Imperial College London

The future cost of electrical energy storage based on experience curves

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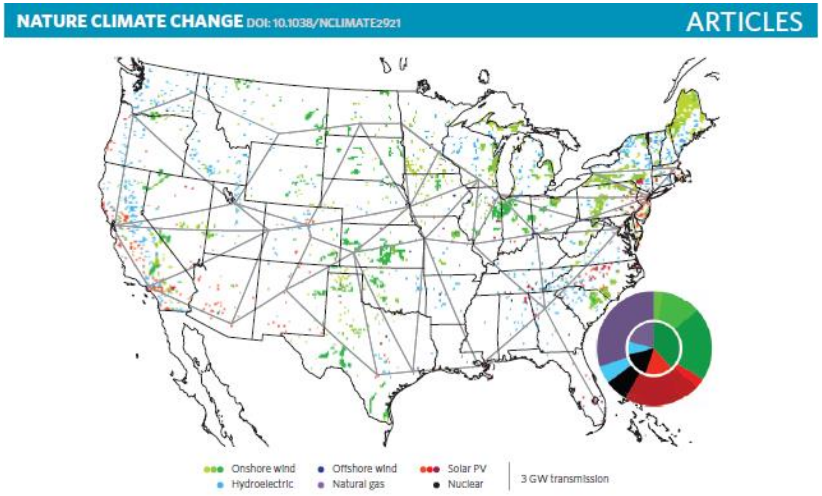
12th Conference on Sustainable Development of Energy, Water and Environment Systems
05 September 2017 | Dubrovnik, Croatia

Grantham Institute

How much will storage cost in the future?

Problem



"Our results show that [...] CO_2 emissions [...] can be reduced by up to 80% [...], **without electrical storage."**

Source: MacDonald AE, Clack CTM, Alexander A, Dunbar A, Wilczak J, Xie Y. Future cost-competitive electricity systems and their impact on US CO2 emissions. Nat Clim Chang. 2016:4–7.

vs.

"Production of Powerwall 2 started on **January 4th 2017**."

Source: www.tesla.com/blog/battery-cell-production-begins-gigafactory
www.youtube.com/watch?v=4F9ON-8rSnM

But, capital costs for lithium-ion batteries have fallen dramatically in recent years

Recent developments

Average: 3,000 $/kWh

Powerwall 1: 1,100 $/kWh

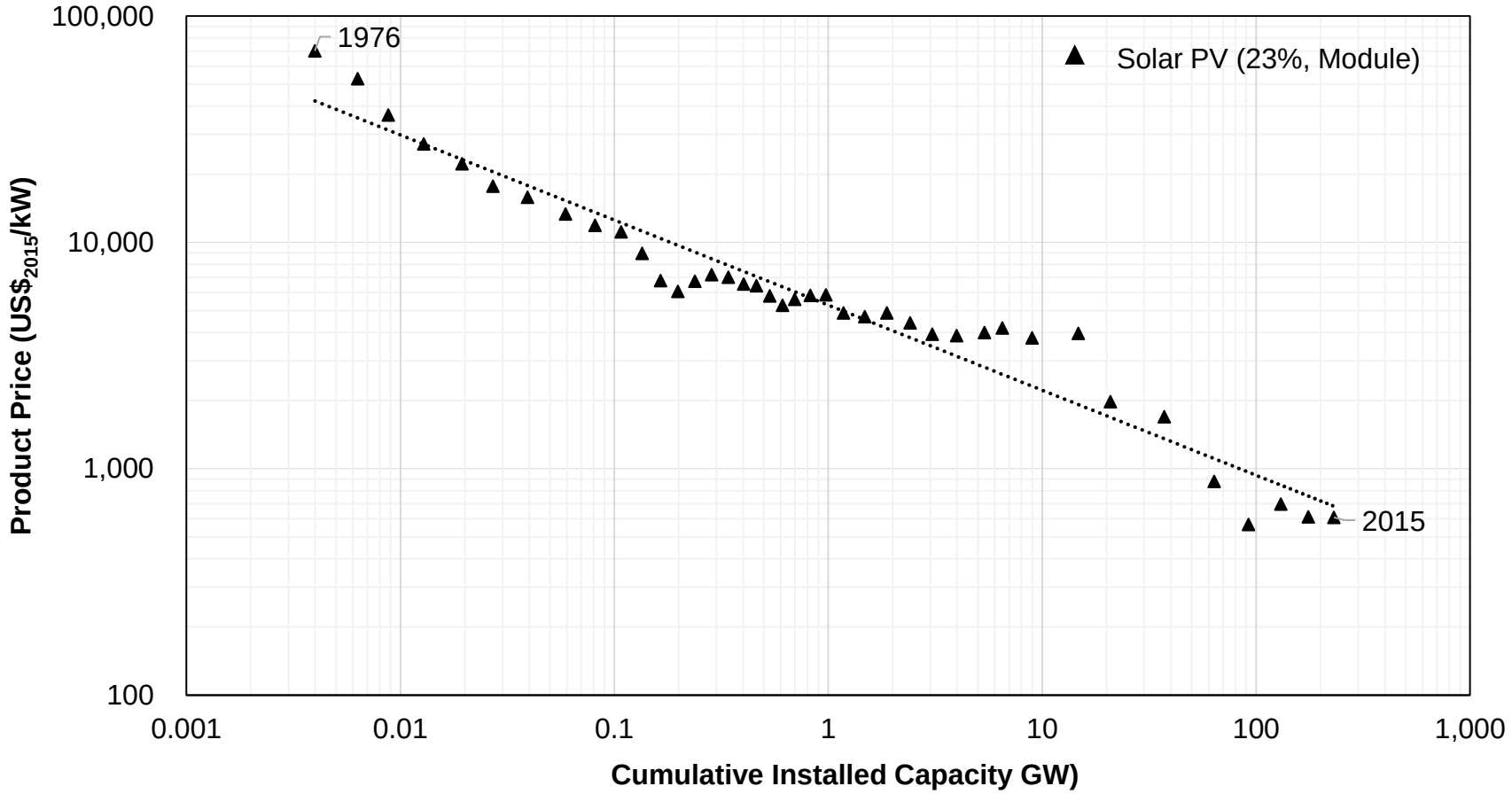
Powerwall 2: 500 $/kWh

October 2013 — April 2015 — October 2016

Sources: Tepper, M. Solarstromspeicher-Preismonitor Deutschland 2016. (Bundesverband Solarwirtschaft e.V. und Intersolar Europe, 2016)
www.solarfixni.co.uk/solarpanelsystems/tesla/
www.tesla.com/powerwall

