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The impact of electricity storage on CO_2 emission in the British Power Sector

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Grantham Institute

Investment costs for lithium-ion batteries have fallen dramatically in recent years

Recent cost developments

Average: 3,000 $/kWh

Powerwall 1: 1,100 $/kWh

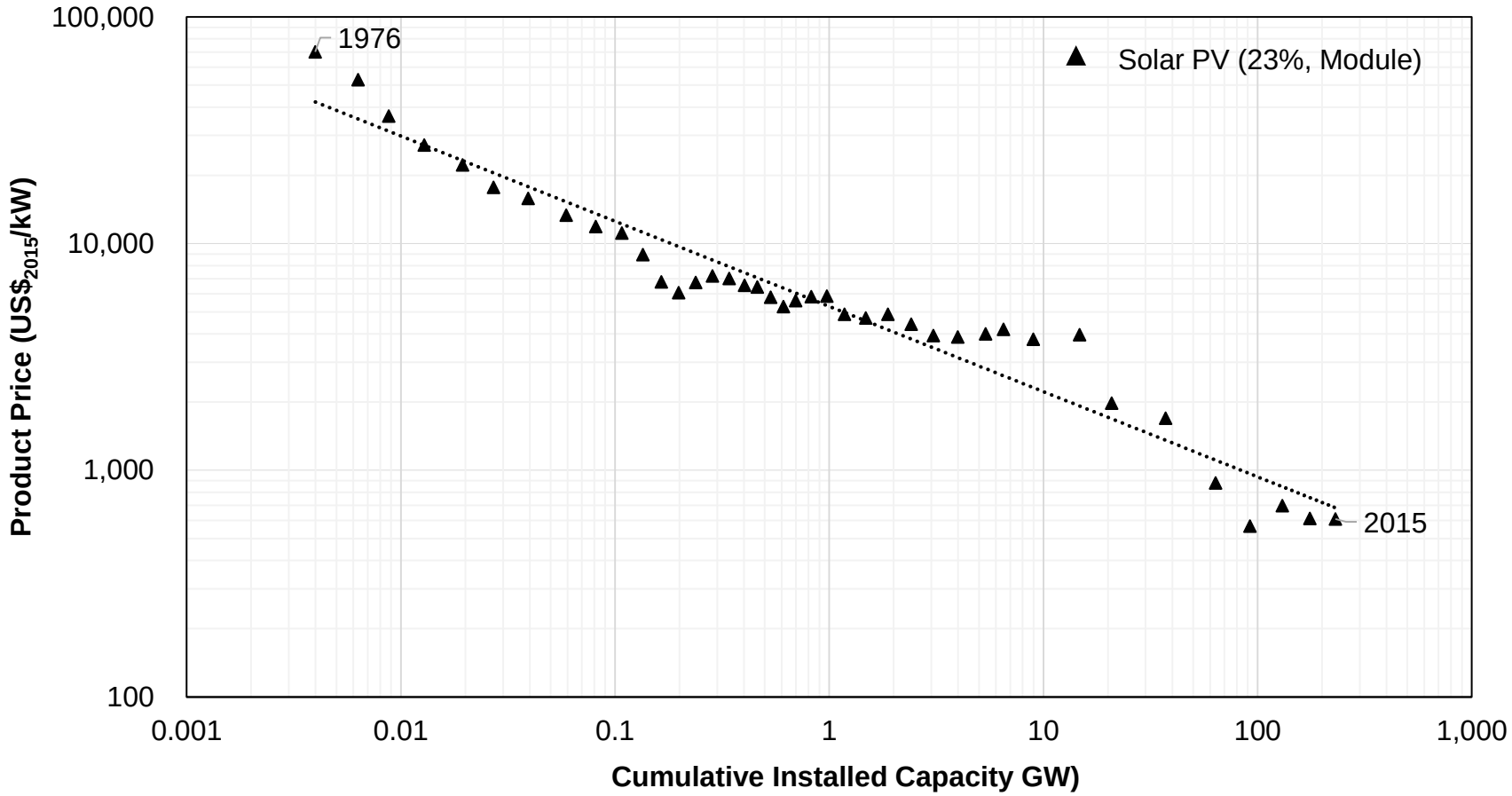
Powerwall 2: 500 $/kWh

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

