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RE: Distributed rooftop solar photovoltaic generation adoption in Puerto Rico

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1. Key insights

On June 1st 2021 LUMA reported 26,077 registered net metering solar PV systems. As of March 1st, 2023, 21 months later, LUMA is reporting 78,096 registered net metering clients. In 21 months, the number of net metering clients has tripled. **The number of net metering clients is doubling every 15 months.**

On June 1st 2021 LUMA reported 228 MW of installed net metering solar PV capacity. As of March 1st, 2023, 21 months later, LUMA is reporting 524 MW of installed net metering solar PV capacity. In 21 months, the installed net metering solar PV capacity increased by a factor of 2.3. **The installed capacity of net metering solar PV systems is doubling 18 to 19 months.**

The newly installed distributed solar photovoltaic generation capacity with net metering is about 20 MW/month and net metering clients are increasing by 1% of total residential clients every 5 months.

On June 1st 2021 LUMA reported 401 MWh of installed distributed electric storage. On April 1st 2023, 21 months later, LUMA reported 807 MWh of installed distributed electric storage. **In 14 months the installed distributed electric storage doubled, from 401 MWh to 807 MWh. This trend is persistent, the installed generation capacity of net metering solar PV systems is doubling every 14 months.**

In contrast, all tranche 1 utility scale renewable energy projects (18 projects in total) are not under construction as planned due to “differences about the points of interconnection between LUMA and PREPA”. **Therefore, in Puerto Rico utility scale renewables are not growing while distributed renewables are growing at an accelerated pace.**

Although demand reduction is attributable to a number of factors: energy efficiency, changing energy demand patterns and distributed solar photovoltaic generation among others, we have detected a demand reduction which is strongly correlated with the irradiance curve. Since the time frame of the demand reduction is short, our rolling window for the analysis is one year, we put forward the following hypothesis: **we are seeing a reduction in demand due to accelerated adoption of distributed solar photovoltaic systems.** However, the net metering solar photovoltaic systems alone do not account to the magnitude of the reduction. We are currently refining our calculations to estimate the non-net metering distributed solar photovoltaic generation.

2. Current rate of adoption of net metering solar rooftop photovoltaic systems and batteries in Puerto Rico vs utility scale projects

The Puerto Rico Energy Bureau has a public docket named “Performance of the Puerto Rico Electric Power Authority” (docket number NEPR-MI-2019-0007)¹ where LUMA Energy is required to report a number of metrics. The most recent report, dated April 20, 2023, provides data on the incremental installed distributed generation systems capacity. This refers to the number of clients with solar photovoltaic

¹ The docket is available at https://energia.pr.gov/numero_orden/nepr-mi-2019-0007/

systems (mostly rooftop systems) and wind turbines that register for net metering. If the client does not register into the net metering program the installation will not appear in this statistic. As of April 2023, only 1 client has a wind turbine system, all other clients use solar photovoltaic generation. Figure 1 shows the total number of net metering clients with solar photovoltaic generation (bars) and the total generation capacity of these systems in MW.