Experience curves are a scientific tool to model these cost reductions

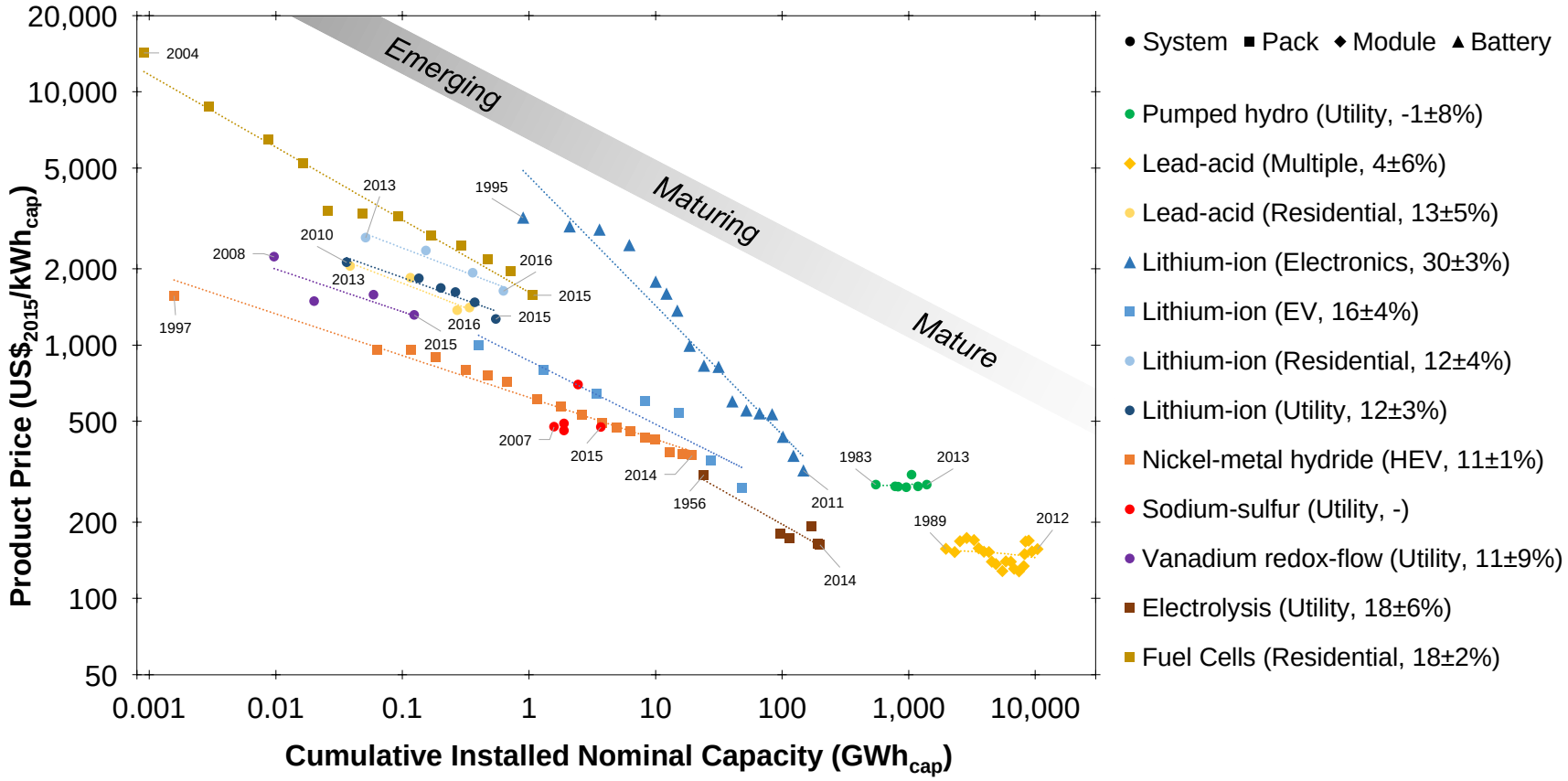
Methodology



Source: Liebreich, M. Keynote - Bloomberg New Energy Finance Summit 2016. (Bloomberg New Energy Finance, 2016).

We derive a 1st-of-its-kind experience curve dataset for storage technologies…

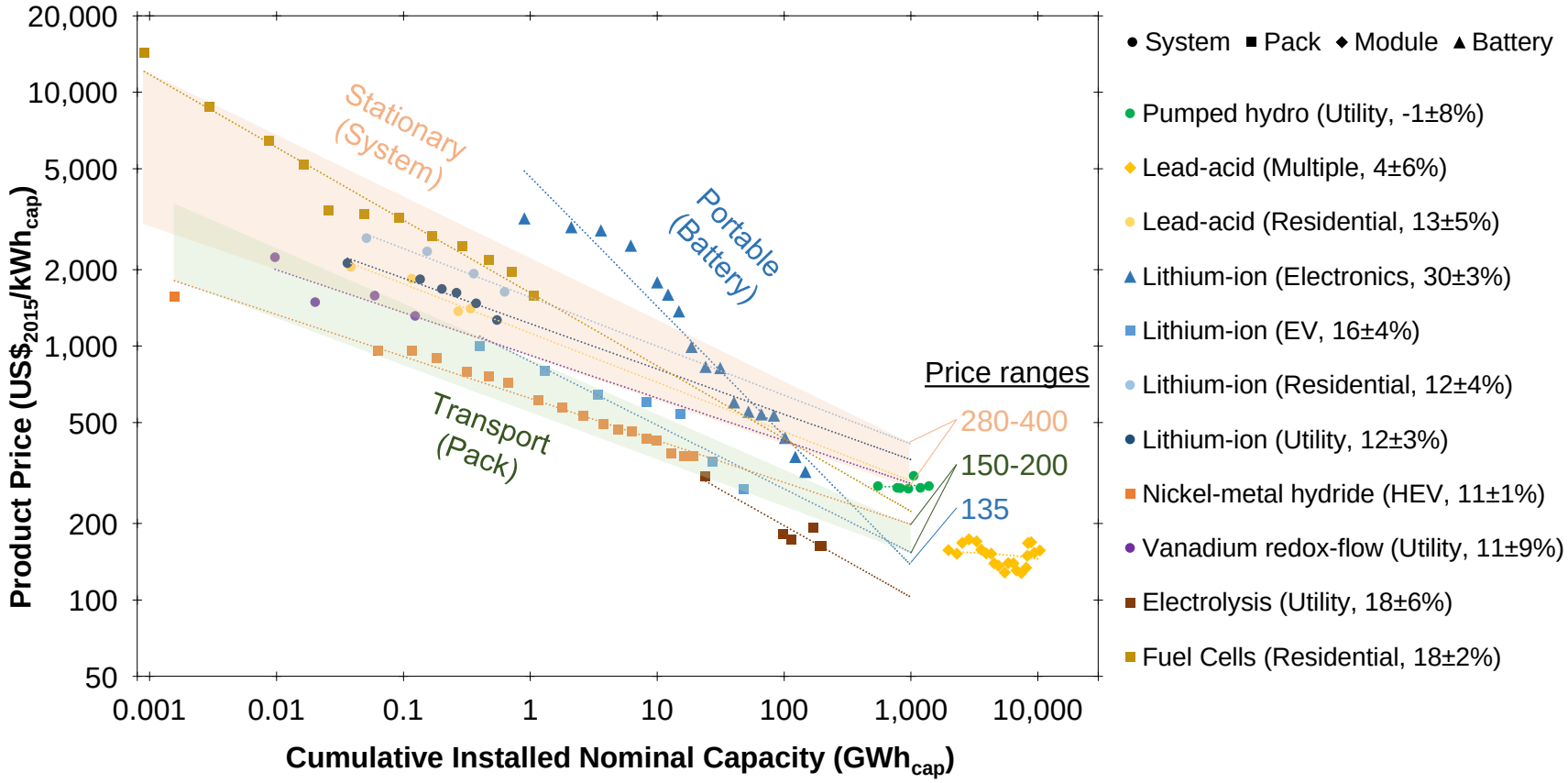
Dataset



Source: O. Schmidt, A. Hawkes, A. Gambhir & I. Staffell. The future cost of electrical energy storage based on experience rates. Nat. Energy 2, 17110 (2017)

… that enables evidence-based cost projections

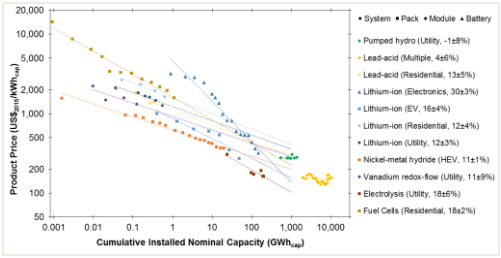
Result

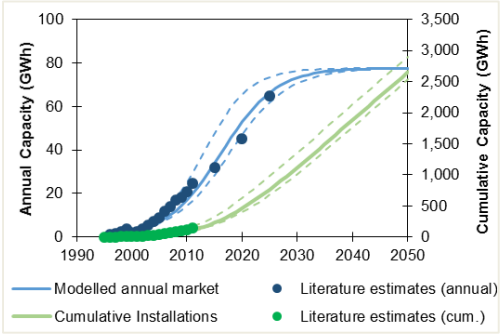


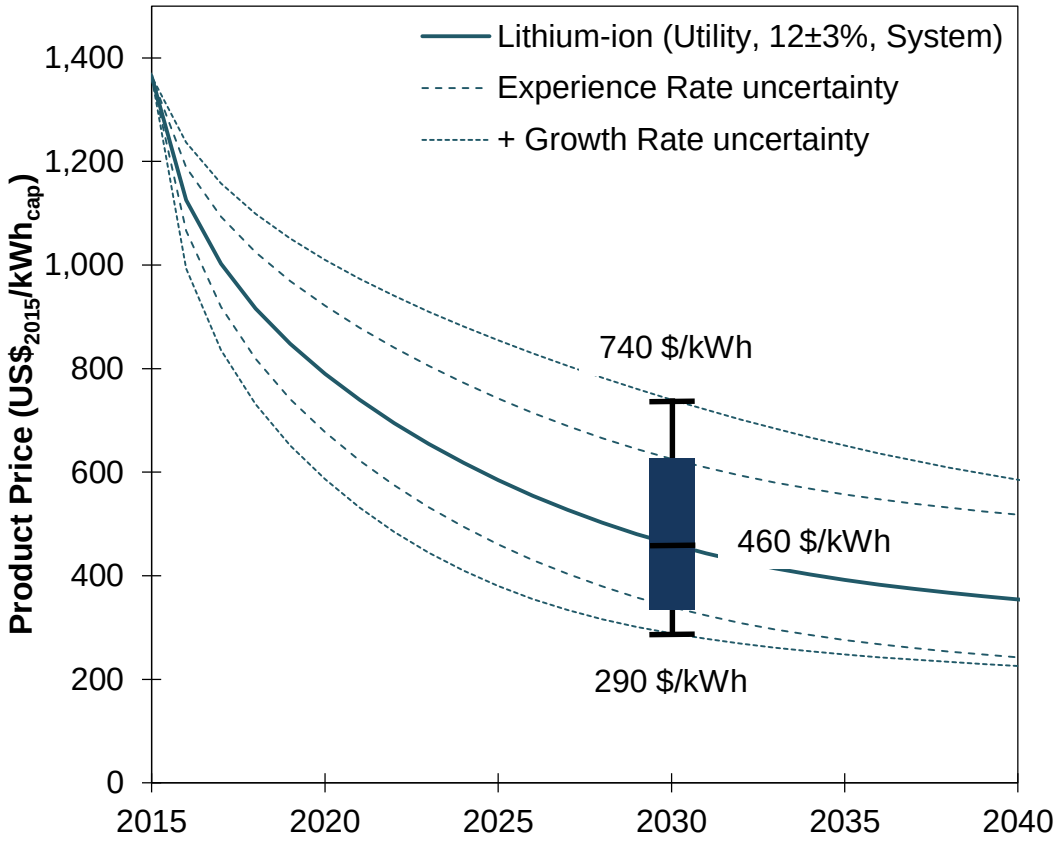
Source: O. Schmidt, A. Hawkes, A. Gambhir & I. Staffell. The future cost of electrical energy storage based on experience rates. Nat. Energy 2, 17110 (2017)

