What's Wrong with Jacobson's Plan for California?

1 - Renewables Alone Can't Keep the Lights On

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Mark Jacobson of Stanford University and his colleagues have attempted to show that electric grids powered only by solar, wind, and hydropower – what they call WWS, or wind, water, and sun – can provide all the energy needed in a completely electrified economy. Ten years ago, a number of analysts provided a comprehensive critique of this claim in the Proceedings of the National Academy of Science. Others have provided solid critiques.

A new tool, the Hourly ELectric Grid Analysis or HELGA model, provides a straightforward vehicle for testing Jacobson's claim. It performs an hour-by-hour analysis of the supply and demand for electricity in a defined area. We have previously applied it to an analysis of California's current decarbonization plan, finding that the state's plan does little to reduce the burning of fossil fuels on the grid. Applying this model to the Jacobson scenario, we find that WWS cannot support a reliable grid.

We entered the energy-source capacities in Jacobson's California WWS scenario into HELGA, using the weather pattern for 2023 to represent the hourly contributions of solar and wind power. We set the average electric demand at 88.2 GW (this is the estimate that Jacobson et al provide for the average load in 2050, when all energy uses are to be electrified).

HELGA shows that at least 80 GW of fossil gas generation would be required to avoid repeated blackouts. The daily graph (below) for the year 2050 shows extended periods throughout the year when the renewables fail to meet the load on the grid. In fact, there are 52 days during the year when significant amounts of gas have to be burned to avoid system failure. Graphs revealing large amounts of gas-fired generation during a week in August and in December are shown below. These days, the wind isn't strong enough to replace the sun at night, and the batteries are depleted or, in some cases, not charged at all during the day.

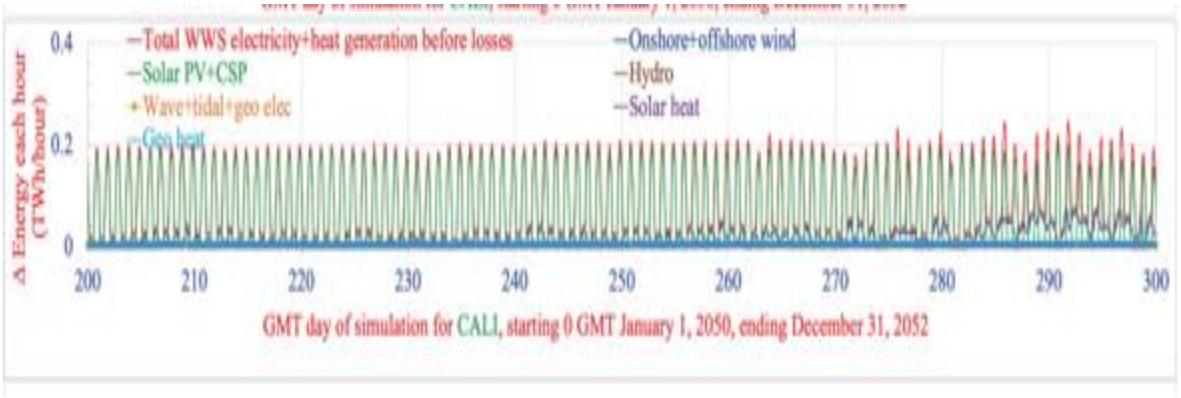
Every grid requires a reliable, dispatchable source that can respond to the variations in demand placed upon the grid. WWS is unable to do that but must be supplemented by another source that doesn't depend upon the weather. If a clean, zero-emission source is desired, only nuclear power meets that requirement.

2- Why is Jacobson so Wrong?

How can Jacobson fined results suggesting that WWS will provide a reliable system when HELGA shows that it definitely will not? The answer is: He does not enter into his model actual data on solar and wind outputs, but only the outputs of an untested global model.