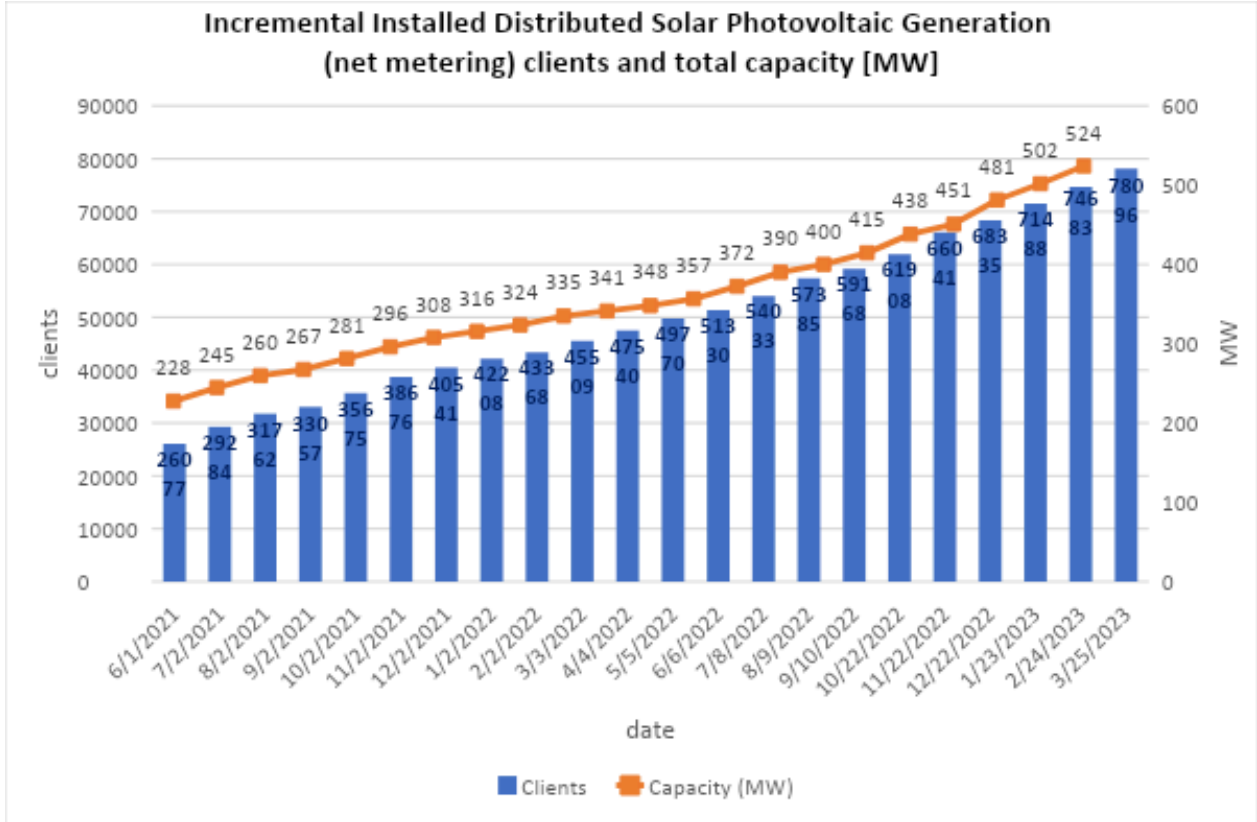


Figure 1. Incremental installed distributed solar photovoltaic generation (registered for net metering) clients and total generation capacity in MW.

Figure 1. shows the increase in solar photovoltaic generation, registered for net metering, since LUMA Energy assumed control of the operation of transmission and distribution. Note that in June 1st 2021 LUMA reported 26,077 registered net metering solar PV systems. As of March 1st, 2023, 21 months later, LUMA is reporting 78,096 registered net metering clients. In 21 months, the number of net metering clients has tripled. Further notice that **the number of net metering clients is doubling every 15 months.**

The incremental installed capacity shows a similar trend. In June 1st 2021 LUMA reported 228 MW of installed net metering solar PV capacity. As of March 1st, 2023, 21 months later, LUMA is reporting 524 MW of installed net metering solar PV capacity. In 21 months, the installed net metering solar PV capacity more than doubled. It increased by a factor of 2.3. Further notice that **the installed capacity of net metering solar PV systems is doubling every year and a half (doubling every 18 to 19 months).**

As shown in Figure 2 **the newly installed distributed solar photovoltaic generation capacity with net metering is about 20 MW/month.**