The cost of installed utility-scale lithium-ion systems fall to 290-740 $/kWh by 2030

Analysis 1 – Capital cost projection







Source: Own Analysis

Instead of a nuclear plant, the UK could have doubled its existing storage capacity

Analysis 2 – Investment comparison

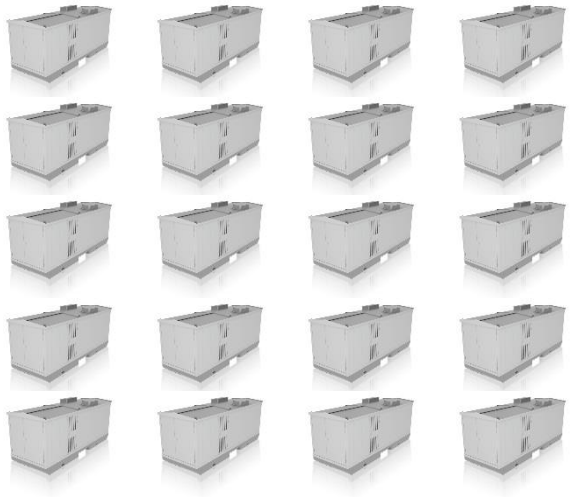
Cost: US$24 billion

Completion: 2025

3.2 GW baseload capacity

"*Meet 5-10% of UK demand*"

OR



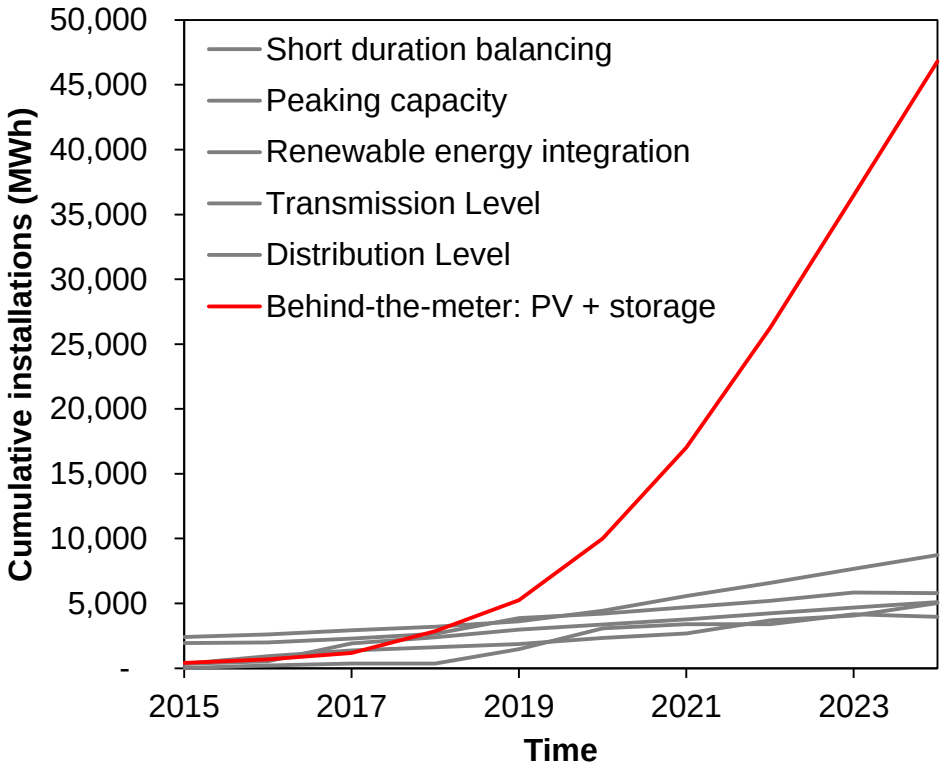
35 GWh storage capacity

"*Double UK's storage capacity*"

Source: Own Analysis

The market for home storage appears poised for growth…

Analysis 3 – Profitability (Home storage)

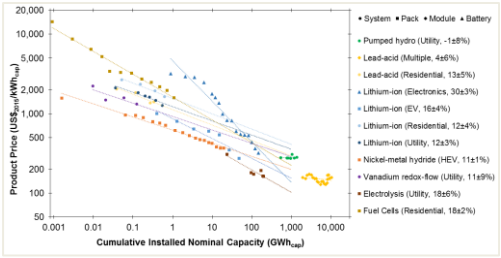


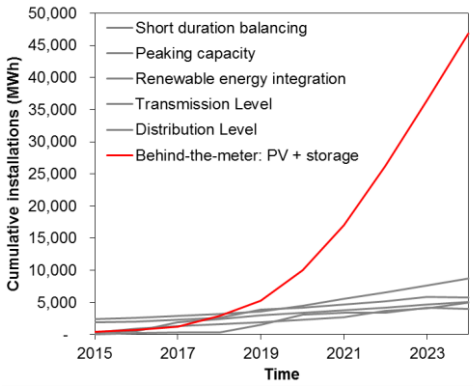
Source: www.tesla.com/powerwall

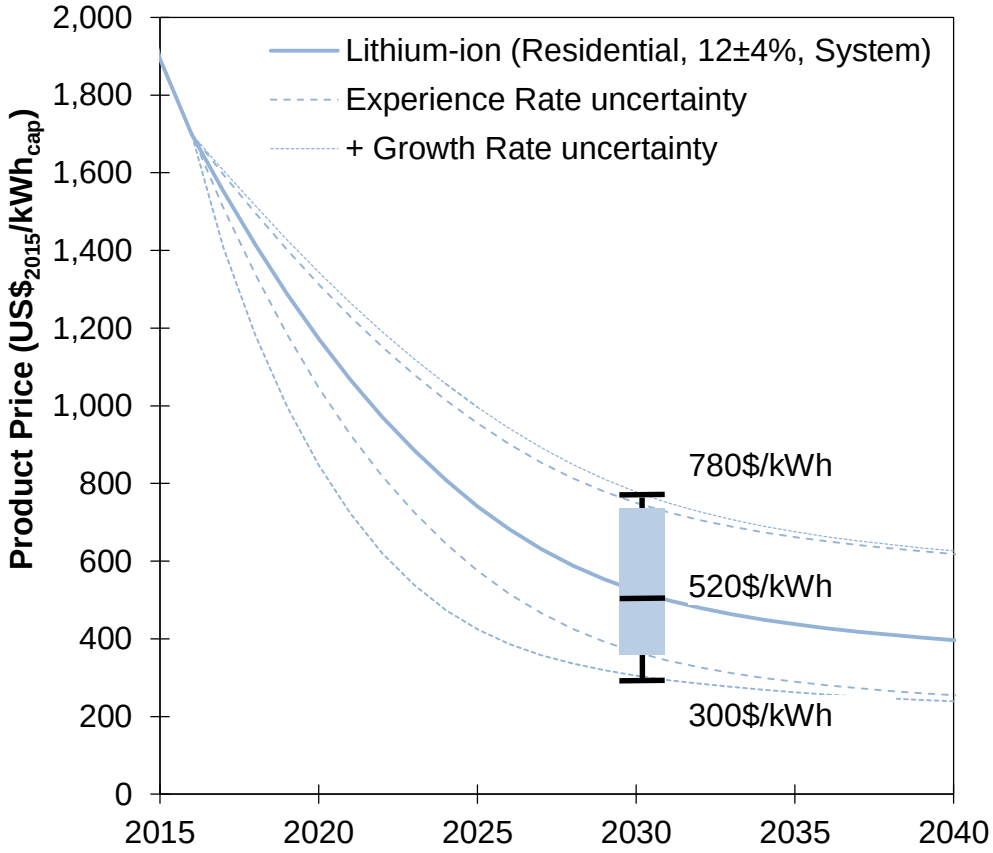
L. Goldie-Scot, Global Energy Storage Forecast 2016-24, Bloomberg New Energy Finance, 2016.

with cost of installed residential li-ion systems falling to 300-780 $/kWh by 2030

Analysis 3 – Profitability (Home storage)



