

Capital cost projections for electrical energy storage technologies to assess future business cases

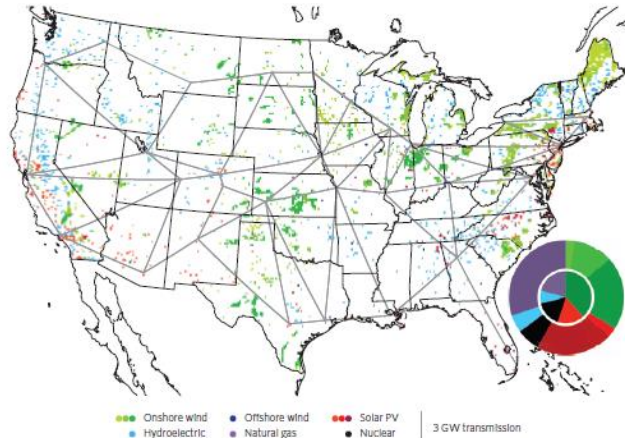
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Energy Storage Conference
07-08 February | Paris

Question: How much will storage cost?

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ARTICLES



VS.



“Our results show that [...] CO₂ 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.

“Production of cylindrical 2170 Li-ion cells used in Powerwall 2 started on **January 4th 2017.**”

“**15 GWh p.a.** will be devoted to stationary battery packs.”

Quote 1: www.tesla.com/blog/battery-cell-production-begins-gigafactory
Quote 2: www.greentechmedia.com/articles/read/Tesla-CTO-on-Energy-Storage-We-Should-All-Be-Thinking-Bigger
Video: www.youtube.com/watch?v=4F9ON-8rSnM

Example: Residential Li-ion systems (inst.)

