analysis especially as we do this kind of work, or you may do this kind of work in other countries? The first is that's clear that it's going to be really key to set up clear objectives

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upfront, so the stakeholders have a realistic idea of what the analysis will include and what it's not going to include. Next, it's going to be primordial to understand the regulatory framework and policies in the country. This is directly going to feed into your quantitative methods to analyze the revenue and tariff impacts from DPV.

We also found it very valuable to use a rigorous and transparent method, as well as transparent data in terms of sources. To ensure that the work is accepted and used by the stakeholders, we worked with various stakeholders, including the utilities, regulators, Ministry of Energy at every stage of the analysis. Getting feedback and engaging all stakeholders through meetings in person and by phone. Emails as well as in-person workshops. And really, I think this was key in getting our stakeholders to trust the results, and maximizing the chance for this to impact policy.

And, finally, local partners, including all the local partners that Tongsopit was able to coordinate, was very important to ensure that we were contacting the right people to maximize the impact. A few points I'd like to end with on the broader applicability of these results. Beyond the Thai context. First, it's going to be important to recognize that the utility revenue and retail rate impacts from PV are always going to be context specific. And this is going to depend on the level of PV targets. So how much deployment are you expecting? And how that compares to the total amount of load in the country.

It's also important to take into consideration the scope of the analysis. The rate setting and PV policies. As well as customer and PV generation characteristics. That said, there are going to be a few basic takeaways from this analysis. One is that as long as PV compensation is not equal to the voided cost from PV generation, then there's necessarily going to be some level of either retail rate or utility revenue impacts either can be positive or negative, depending on exactly how much PV customers are being compensated for. Another point here is that low PV penetrations on an energy basis are always going to yield low revenue impacts. So, in the case of Thailand, 3 gigawatts in 2020 would be about two per cent PV penetration on an energy basis. And given that DPV generation has some value to the utility, maybe not as high as the retail rates, but still, the rate impacts aren't necessarily going to be less than that two per cent level, and often much lower, depending on the compensation scheme and levels.

So, with that, I'd like to thank you for attending the presentation. Thank my other co-presenters. And we can move on to the question and answer session. So, if you haven't done so already, you can ask questions in the chat box, on the screen here.

Kate Contos Wonderful. Thank you so much, Naim. As Naim mentioned, if you'd like to submit a question, we ask that you use the question pane, where you can type in your question, and we will answer it. And I will now turn it over to Alex to moderate the question and answer session.

Alexandra Aznar Hello again, everybody. Yes. Please send us your questions if you have some about this analysis and its implications. I'd like to start off the discussion with

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a question for both of you. As you know, the idea of quantifying the cost and benefits of distributed PV is of interest to regulators and utilities around the globe, and in this specific analysis, you decided to choose specific cost and benefits to analyze, and you did not analyze other costs and benefits. So, my question is how—what was the process for selecting the cost and benefits you did analyze, why did you choose those over others? What other costs and benefits could be considered an analysis, and what might be some of the implications of considering other costs and benefits?

Naim Darghouth Sure. I can start with that. If we could go to the slide with the cost and benefits, I don't remember the number. But in the meantime, so I guess one of the big decisions that need to be made for these kinds of analyses is the timeframe for the analysis. Whether we're dealing with short term or medium term, so let's say the next five years, or if we're looking at really much longer-term analysis going past let's say 2030, and the reason why this is important—well, there are the policy implications, and then also the quantitative analytical implications to those. So, the policy implications for many countries that are just trying to get their PV program off the ground, it may be useful, and this is the case for Thailand, it was useful to do this kind of analysis to in some sense reassure policymakers and utilities, or at least confirm—to ensure that the program—the solar program impacts to rates and to utility revenues are not going to be significant in the short term.

So, in the short term, this allows the policy makers to say okay, we are willing to start this program. We haven't looked in depth at a long-term analysis, but we know it's not going to impact in the short term. We can get started on this while we do the more complex, longer term analysis. And again, maybe using some kind of system cap to make sure there are no runaway rate impacts. So those are the policy implications of that choice. Over the longer term, you're going to include a number of other kind of cost and benefits than we did. And the reason is—in the longer term, you're going to have some cost and benefits that are due to offset investments. So, for example, having higher levels of solar in a distribution grid can potentially offset distribution upgrade investments, because perhaps especially for distribution systems that peak during the daytime, they can offset kind of the need to build up that distribution network, because of self-consumed or at least DPV generation.