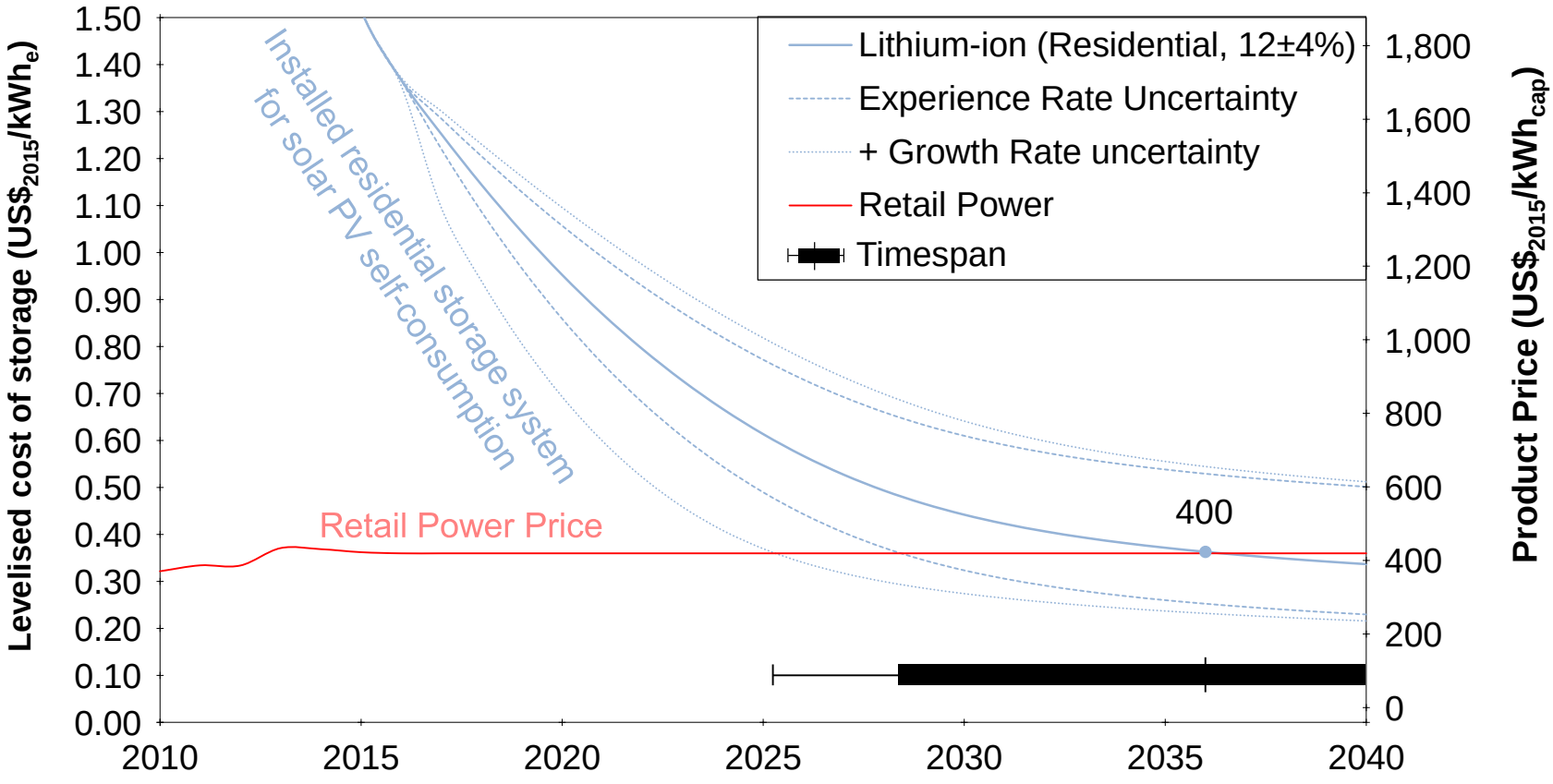




Source: Own Analysis

Still, residential batteries are unlikely to make economic sense in GER before 2030

Analysis 3 – Profitability (Home storage)



Source: Own Analysis

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NERC SCIENCE OF THE ENVIRONMENT

Questions?

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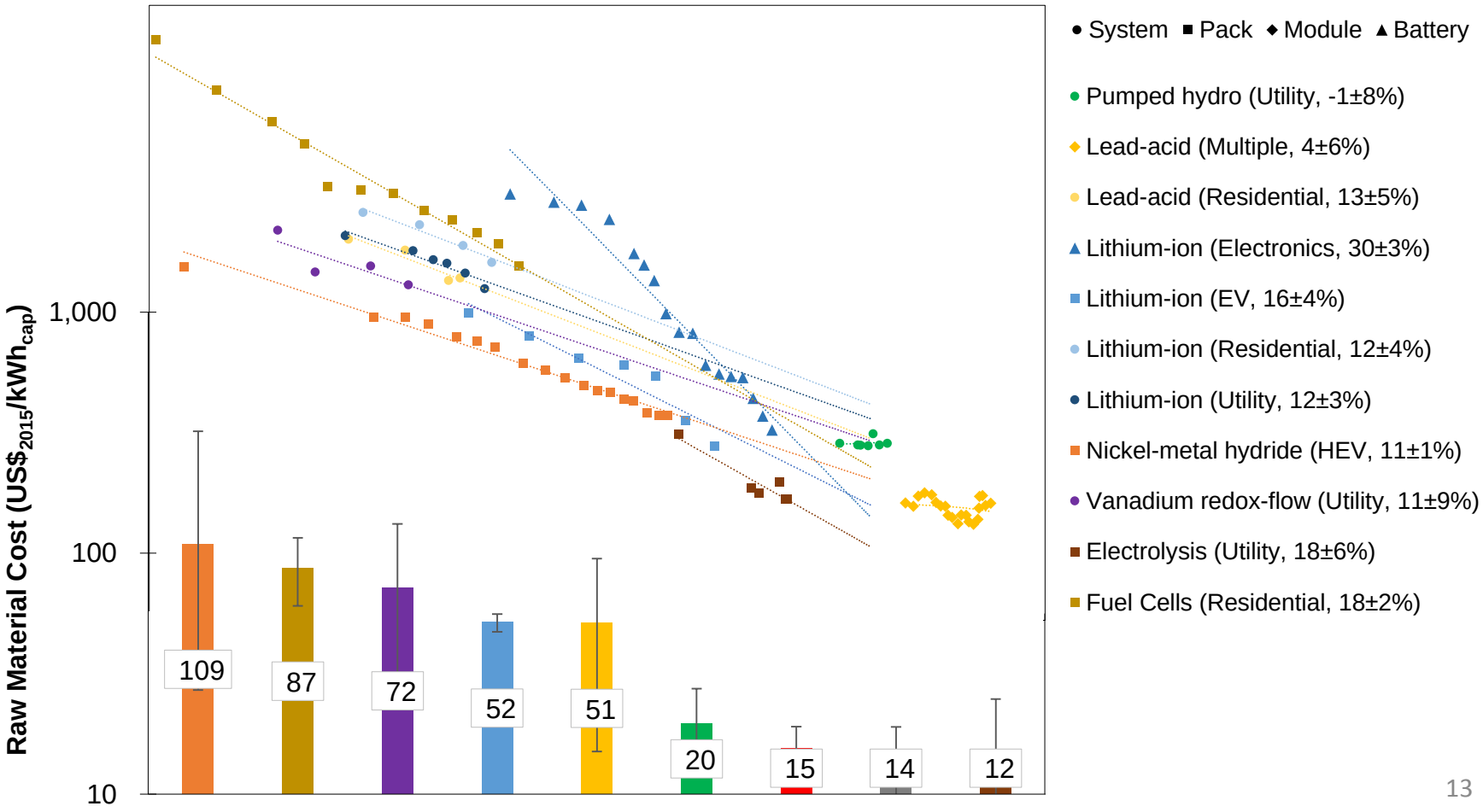
Grantham Institute