Average: 3,000 \$/kWh



Powerwall 1: 1,100 \$/kWh



Powerwall 2: 500 \$/kWh



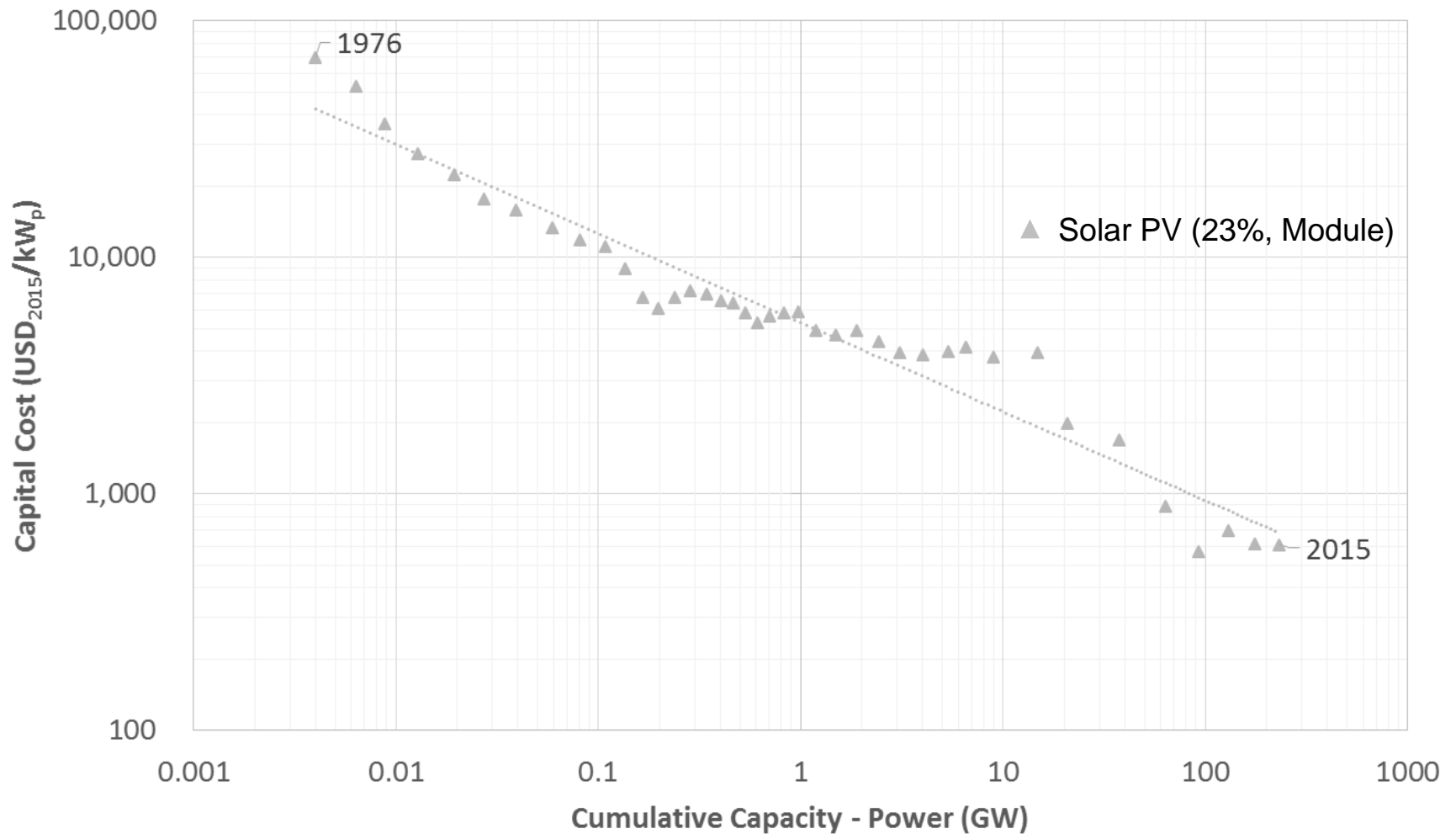
October 2013

April 2015

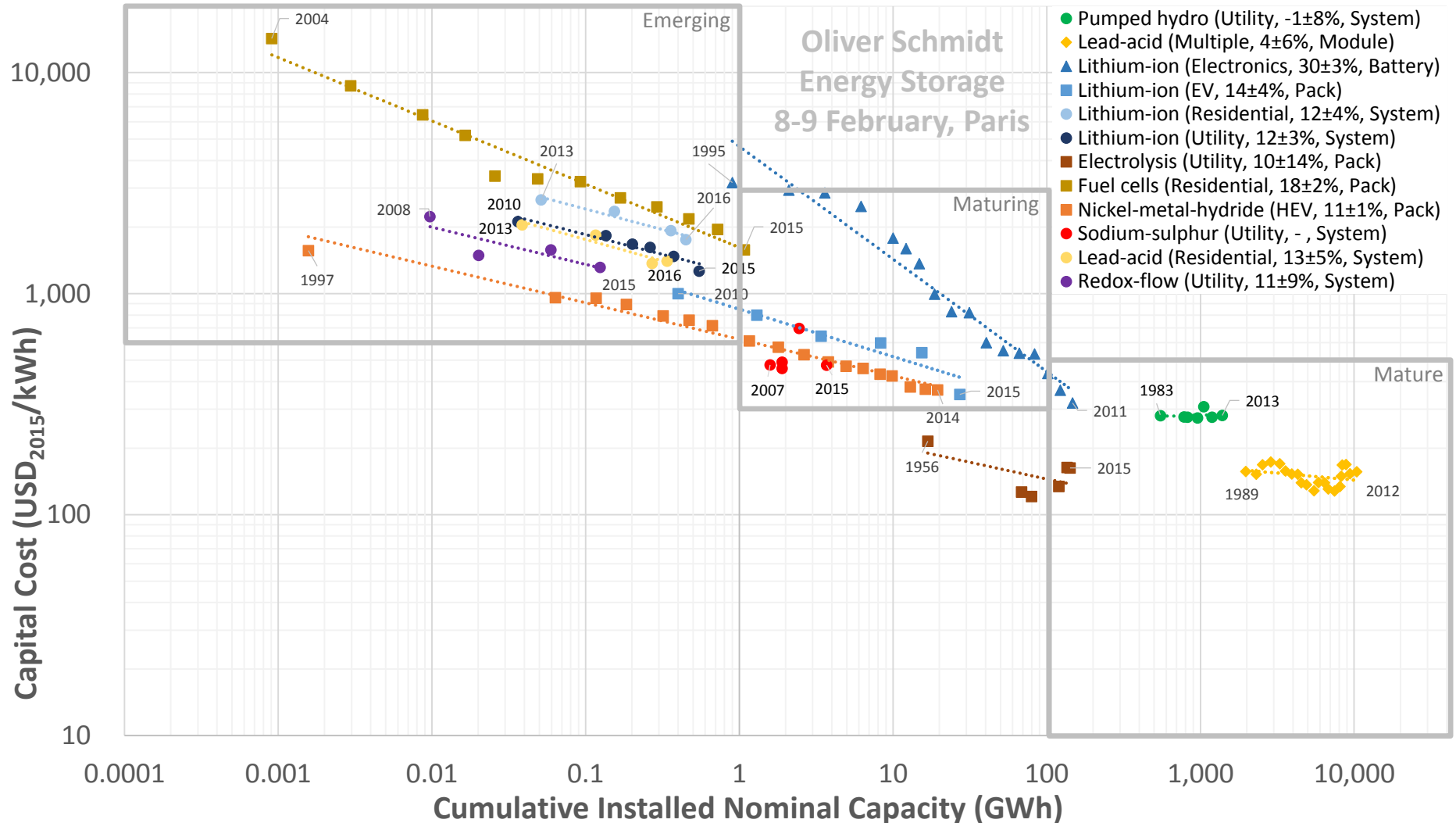
October 2016

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

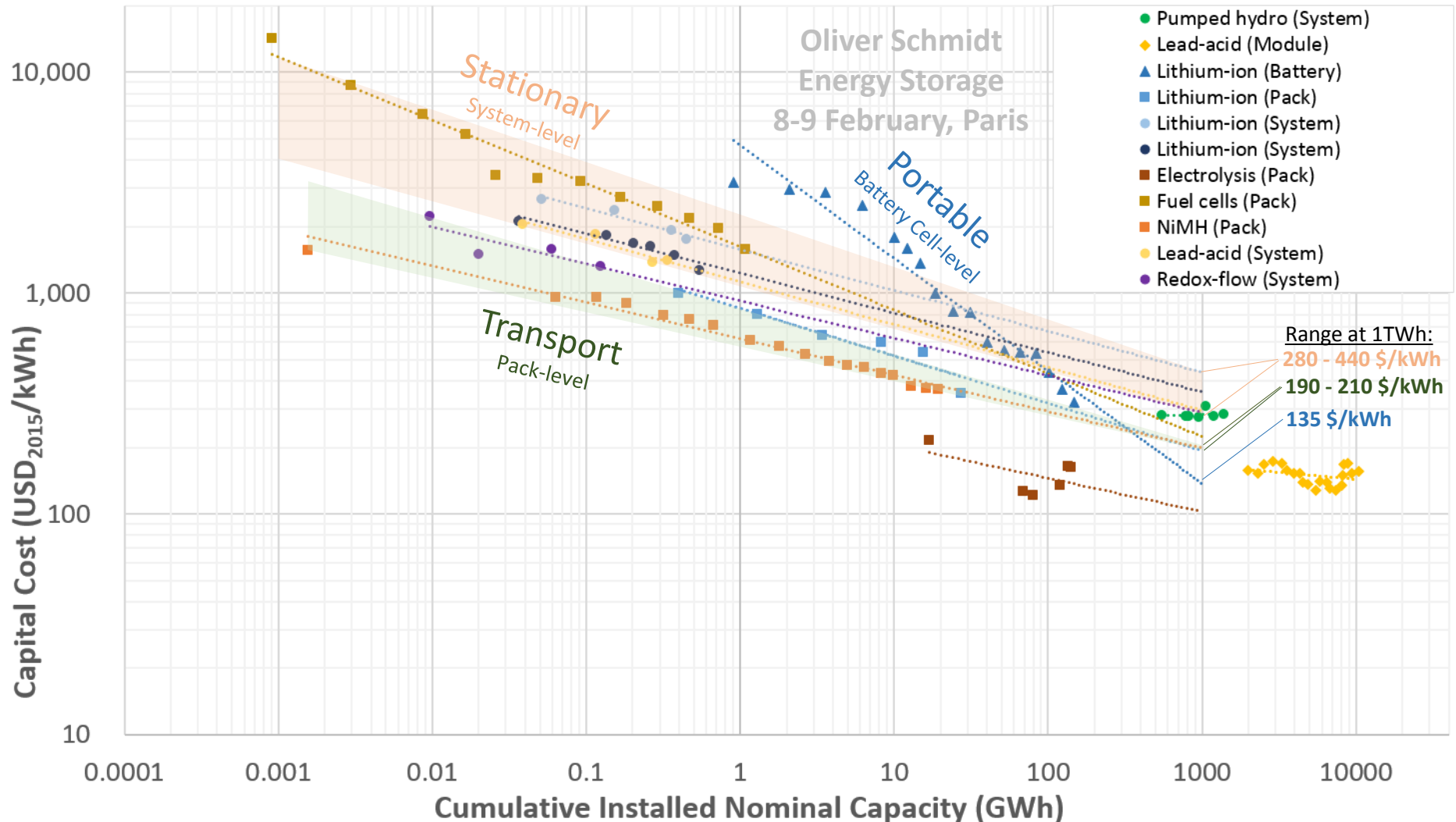