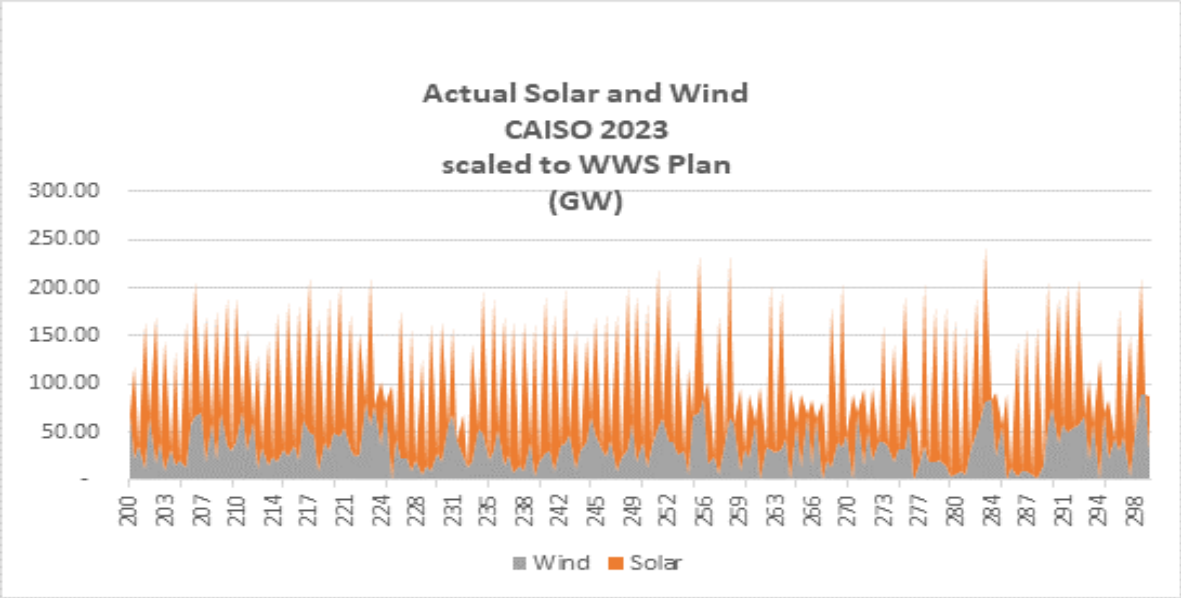
Jacobson uses his GATOR-GCMOM global atmospheric model to supply the solar and wind inputs to LOADMATCH, his model for matching energy supply with demand (or load). The atmospheric model may work well for the atmospheric characteristics it was designed to

describe, but it is not capable of describing accurately the short-term variations in insolation and wind speed in the real world. Here's an example from Figure 1 of his California report:



This graph shows the solar and wind output for 100 days from mid-July to mid-October. They appear to be nearly constant throughout this period.

By contrast, here is the actual CAISO daily solar and wind data (based on their 5-minute reported output) for the same period in 2023, for the portion of California that they cover.



This clearly presents a very different picture, with wide daily and seasonal variations not shown in the Jacobson model's output. It shows gaps that neither hydro or batteries are capable of bridging.

A global model for this crucial energy supply simply cannot provide reliable results on an hourly or daily basis. So far as I have been able to determine, results from this model have not been compared anywhere with the actual solar and wind output in any location.