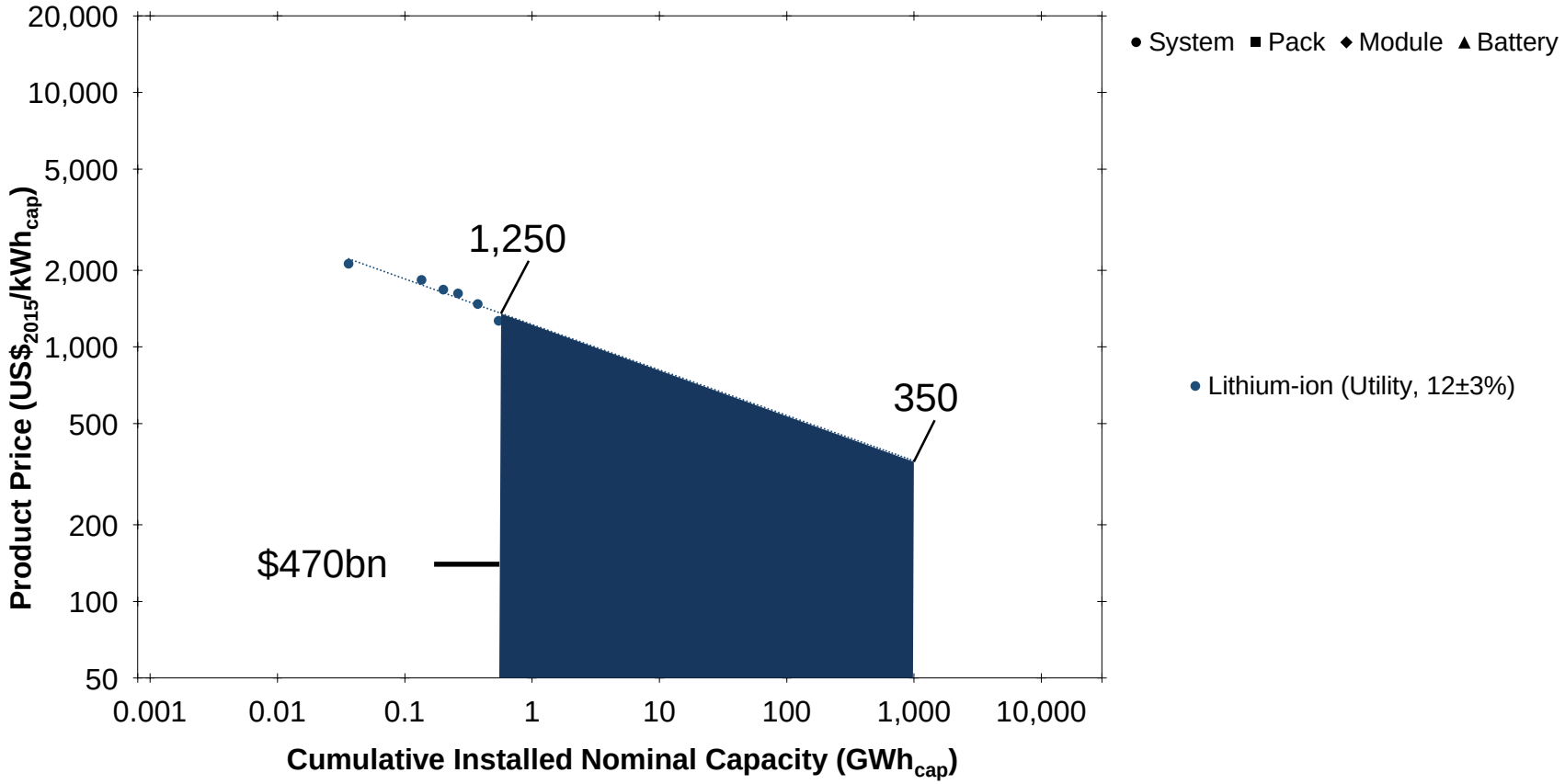
Raw material costs suggest that these cost projections are not infeasible

Sanity Check – Raw material cost



Required investments in deployment to achieve projected costs appear sensible

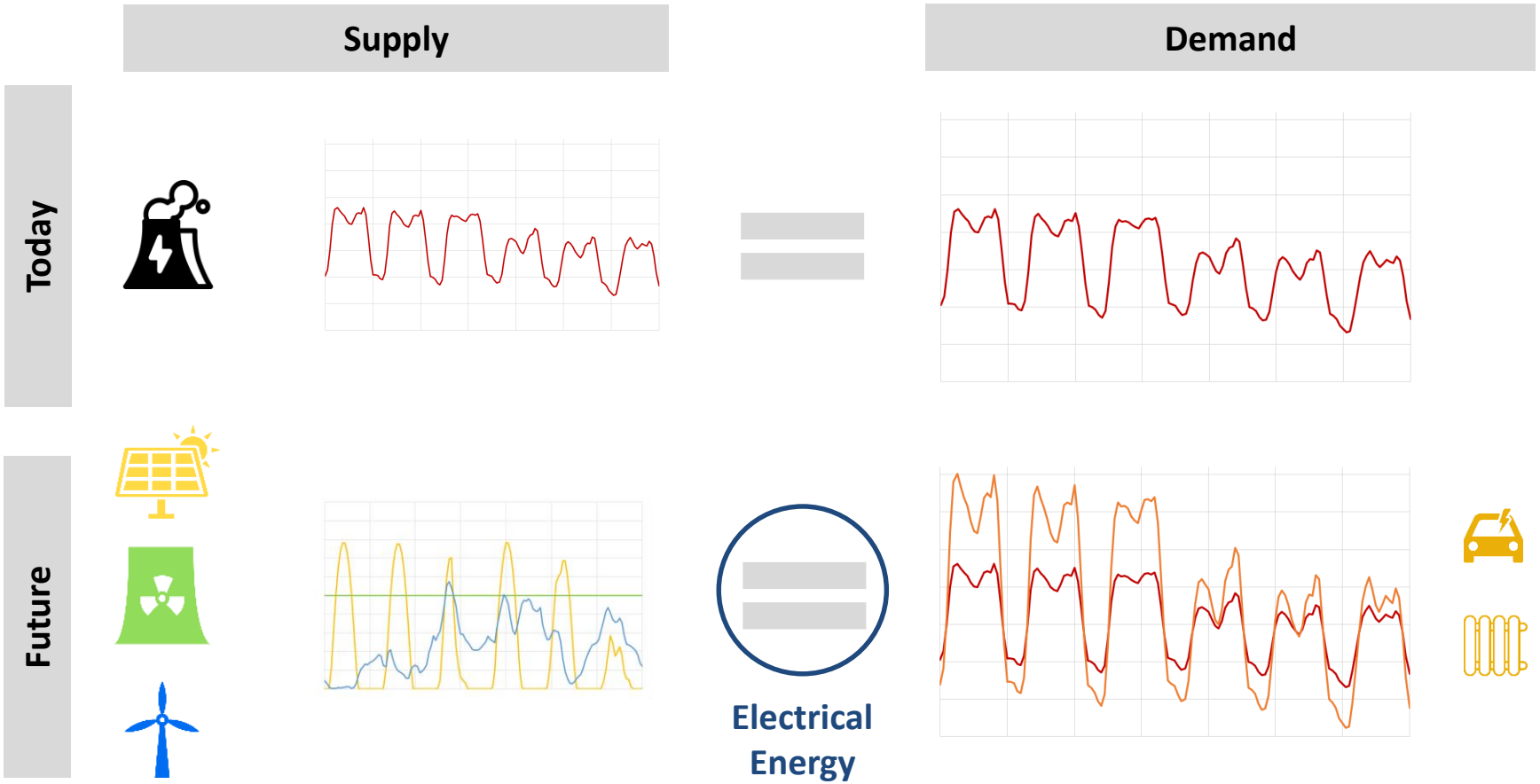
Sanity Check – Investment requirement



Source: O. Schmidt, A. Hawkes, A. Gambhir & I. Staffell. The future cost of electrical energy storage based on experience rates. Nat. Energy 2, 17110 (2017)

Energy storage could play a critical role in balancing future energy systems

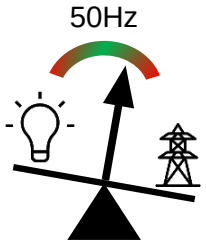
Introduction



Source: Icons made by Freepik from www.flaticon.com

This has implications on the profitability of storage in various business cases

Profitability Analysis



Primary frequency control

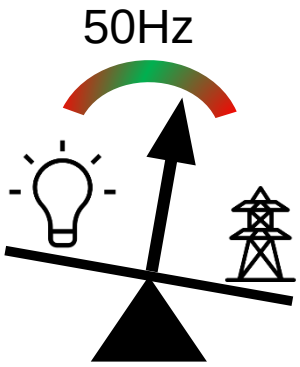
Wind farm

Home storage

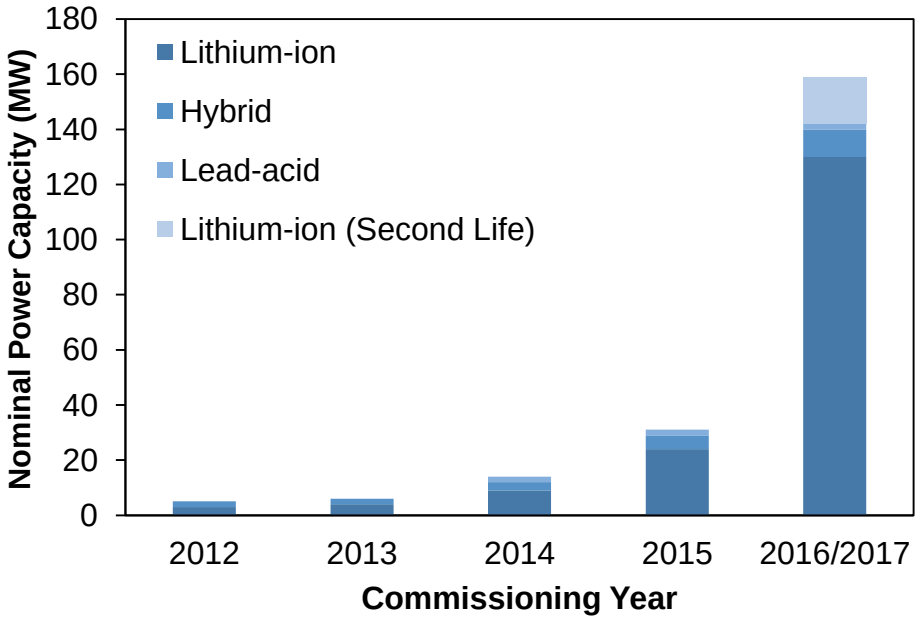
Electric vehicles

Recent investments in storage to provide balancing services show that…

Profitability Analysis (Frequency control)