Method: Experience curve analysis



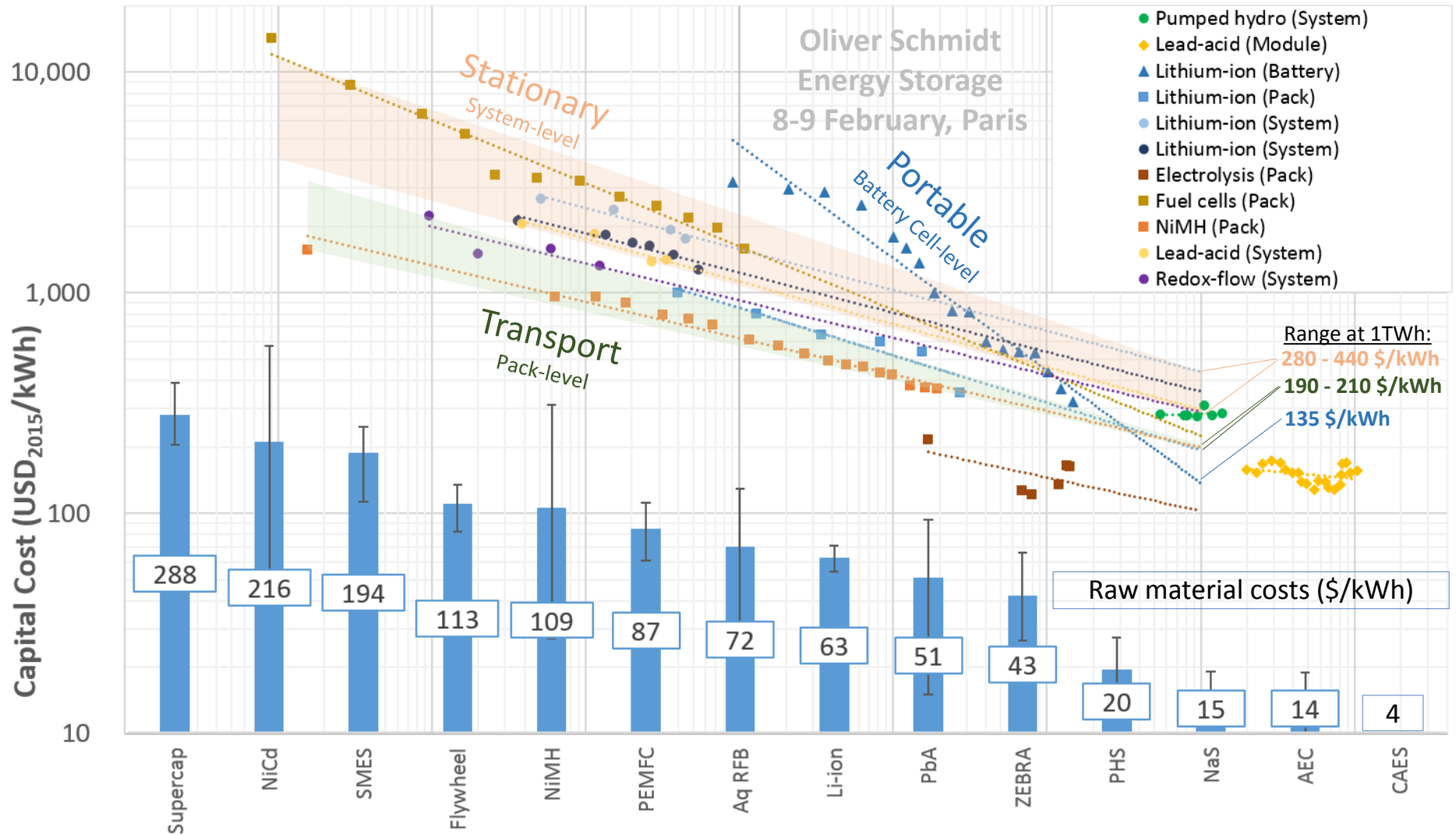
Result: Energy storage experience curves



Costs for installed stationary systems fall to 280-440 \$/kWh once 1 TWh is built

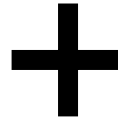
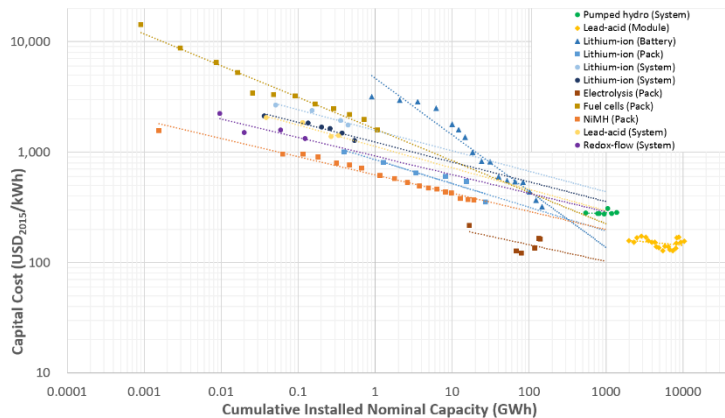


