Progress ratio for storage: You can adjust the assumptions in the model about the progress ratio for storage. Scroll down to “Progress ratio” and open the sub-menu by clicking on the triangle next to it, then scroll down to the Storage slider and select a value. This slider represents how much costs fall due to learning, experience, and ‘economies of scale’. Every doubling of cumulative capacity of storage brings a percentage reduction in costs. The progress ratio equals 1 minus that percentage reduction. For example, if the progress ratio is 0.8, then every doubling would bring a 20% drop in cost (since 1 - 0.8 = 0.2 or 20%). With every doubling of cumulative installed capacity, the cost gets multiplied by the progress ratio. A lower value would indicate faster learning.

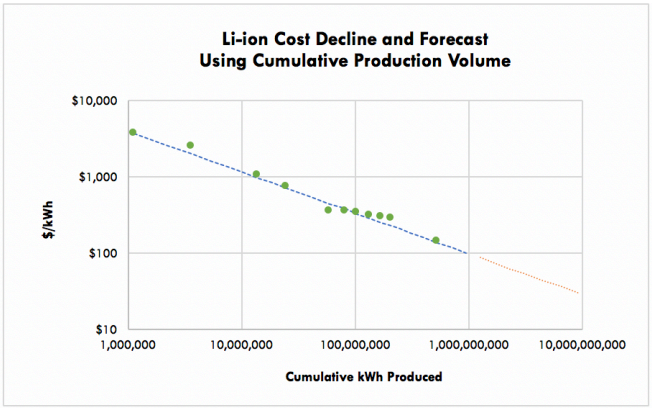
Sensitivity Testing

Changing the Business As Usual assumption from 0.80 to 0.70 results in decrease of 1ppm CO2 and 15 gigatons CO2 avoided by 2100.

Changing the assumption to 0.60 (lowest possible) results in decrease of 2ppm CO2 and 21 gigatons CO2 avoided by 2100.

If the progress ratio is 0.6 then every doubling of cumulative capacity of storage brings a 40% reduction in costs. However, let’s look at Wright’s Law:

Wright’s Law Formula $Y = aX^b$
Y = cumulative average $/kWh
X = cumulative kWh produced
a = cost required to produce 1st unit
b = slope of the function



Source: ARK Investment Management LLC, 2018; IEA, Bloomberg New Energy Finance, Avicenne Energy

For example, the graph shows Li-ion cost decline and forecast using cumulative production volume. Estimating the values from the graph and entering them into a spreadsheet, then estimating the equation for the line, Wright’s Law formula for Li-ion cost decline approximately fits:

LN(Y) = 9.2 - 0.55LN(X)

As a result, we forecast future battery cost declines based on increases in cumulative kWh produced. 2020 costs average $100/kWh. Estimated 2021 and 2022 are $95/kWh and $90/kWh respectively. However Tesla has stated they have a new 10 gWh factory producing the new 4680 cells in California at full capacity by 2022. This means Tesla will probably be producing batteries at about $40/kWh in 2022 and the older designed batteries and factory will still be at $90/kWh.

This aligns with Tesla's estimate that they will reduce $/kWh battery costs by about 50 percent in 2022 when operating at full capacity. As volume increases, based on scaling up to Terawatt-hour factories (probably in Texas and Berlin), then the battery costs per kWh will continue to decline until batteries are a commodity both for vehicles and grid scale, residential or commercial energy storage. Using Wright's Law equation, Table 1-1 shows the future decline in $/kWh compared to increase in cumulative kWh produced.

Limiting the progress ratio of 0.6 ,resulting in a 40% reduction in costs, does not appear to allow an assumption that aligns with forecasts of Tesla's innovations in battery technology and manufacturing.

Table 1-1

$100.00	1,000,000,000
$60.00	5,000,000,000
$40.00	10,000,000,000
$23.57	20,000,000,000
$13.46	40,000,000,000
$7.69	80,000,000,000
$4.39	160,000,000,000