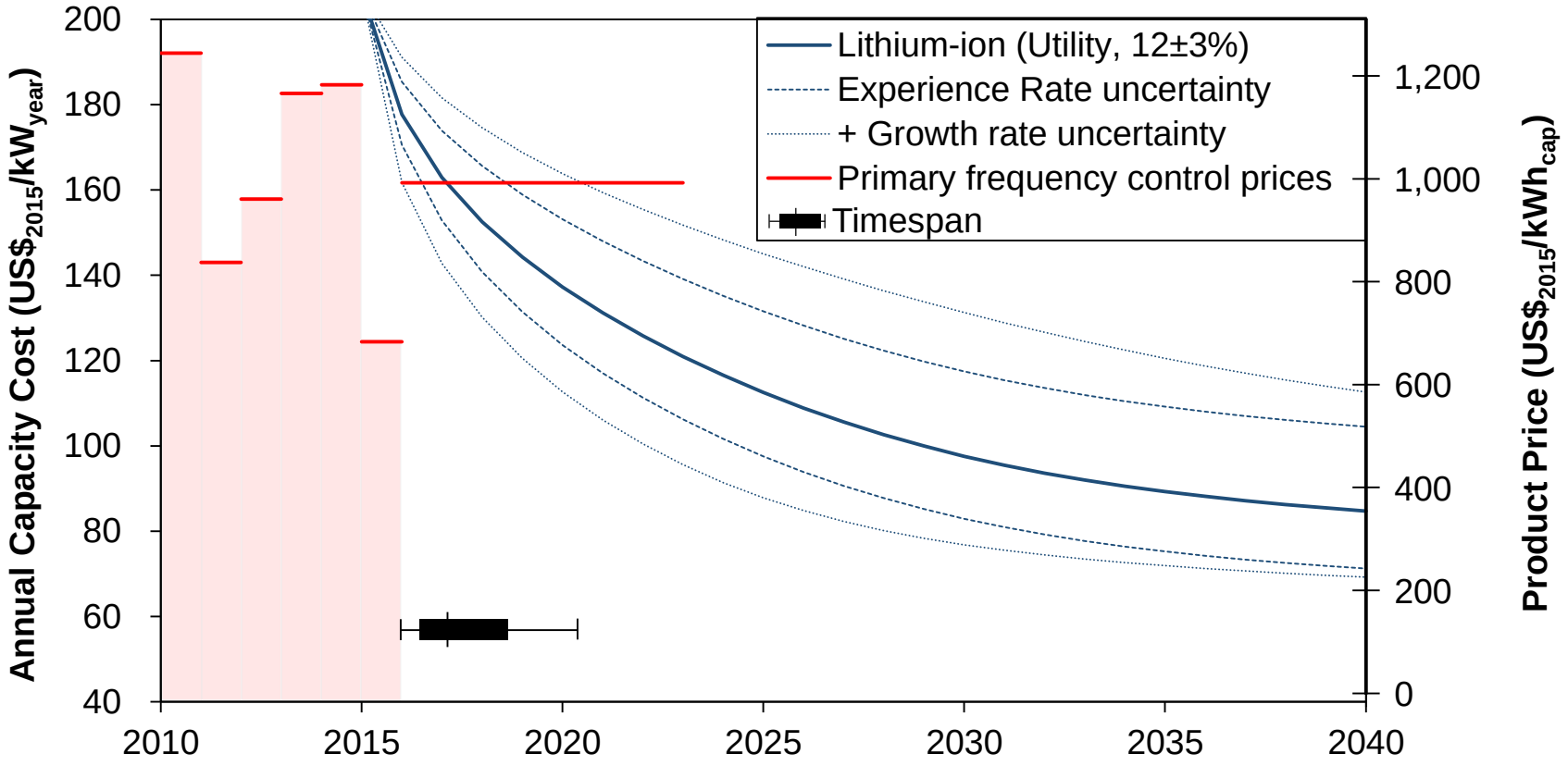
Siemens to deploy market-based grid balancing battery for German utility



Source: https://www.energy-storage.news/news/siemens-to-deploy-market-based-grid-balancing-battery-for-german-utility
P. Stenzel, Bereitstellung von Primärregelleistung durch stationäre Großbatteriespeicher, Forschungszentrum Jülich, Institut für Energie- und Klimaforschung – Systemforschung und Technologische Entwicklung (IEK-STE), 2016.

… primary frequency response could be a business case for storage

Profitability Analysis (Frequency control)

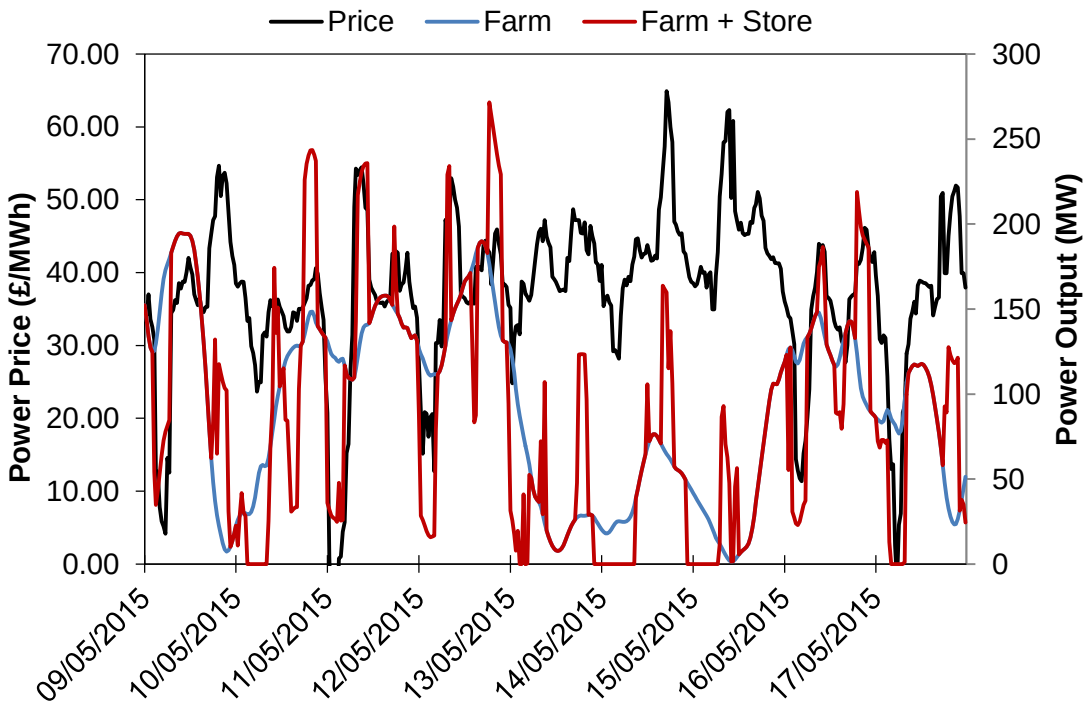


Source: Own Analysis
D.P. Svoboda, D.R. Schemm, M. Bartelt, Aufbruch in den Regelenergiemarkt?, Energ. Manag. (August 2015) 28.

Using batteries to optimise renewable power output for profit…

Profitability Analysis (Wind farm)