Price range seems feasible when comparing to raw material costs as lower boundary

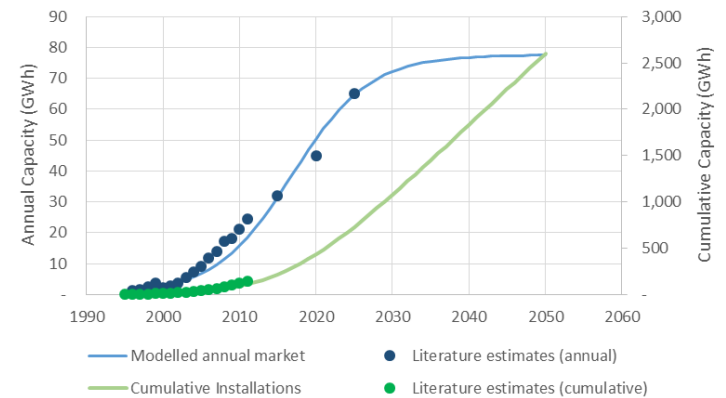


Analysis: Timeframe of cost reduction

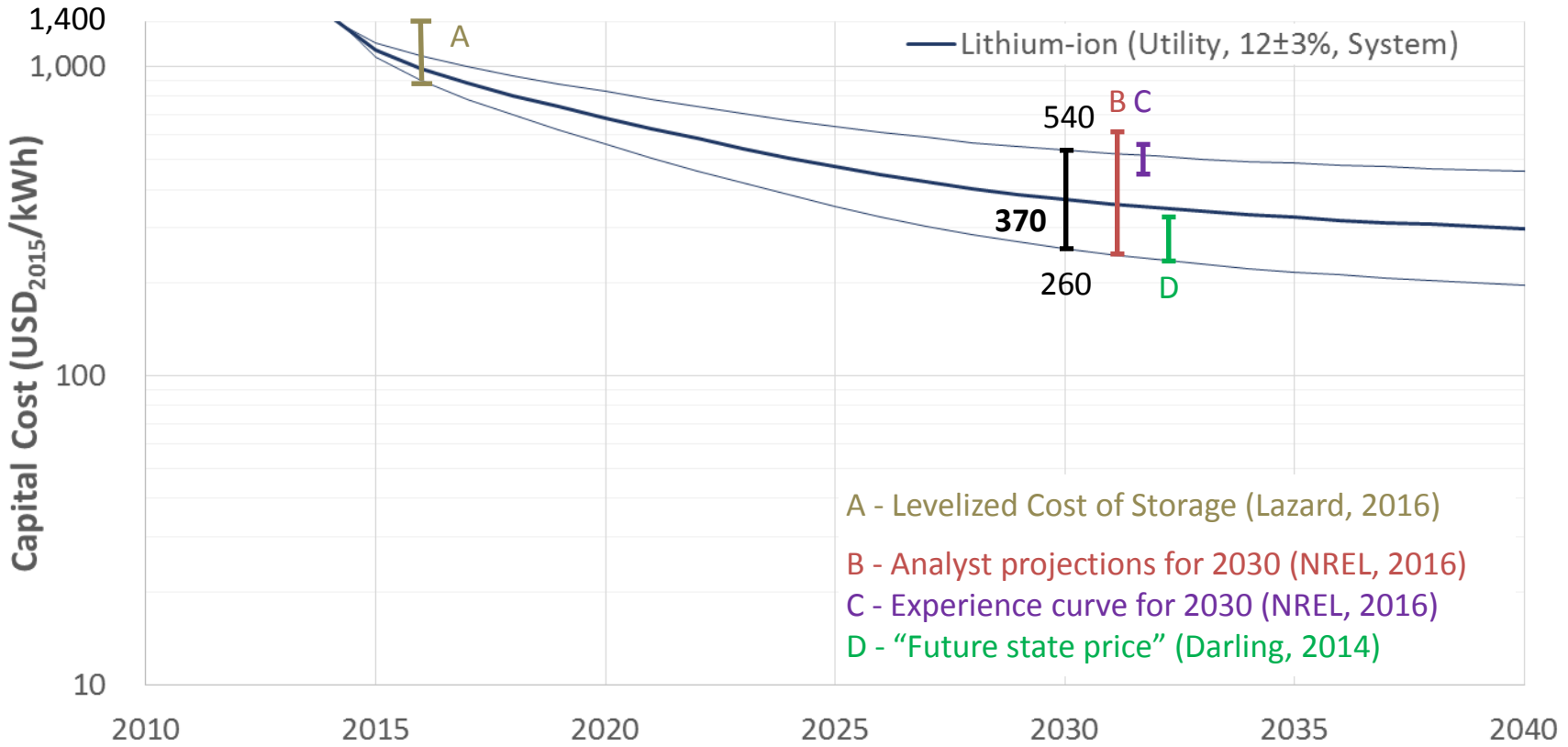
Experience curves (f: cumulative capacity)



Growth rate (in cumulative capacity)



Projections for utility-scale Lithium-ion systems in line with similar estimates



Sources: www.lazard.com/media/438042/lazard-levelized-cost-of-storage-v20.pdf

Feldman, D. et al. Exploring the Potential Competitiveness of Utility-Scale Photovoltaics plus Batteries with Concentrating Solar Power, 2015 – 2030. (NREL, 2016).

Darling, R. M., et al. Pathways to low-cost electrochemical energy storage: a comparison of aqueous and nonaqueous flow batteries. Energy Environ. Sci. 7, 3459–3477 (2014).