Monthly Installed Distributed PV Generation Capacity: Net Metering

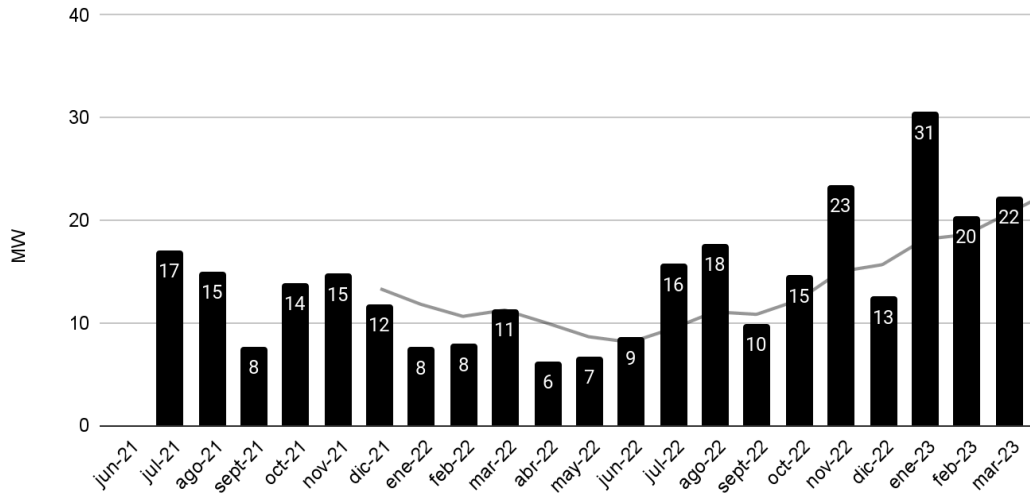


Figure 2. Monthly installed distributed solar photovoltaic generation capacity with net metering. NEPR Data Analysis, PR100 Update 2023. Data source: Negociado de Energía de Puerto Rico (NEPR) https://energia.pr.gov/numero_orden/nepr-mi-2019-0007/

The rate of adoption of rooftop solar photovoltaic systems is increasing since 2014, the year net metering was mandated by law. Figure 3 shows the percentage of residential, commercial and industrial clients with net metering systems from June 2014 thru December 2022. **Currently net metering clients are increasing by 1% of total residential clients every 5 months.**

Clientes con sistemas PV medición neta (%)

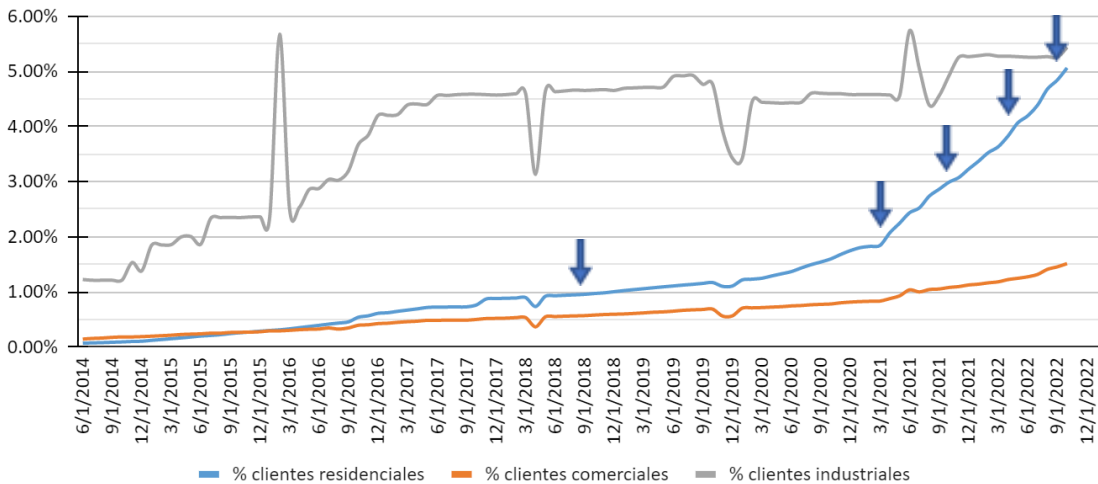


Figure 3. Percentage of residential, commercial and industrial clients with net metering systems. Note that it took 60 months to reach 1% of net metering residential clients, 25 months to reach 2%, 7 months to reach 3%, 6 months to reach 4% and 5 months to reach 5%. As of March 1, 2023, the percentage of net metering residential clients is 6.5% (78,096 residential clients).

Installed distributed electric energy storage is also increasing. Figure 4 shows incremental installed distributed energy storage clients and total capacity, in MWh from June 2021 thru April 2023.