Vattenfall plans 22MW battery storage facility at South Wales wind farm

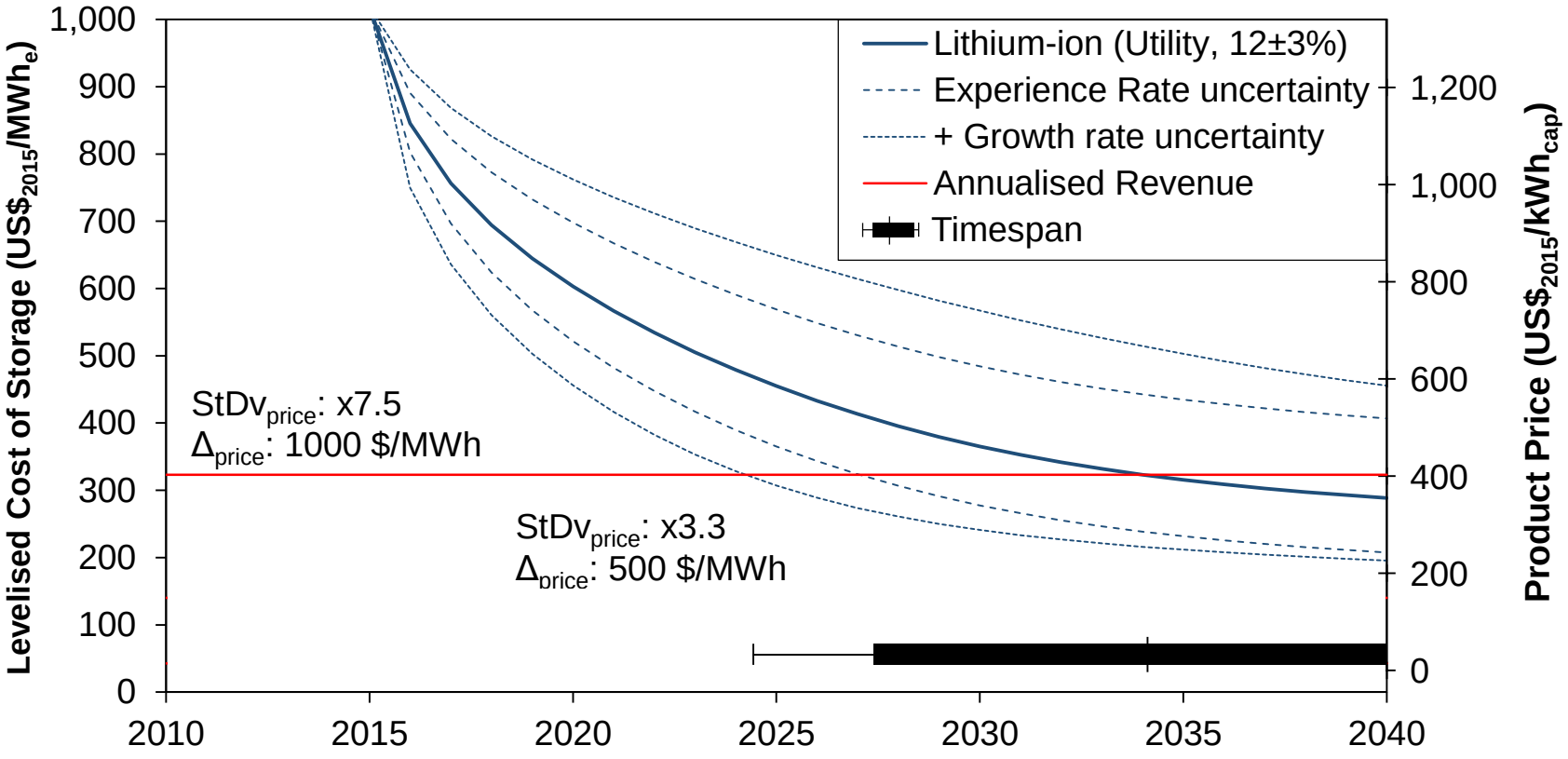


Source: https://theenergyst.com/vattenfall-plans-22mw-battery-storage-facility-at-south-wales-wind-farm/
Own analysis

… is only viable when the variability of power prices increases by a factor of 7.5

Profitability Analysis (Wind farm)

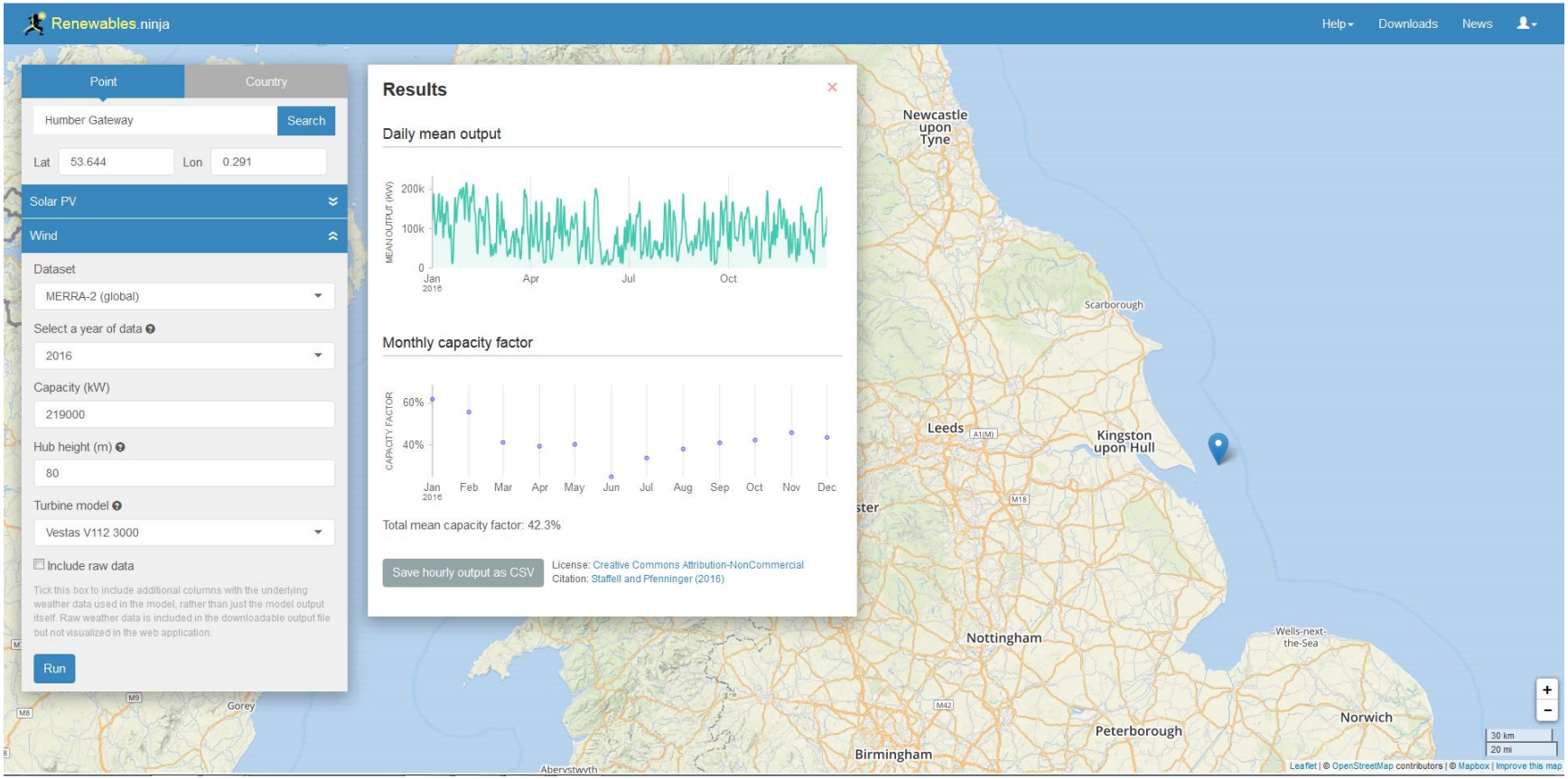
Wind farm: 219 MW
Battery: 95 MW / 330 MWh



Source: www.renewables.ninja
Own analysis

Wind farm output from Renewables.Ninja

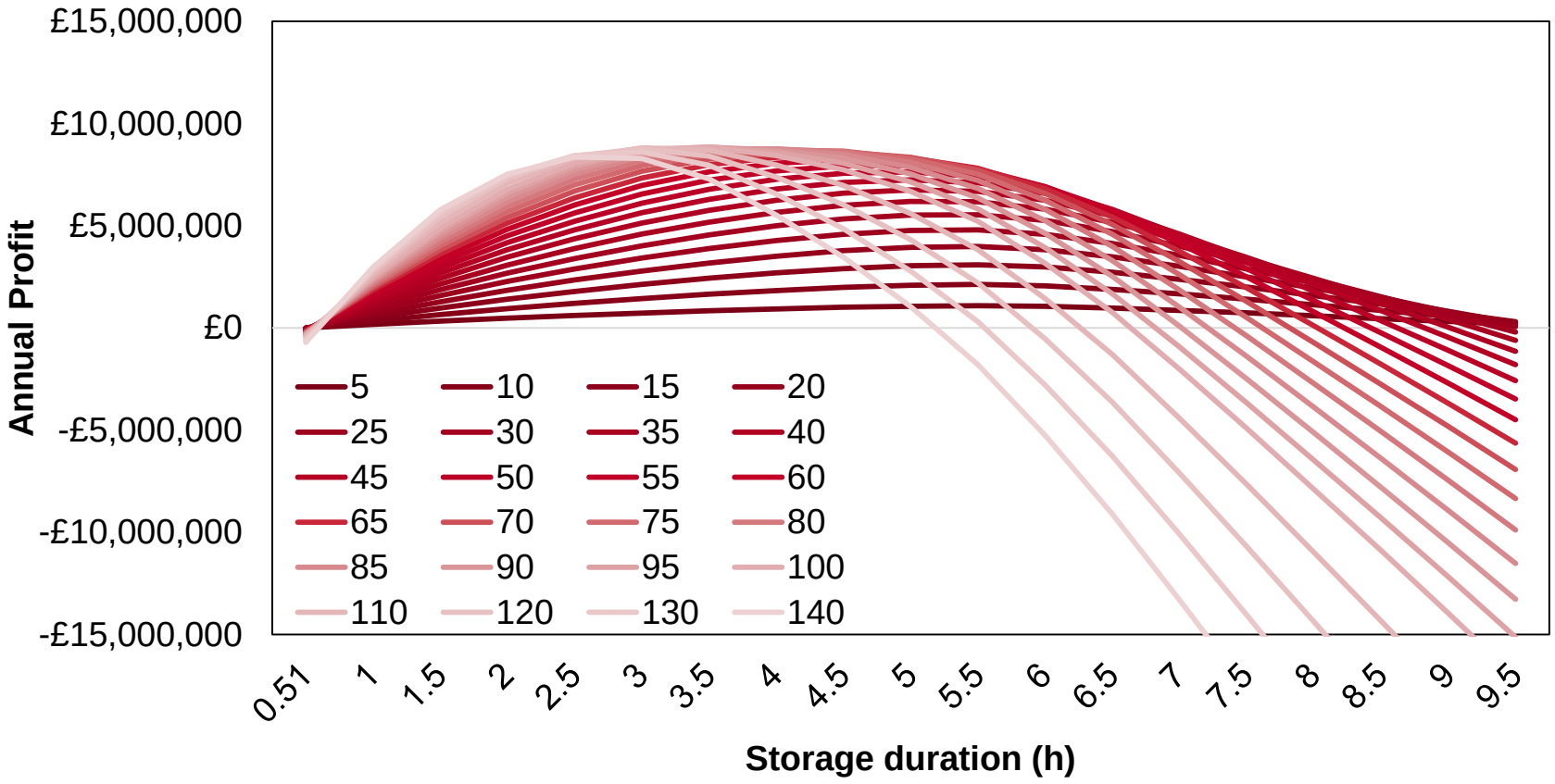
Analysis 4 – Profitability (Wind farm)