Analysis: Frequency Response Profitability

Reduction as a function of:

- Experience rate
- Growth rate

No increase in lifetime assumed

Reduction in line with Capex

$$\text{Annual Capacity Cost} \left[\frac{\$}{\frac{kW}{\text{year}}} \right] = \frac{\text{Capex}_{\text{annualised}} + \text{Opex}_{\text{annual}}}{\text{Capacity}}$$

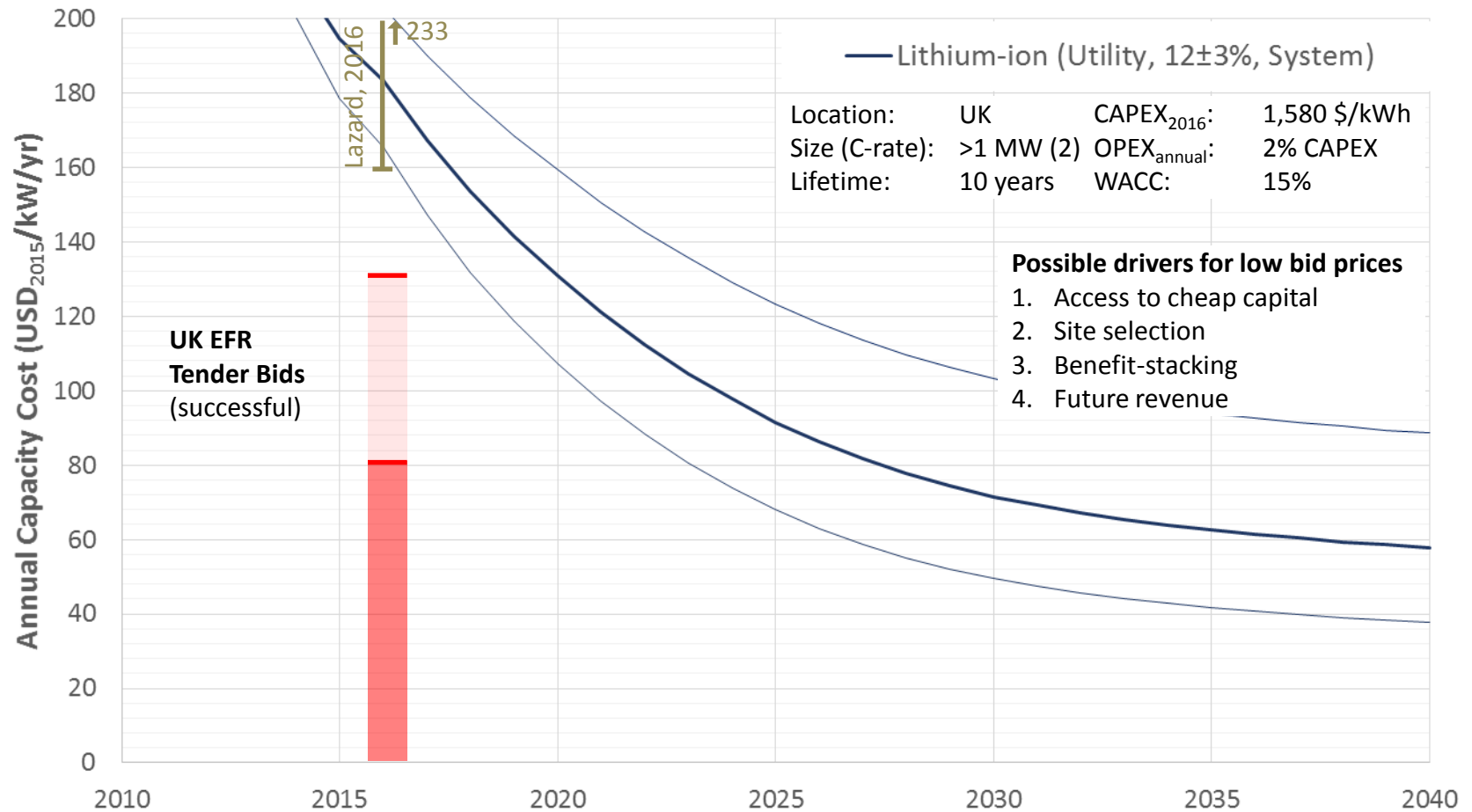
Application: **Enhanced Frequency Response**

Location: United Kingdom
 Capacity: >1 MW
 Response time: <500 ms
 Ramp-time: <500 ms (0% - 100%)
 Min. duration: 15 minutes
 Contract: 4 years

Technology: **Utility-type Li-ion battery**

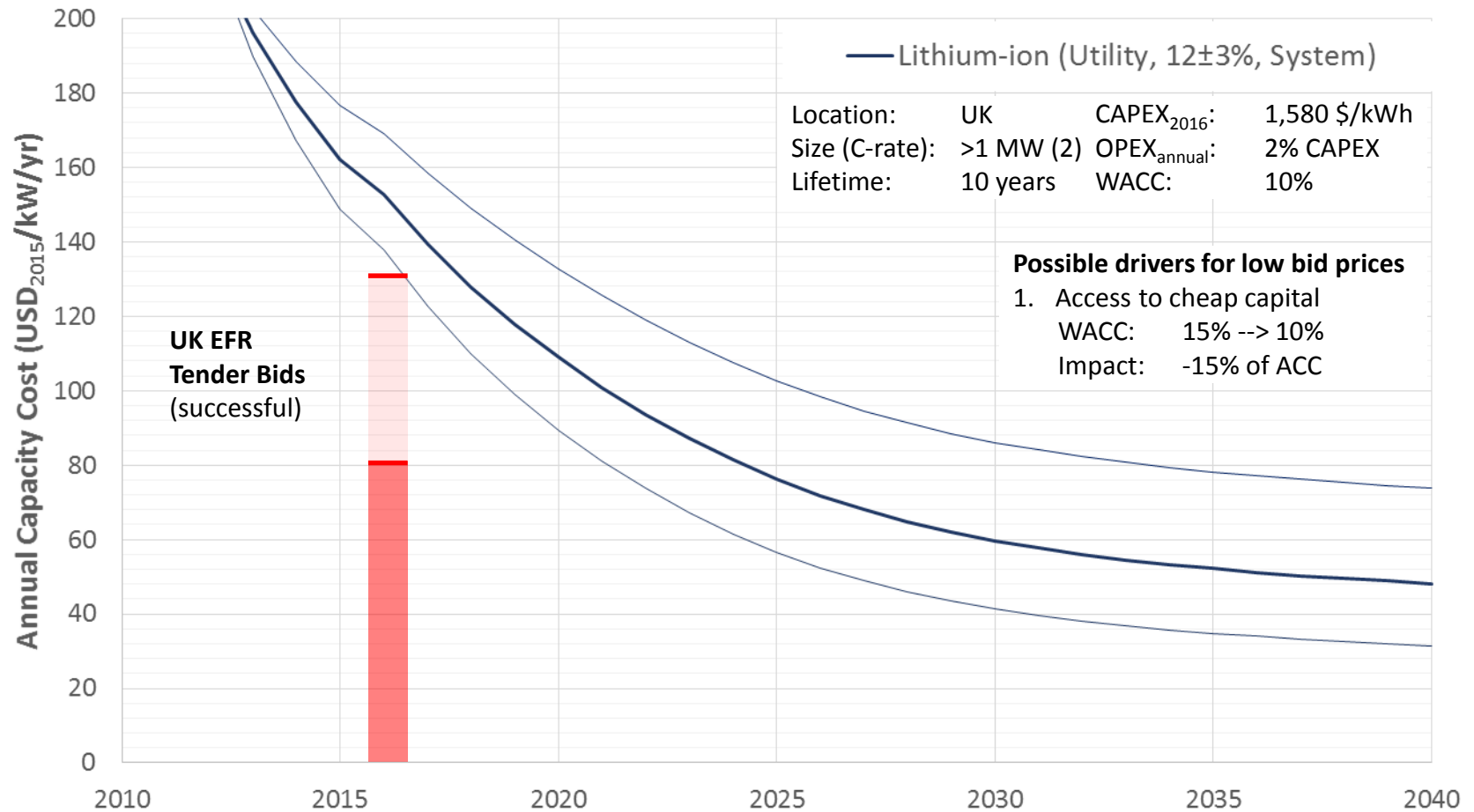
Capacity (C-rate): 1 MW (2)
 Capex₂₀₁₆: 950 \$/kWh_{nominal}
 Capex_{2016,100%DoD}: 1,200 \$/kWh_{usable}
 Capex_{2016,100%DoD,Grid}: 1,580 \$/kWh_{total}
 Experience rate: 12% ± 3%
 Opex: 2% of Capex₂₀₁₆
 Lifetime: 10 years