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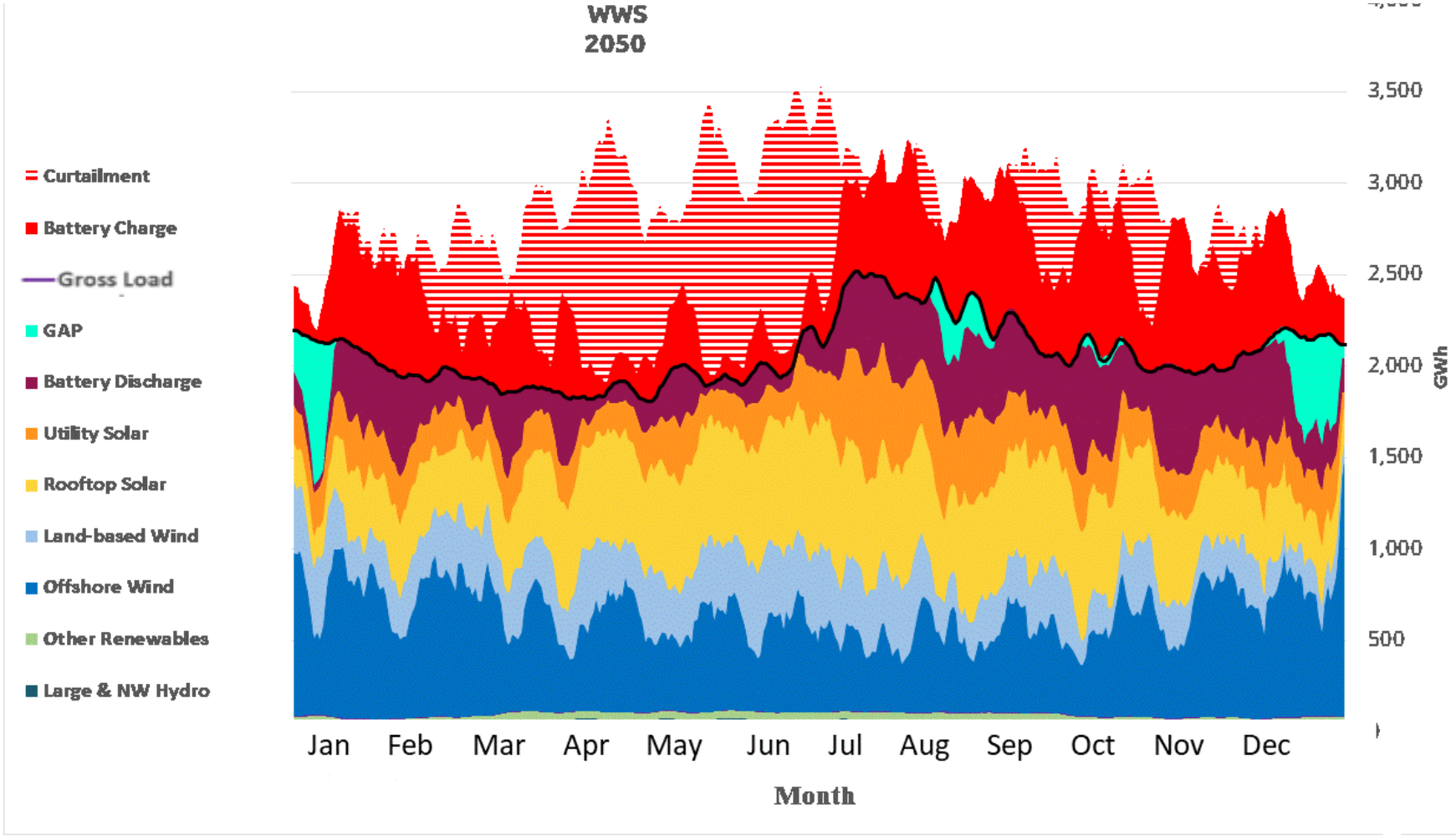
The GAP in Mark Jacobson's Plan for California



