Lithium-ion battery energy storage 590 kWh

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Grid-scale battery costs can be measured in $/kW or $/kWh terms. Thinking in kW terms is more helpful for modelling grid resiliency. A good rule of thumb is that grid-scale lithium ion batteries will have 4-hours of storage duration, as this minimizes per kW costs and maximizes the revenue potential from power price arbitrage.

Quantum mechanics asks us to think of the electron as both a particle and a wave. Despite the obvious fact that a particle is not a wave, and a wave is not a particle. This is probably a reason that most people do not love quantum mechanics.

Battery models similarly ask us to think about a battery as a ‘per kW’ device and as a ‘per kWh’ device. Where 1 kWh is the supply of 1 kW for precisely 1-hour (or some similar multiplication, such as 0.5 kW for 2-hours, or 0.25 kW for 4-hours, per our overview of energy units). Clearly, kW are not kWh and kWh are not kW.

Our own grid-scale battery model is guilty of this dualistic behaviour, quantifying the costs of grid-scale batteries both in $/kW terms and in $/kWh terms. Our view is that it makes marginally more sense to think about a grid-scale battery in kW terms, when modelling the costs of integrated power systems. But there is some flexibility.

Battery costs are often quoted in $/kWh on a standalone basis, tabulated here, charted below, and showing the amazing deflationary profile of moving the mass manufacturing of batteries over the past decade and leaving mostly material costs (note the units of the y-axis).

Especially in the realm of electric vehicles, this is the cost at which battery packs tend to be procured, for integration into a vehicle. And $/kWh is the most relevant cost metric when thinking about the enormous impending ramp-up of EV batteries.

The output from a battery module is DC electricity at a voltage level driven by electrochemistry. However, circuits in the power grids consist of AC electricity at a very specific and pre-defined voltage. Hence power electronics are required to connect a battery into the grid.

An inverter containing multiple layers of MOSFETs is used to synthesize an AC sine wave from the DC output of a battery. Inverters are sized in kW terms, and priced in kW terms.

A transformer then steps up the voltage of the AC electricity to whatever level is required by the specific grid loop downstream. Transformers are sized in kW terms, and priced in kW terms.

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A physical connection is then made between the step-up transformer and the circuitry of the power grid, using cables and other power electronics. These connections are usually rated in kW terms and their costs are best quantified in $/kW terms, or even per kW-km of transmission and distribution distance.

When we add up the total installed costs of a grid-scale battery, about 40% is the core battery, best measured in $/kWh; another 30-40% is the power electronics and grid connection, best measured in $/kW; and the remainder includes costs such as engineering, permitting, land-leasing, construction, which are best measured in absolute $ terms.

It is a philosophical choice how to present battery costs. You can add all of the cost lines together (in $) and divide them by the total power rating in kW (yielding a $/kW metric). Or you can add all of the cost lines together (in $) and divide them by the total energy storage in kWh (yielding a $/kWh metric).

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