Successful EFR tender bid levels below modelled cost; could be reached by 2020



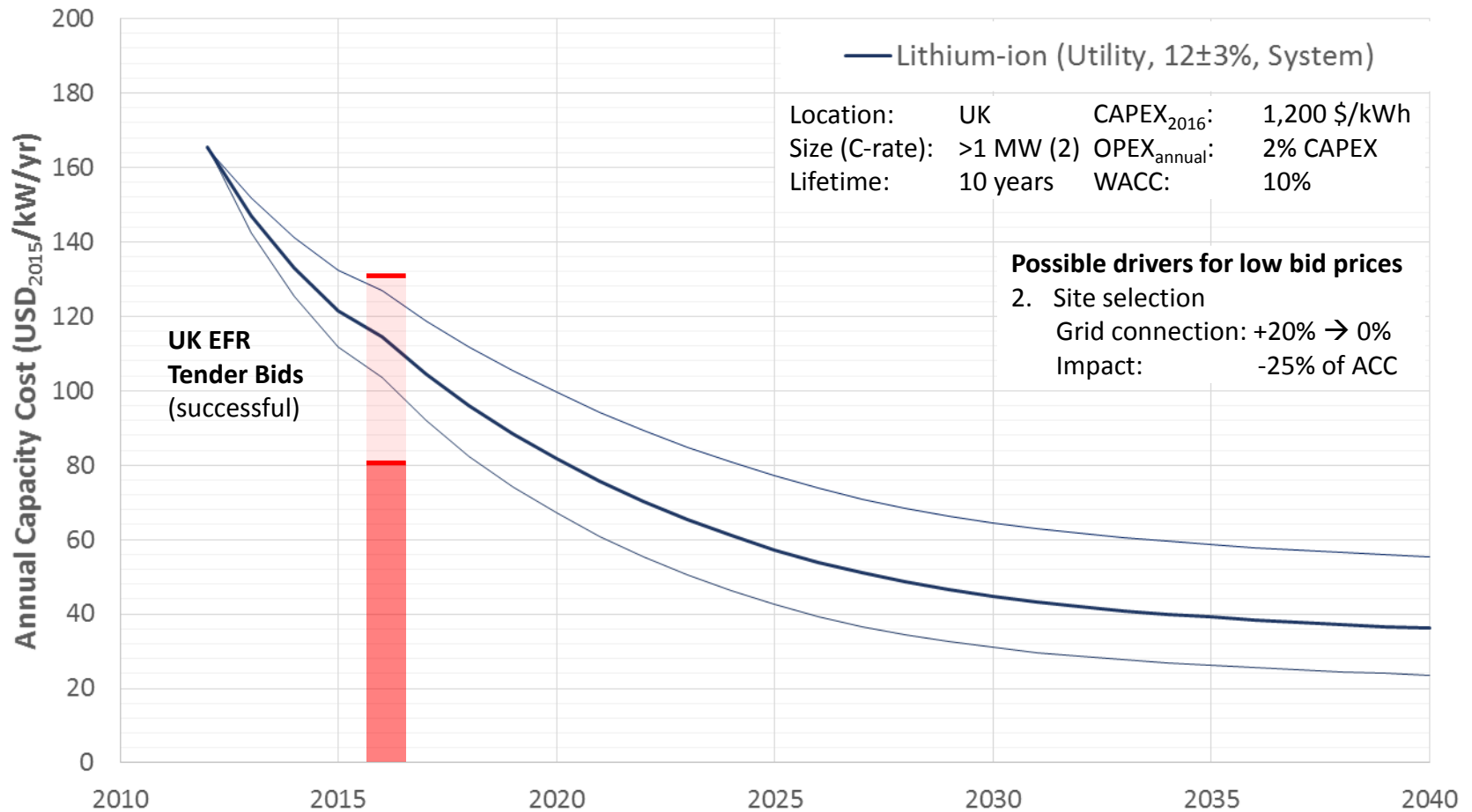
Sources: www2.nationalgrid.com/Enhanced-Frequency-Response.aspx
www.regensw.co.uk/news/energy-storage-the-enhanced-frequency-response-auction-30-september-2016