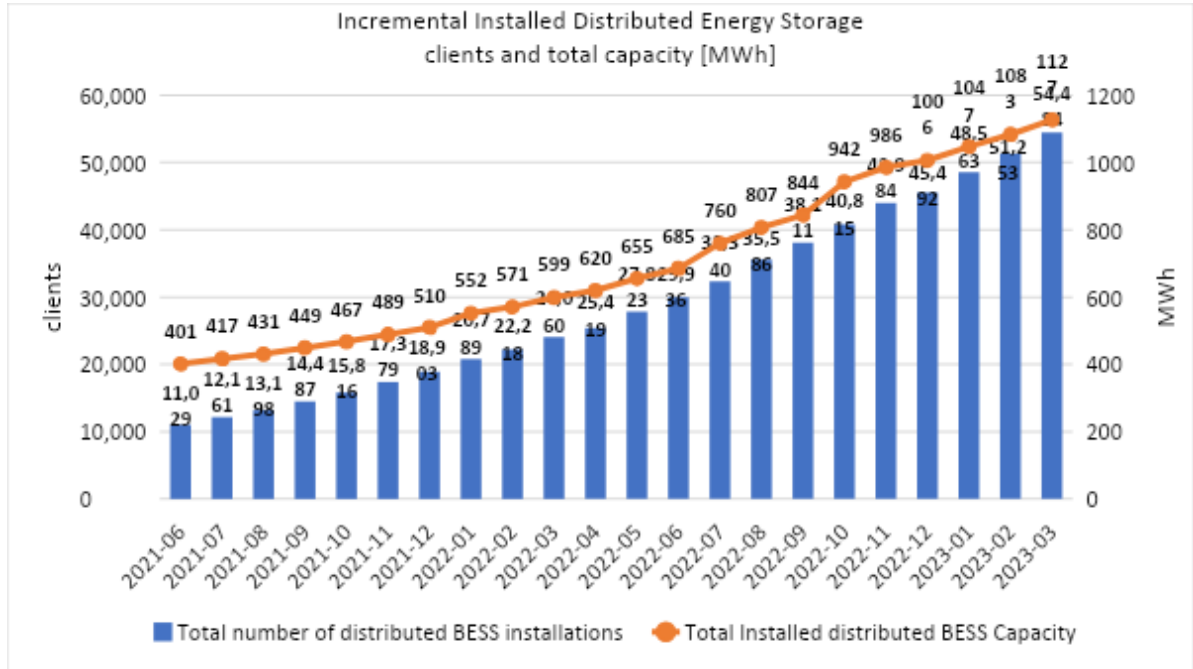


Figure 4. Incremental installed distributed energy storage, in MWh, and corresponding net metering clients from June 2021 thru April 2023 as reported by LUMA to PREB.

In June 1st 2021 LUMA reported 401 MWh of installed distributed electric storage. In April 1st 2023, 21 months later, LUMA reported 1127 MWh of installed distributed electric storage. **In 14 months, from June 2021 to August 2022, the installed distributed electric storage doubled, from 401 MWh to 807 MWh. This trend is persistent, the installed generation capacity of net metering solar PV systems is doubling every 14 months.**

In contrast, on March 30, 2023 the president of the Puerto Rico Energy Bureau, Edison Aviles, declared on a hearing of the Puerto Rico Senate Committee on Strategic Projects and Energy that all tranche 1 utility scale renewable energy projects (18 projects in total) are not under construction as planned due to “differences about the points of interconnection between LUMA and PREPA”. Therefore, in Puerto Rico utility scale renewables are not growing while distributed renewables are growing at an accelerated pace. This is shown graphically in Figure 5. In June 1 2021 distributed rooftop solar photovoltaic generation overtook utility scale solar photovoltaic generation.