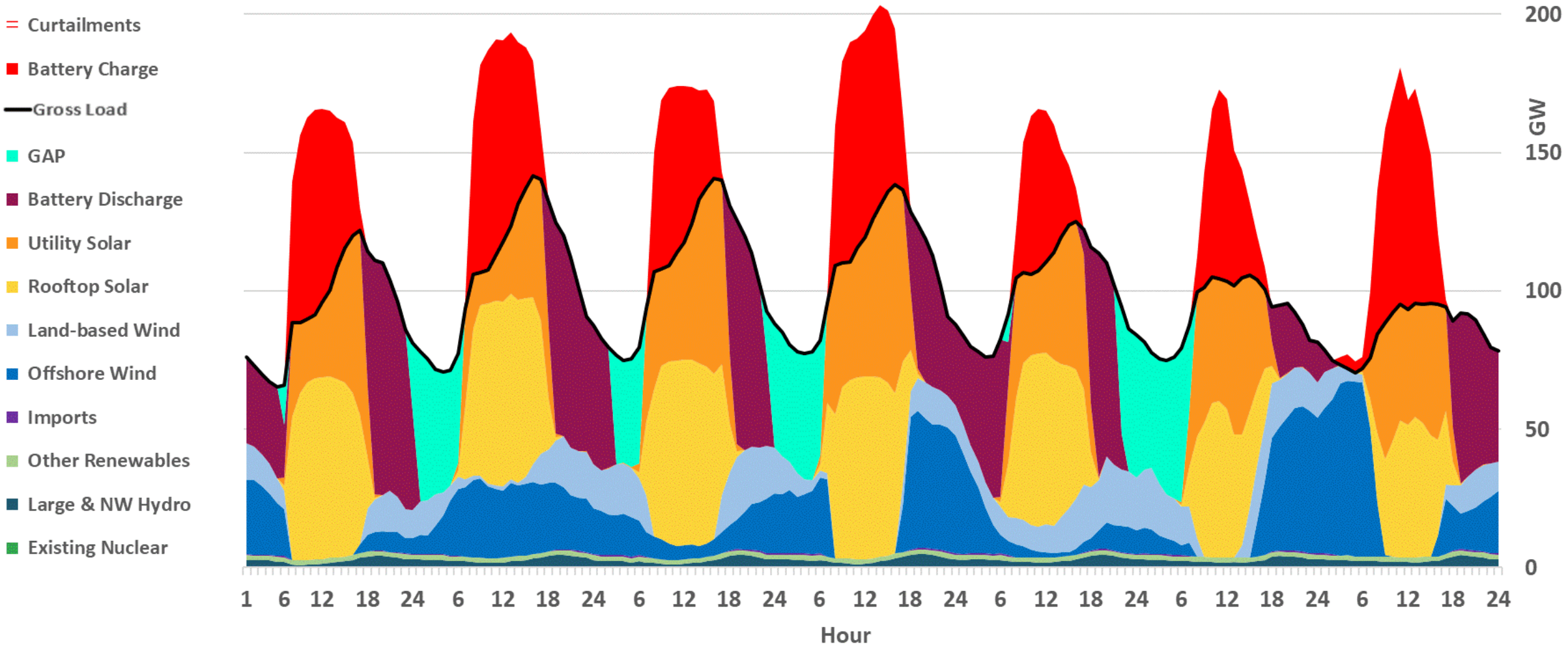
Electricity Generation
WWS
2050

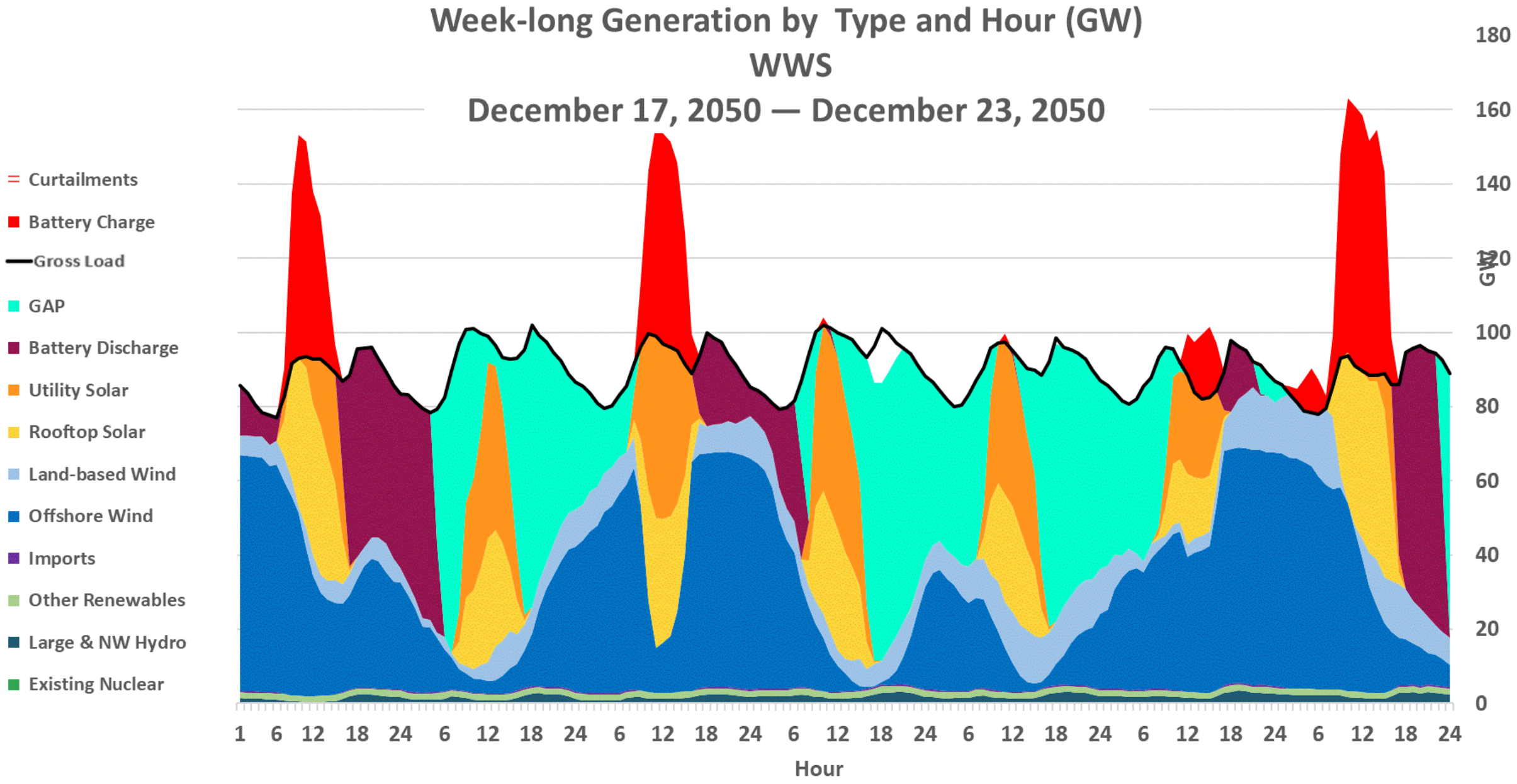
Energy Source	Capacity (MW)	Output (GWh/yr)	Capacity Factor (%)	% Load
Large & NW Hydro	11,300	20,118	20.3%	2.6%
Other Renewables	6,000	14,622	27.8%	1.9%
Rooftop Solar	91,600	183,160	22.8%	23.6%
Utility Solar	125,000	178,568	16.3%	23.0%
Land-based Wind	44,300	124,105	32.0%	16.0%
Offshore Wind	64,420	233,699	41.4%	30.1%
Battery Discharge*	507,000	111,131	2.5%	14.3%
GAP	80,000	20,609	2.9%	2.7%
Imports		1,525		0.2%
Load		776,405		100.0%

* Battery charging included in solar and wind generation.

Source: HELGA 9/25/2025

Week-long Generation by Type and Hour (GW)
WWS
August 27, 2050 — September 2, 2050




Week-long Generation by Type and Hour (GW)
WWS
December 17, 2050 — December 23, 2050
Curtailments
Battery Charge
Gross Load
GAP
Battery Discharge
Utility Solar
Rooftop Solar
Land-based Wind
Offshore Wind
Imports
Other Renewables
Large & NW Hydro
Existing Nuclear
180
160
140
120
100
80
60
40
20
0
GW
1 6 12 18 24 6 12 18 24 6 12 18 24 6 12 18 24 6 12 18 24 6 12 18 24 6 12 18 24
Hour