Access to cheap capital could reduce annual capacity cost by 15%



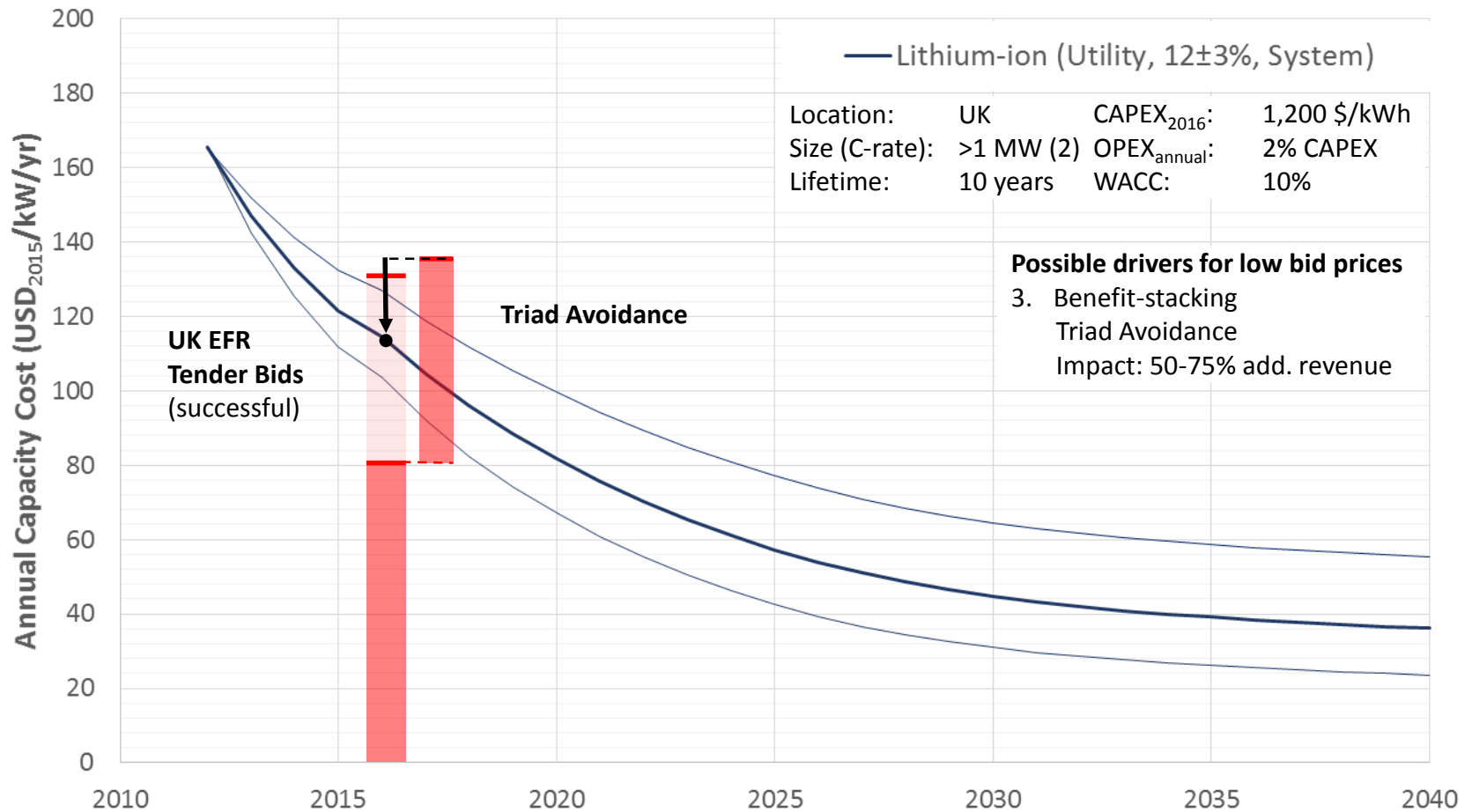
Sources: www.regensw.co.uk/news/energy-storage-the-enhanced-frequency-response-auction-30-september-2016

A 20% reduction in capital costs leads to 25% reduction in annual capacity costs



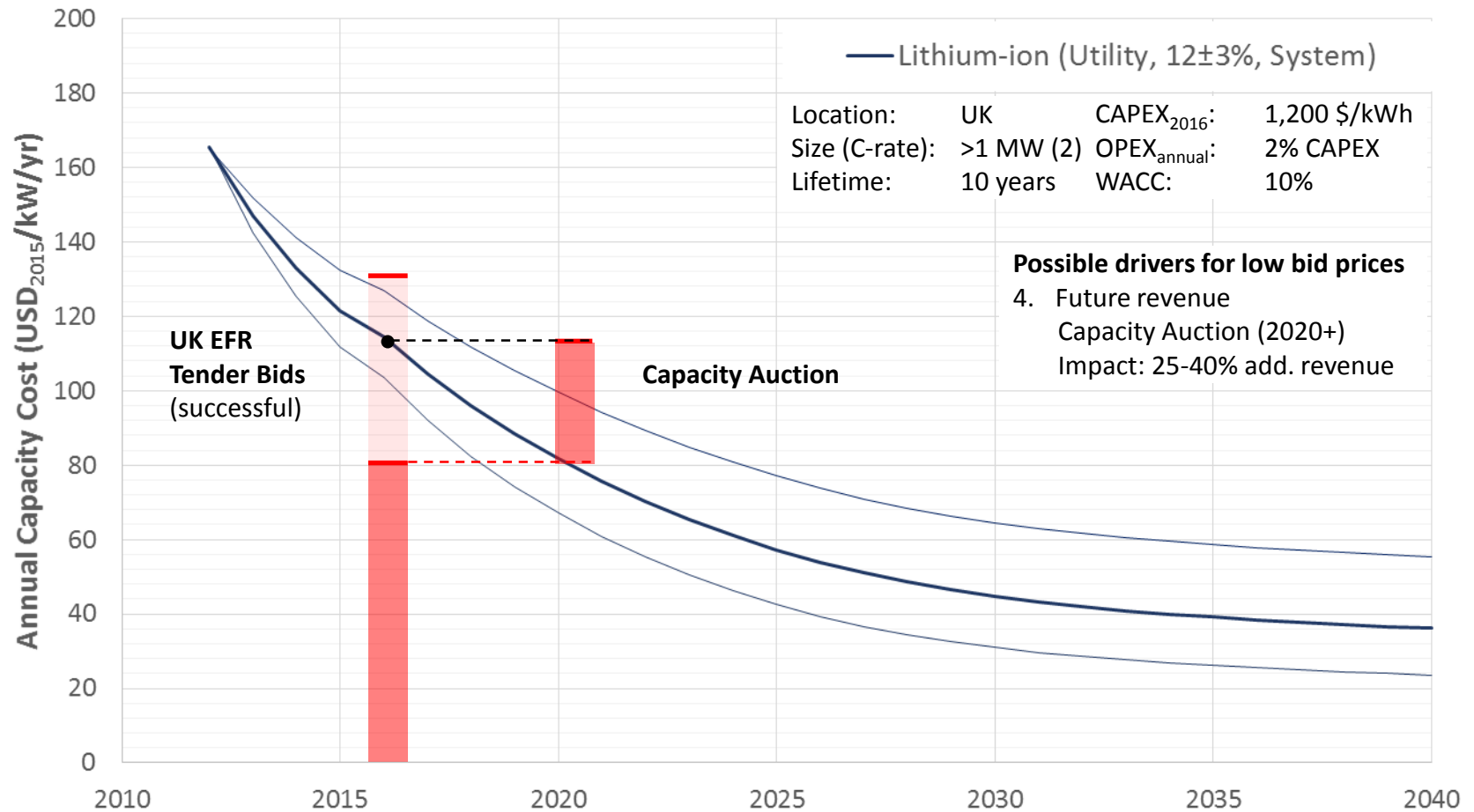
Sources: www.regensw.co.uk/news/energy-storage-the-enhanced-frequency-response-auction-30-september-2016