Capacidad Instalada: Generación Solar Fotovoltaica Boricua (MW)

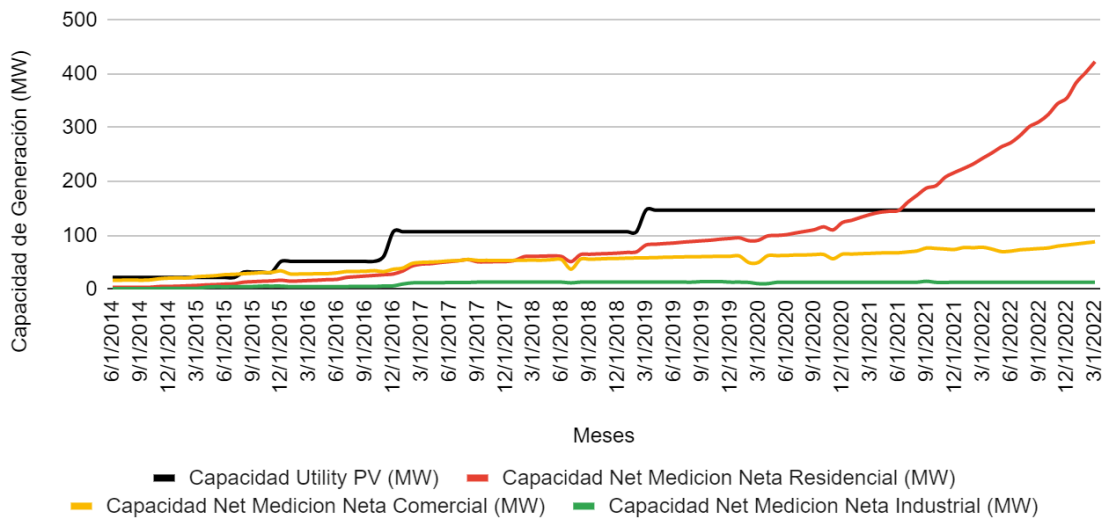


Figure 5. Generation capacity, in MW: utility scale and residential, commercial and industrial net metering capacity.

It is important to note that citizens that install solar PV systems with batteries to serve a portion of their home, disconnecting that portion of the electric load from the grid, do not apply for net metering and therefore are not part of the previous statistics. We currently have no official data of how many these are. However, we do have aggregated electric energy demand data. In the next section we attempt to estimate the installed capacity of solar rooftop systems not connected to the electric grid.

3. *Non-net metering solar rooftop photovoltaic systems in Puerto Rico: can we estimate these using the demand reduction from one year to the next?*

We have studied the average hourly electricity demand (system aggregate demand) from June 2019 thru September 2023 using public data.² We have calculated the average hourly electricity demand change for every month, and using a one year sliding window, compare the year to year hourly demand change. We observe a tendency of demand reduction from year to year.

We also calculate the average hourly electricity demand change during night hours (7pm thru 7 am) for each month.

When we subtract the average night time demand reduction from the hour-to-hour total demand reduction we identify a “net reduction” that may be attributed to distributed solar photovoltaic generation. Why we attribute this “net reduction” to solar generation? Because the shape of the “net reduction” curve; it is very similar to the solar irradiance curve

The strong similarity between the “net reduction” curve and solar irradiance curve is noticed first in the October 2021 – October 2020 period. The similarity between these two curves is consistent for every one year sliding window starting with February 2023 – February 2022, except April 2021 – April 2022 and September 2021 – September 2022. We believe these discrepancies are due to major blackouts caused by a sub-station fire in the Costa Sur generation plant in April 2022 and Hurricane Fiona in September 2022.

² Robert García-Cooper, Graduate Student, PR100 UPRM Team. Data source: Negociado de Energía de Puerto Rico (NEPR) https://energia.pr.gov/numero_orden/nepr-mi-2019-0007/

We acknowledge that demand reduction is attributable to a number of factors: energy efficiency, changing energy demand patterns and distributed solar photovoltaic generation among them. But since the “net reduction” curve is so similar to an irradiance curve, and the time frame of the change is small, 12 months, we put forward the following hypothesis: the reduction in demand is mostly due to accelerated adoption of distributed solar photovoltaic systems.

Our preliminary calculations show that new net metering solar photovoltaic systems, those added within the year under study, alone do not account to the magnitude of the net reduction.

We are currently refining our calculations to estimate the non-net metering distributed solar photovoltaic generation.

4. Acknowledgements:

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