In the long term as well, you can have kind of changes to the electricity mix, which will impact the benefit of reduced wholesale prices. So, the wholesale prices are going to change. And you need to understand how they change with PV distributed generation. So those are costs and benefits we didn't consider, because we looked in the near term, but that would need to be considered, and that are likely to be much more complex in the longer term.

Alexandra Aznar Thank you.

Sopitsuda Tongsopit And also I'd like to add a point that—the cost benefits we chose to consider were also based on the level of megawatts of DPV that we deployed, which was 3,000 megawatts, considered to be a tiny portion of the sales, during the analysis period. And the reason why we chose 3,000 megawatts was because _____ _____ stakeholder consultation that this is the remaining target to be achieved for solar PV in Thailand's national renewable energy plan. Thank you.

Alexandra Aznar Thank you both. I think we have time for one more question. This is from the audience. And it has to deal with the FT that you both referred to. You demonstrated that natural gas has a greater impact on the FT than DPV. But natural gas is a bigger percentage of generation in Thailand. So, would you expect to see a much greater impact on the FT, if you see a larger group _____ _____ DPV _____ _____ above that 3 gigawatts that you modeled?

Naim Darghouth Yeah. So, in some sense, the impact on rates is going to be proportional to the amount of distributed PV in the system. So, depending on the compensation scheme, you would definitely expect if for example there was 10 gigawatts, which would be a significant increase in DPV _____ _____ deployment, you'd definitely _____ _____ not quite proportional, but you'd definitely expect a further increase in the rates. And policymakers would have to decide whether they're comfortable with these increases in electricity tariffs, and perhaps there are ways to kind of change—to make sure that the most vulnerable population are protected from large increases in rates. But we would definitely expect an increase. But that's going to be dependent on the PV compensation mechanism chosen, as well as the avoided costs which I mentioned before.

Alexandra Aznar Okay, thank you. We have a final question from our audience. And that is—are there plans to consider the impact of self-storage _____ distributed PV in the future on these questions?

Sopitsuda Tongsopit _____ _____ plans for NREL, for USAID, right?

Alexandra Aznar Sure, maybe kind of at large, in terms of NREL, USAID, or is the issue of storage also coming up in conversations with Thai energy institutions?

Sopitsuda Tongsopit Yeah, definitely. Because in Thailand, for renewable energy support, especially large scale renewable energy, _____ considering—moving in the direction of encouraging energy storage in order to reduce the intendancy of renewable energy sources. So definitely energy storage shows up in conversations, and it definitely should be part of the analysis in the future.

Alexandra Aznar One final related question is—what can we expect to see in the distributed PV markets in Thailand, going forward? What might be some of those trends?

Sopitsuda Tongsopit The trend going forward is that there'll be compensation for excess electricity from DPV system proposed by the government, in the next year. But at the same time, without any kind of policy framework to support DPV, as I mentioned, DPV's electricity is already competitive _____ _____ _____ electricity prices. So _____ _____ and _____ _____ going ahead and install their DPV systems to be interconnected to the grid, and also to help save the electricity costs. So that's the trend that is happening. The question is how much of the penetration will the government allow? And the government has concerns. Because for the larger system, we have access capacity from the centralized generation. So that is seen as the one—one of the constraints from the government standpoint. They would expand the DPV market quickly. That could prevent from rapid support from the government.

Kate Contos

Great. Thank you again. On behalf of the Clean Energy Solutions Center, I'd like to extend a thank you to all of our expert panelists, and to our attendees for participating in today's webinar. We very much appreciate your time, and hope in return that there are some valuable insights that you can take back to your ministries, departments, or organizations. We also invite you to inform your colleagues and those in your networks about the Solutions Center resources and services, including no-cost policy support through our Ask an Expert service. I invite you to check the Solutions Center website if you'd like to view our slides and listen to the recording of today's presentation, as well as previously held webinars.

Additionally, you'll find information on upcoming webinars and other training events. We're now posting the webinar recordings to the Clean Energy Solutions Center YouTube channel. Please allow about a week for the audio recording to be posted. And finally, I would like to kindly ask you to take a moment to complete the short survey that will appear when we conclude this webinar. Please enjoy the rest of your day and we hope again to see—hope to see you again in the future Clean Energy Solutions Center events. This concludes our webinar.

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