Source: https://theenergyst.com/vattenfall-plans-22mw-battery-storage-facility-at-south-wales-wind-farm/

Annual profit for battery of different sizes coupled to 219MW wind farm

Analysis 4 – Profitability (Wind farm)



The electrification of transport attracts most attention, because …

Profitability Analysis (Electric vehicles)

Tesla's Model 3 could be the car that makes electrics mainstream

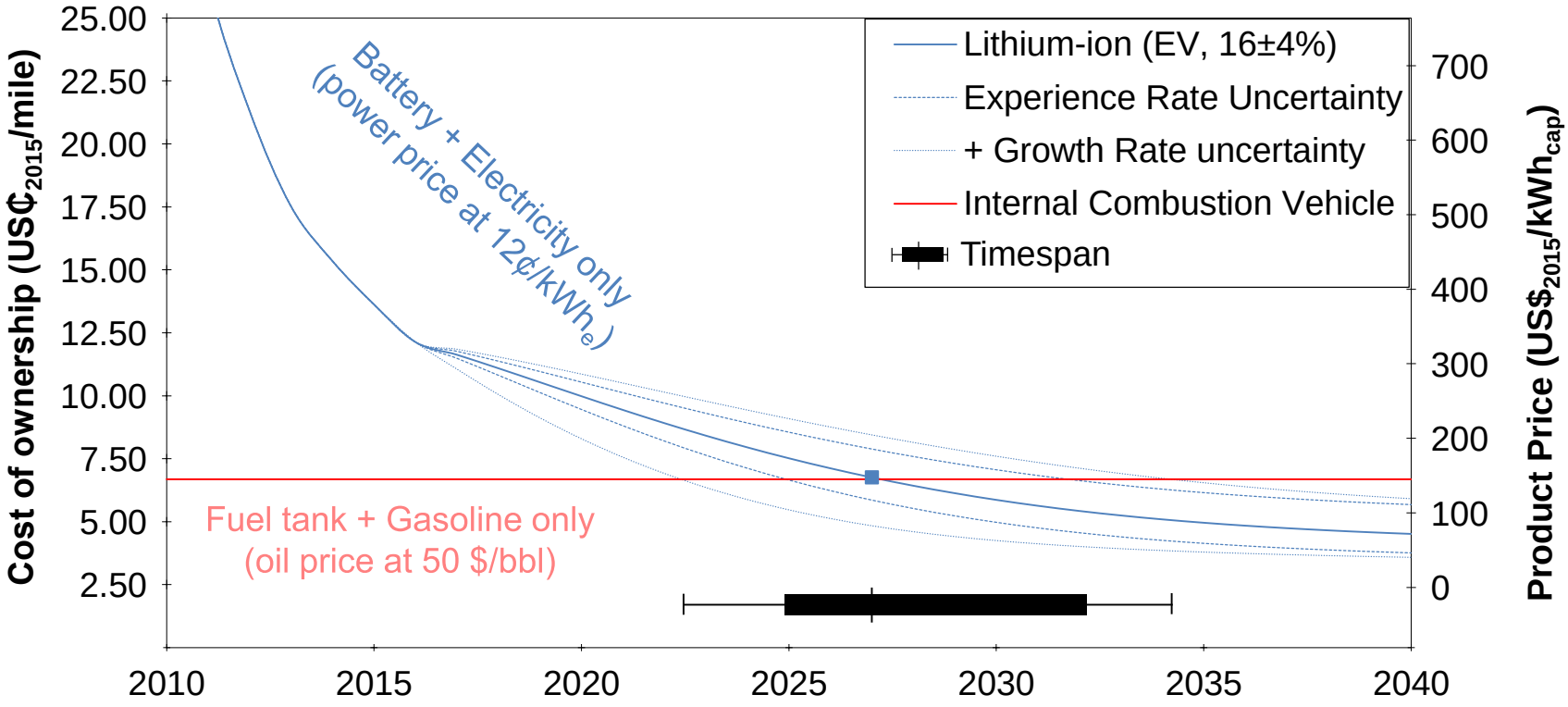
60,000 GWh

(annual demand for EV batteries if 1.2bn passenger cars are electric)

Source: https://www.thestar.com/business/2016/04/01/teslas-model-3-could-be-the-car-that-makes-electrics-mainstream.html
https://www.evoto.ca

… electric cars will beat conventional ones between 2022 and 2034

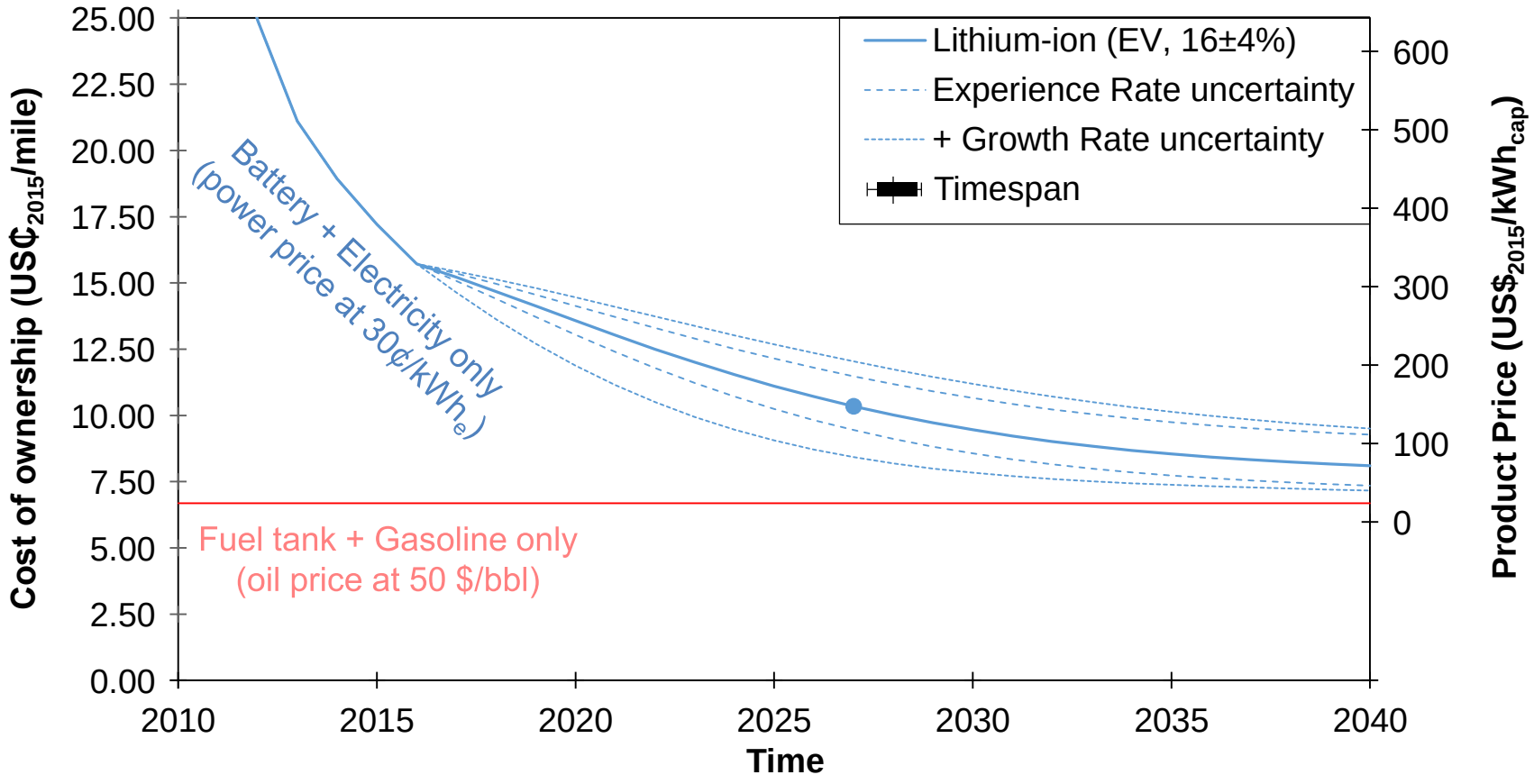
Profitability Analysis (Electric vehicles)



Source: O. Schmidt, A. Hawkes, A. Gambhir & I. Staffell. The future cost of electrical energy storage based on experience rates. Nat. Energy 2, 17110 (2017)

Germany

Profitability Analysis (Electric vehicles)



Source: O. Schmidt, A. Hawkes, A. Gambhir & I. Staffell. The future cost of electrical energy storage based on experience rates. Nat. Energy 2, 17110 (2017)