Benefit-stacking could push bids into profitability



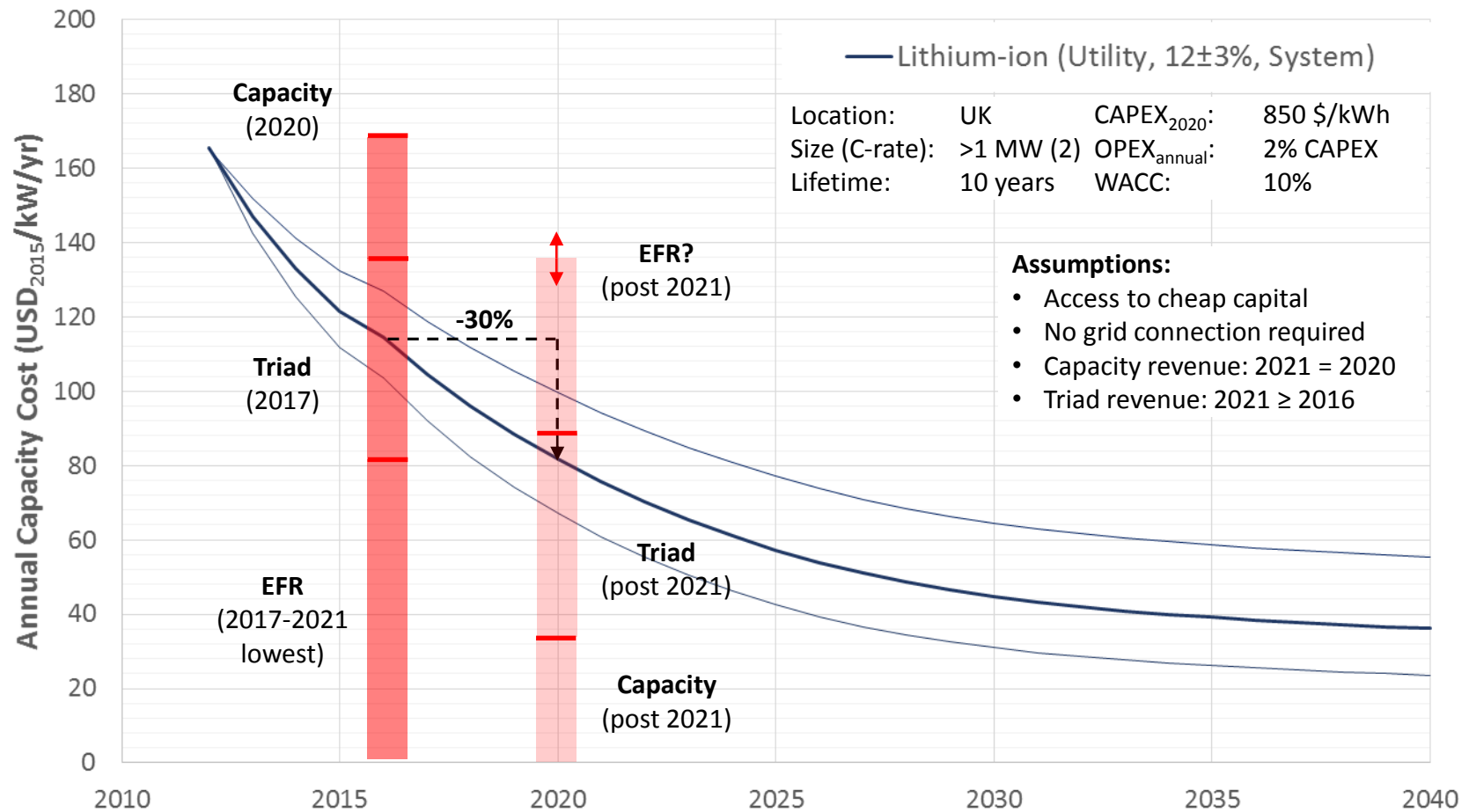
Sources: www.timera-energy.com/the-uks-battle-for-new-capacity-peakers-vs-ccgts/

Prospect of additional future revenues could further improve business case



Sources: www.emrdeliverybody.com/capacity%20markets%20document%20library/provisional%20results%20report%20-%204%202016.pdf

Experience curve based cost analysis, allows assessment of future business cases



Sources: www.emrdeliverybody.com/capacity%20markets%20document%20library/provisional%20results%20report%20-%204%202016.pdf
www.timera-energy.com/the-uks-battle-for-new-capacity-peakers-vs-cgts/
www2.nationalgrid.com/Enhanced-Frequency-Response.aspx

Questions?

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