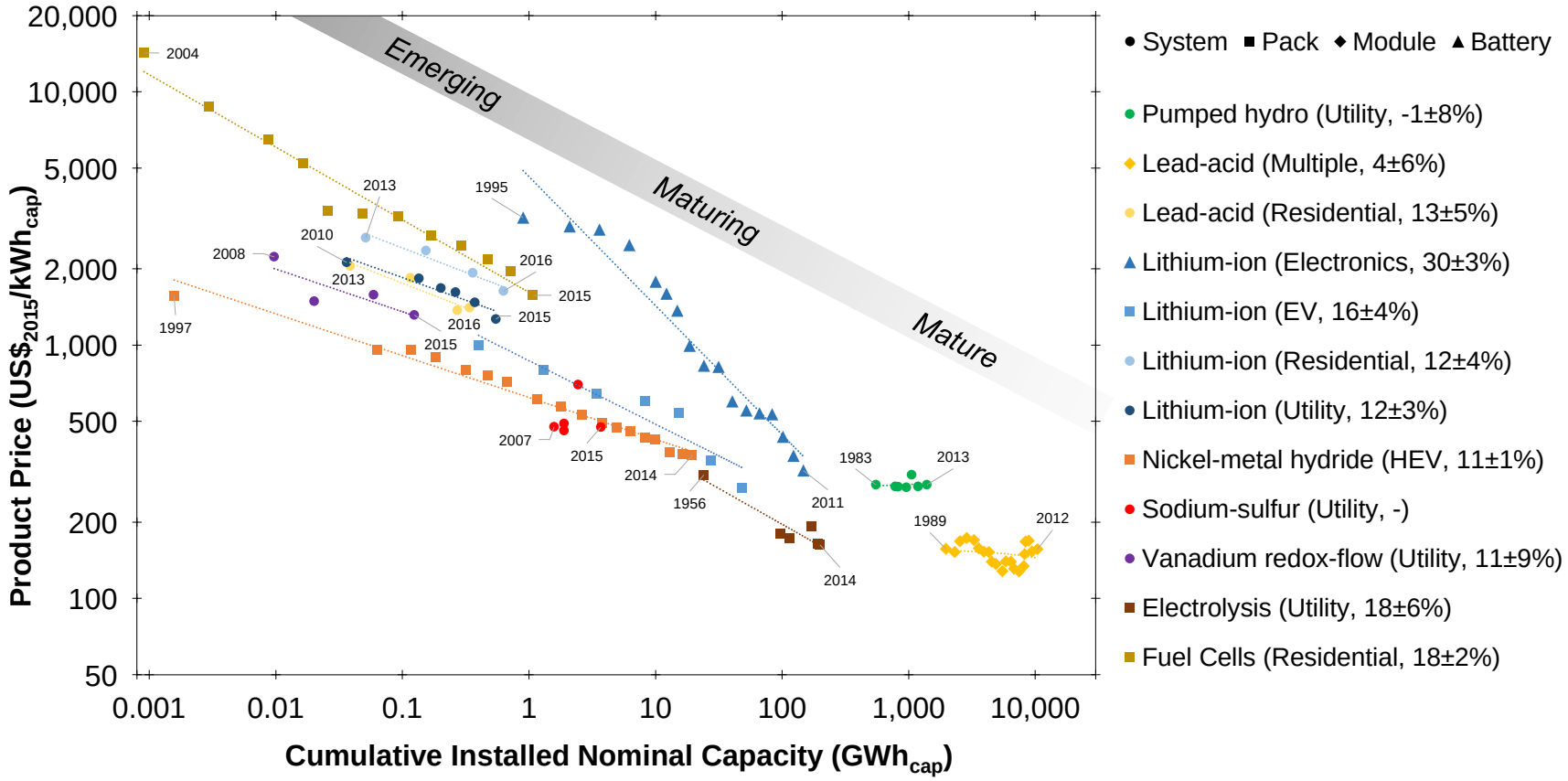
Cost projection method



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

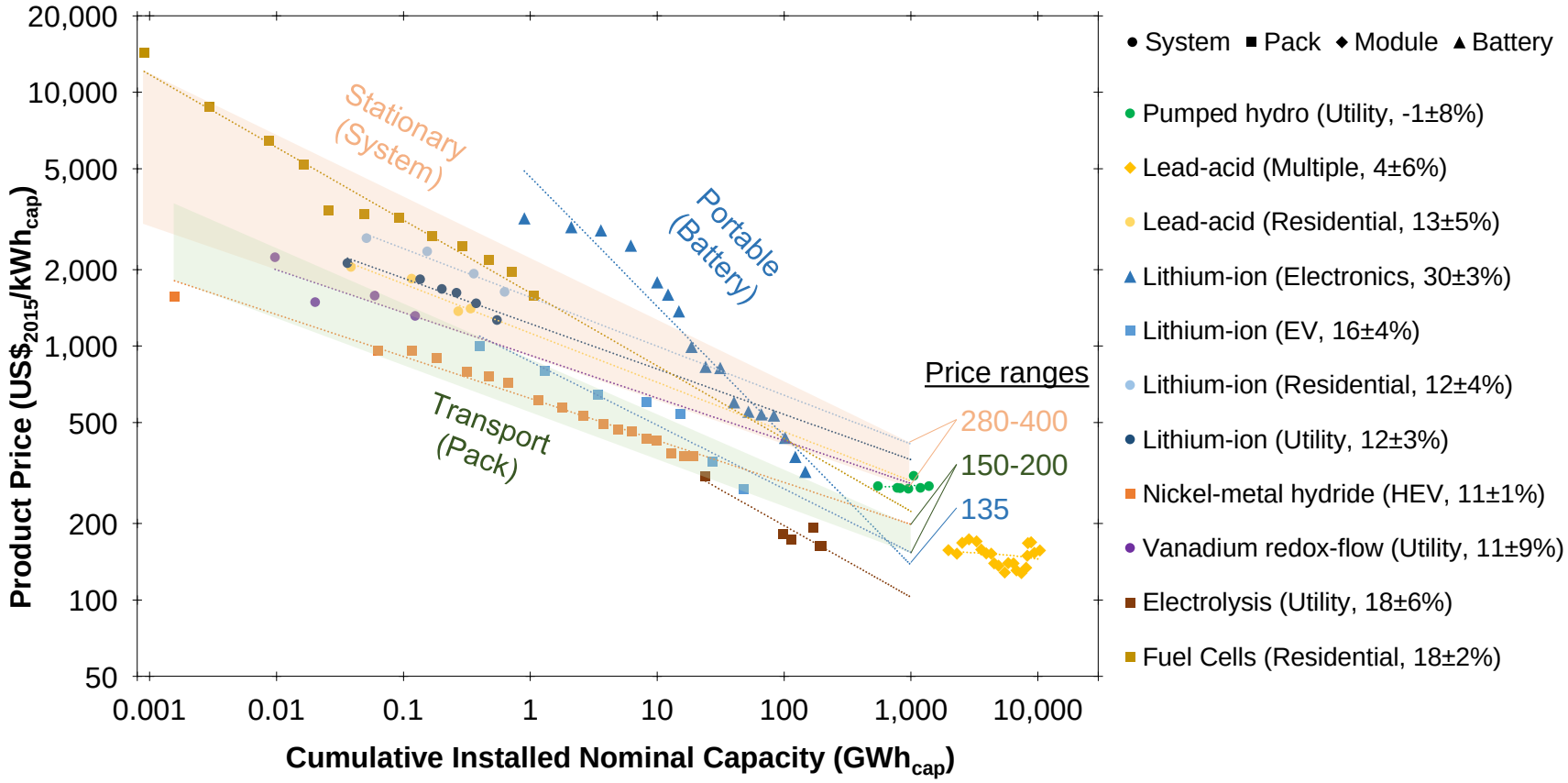
Dataset



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

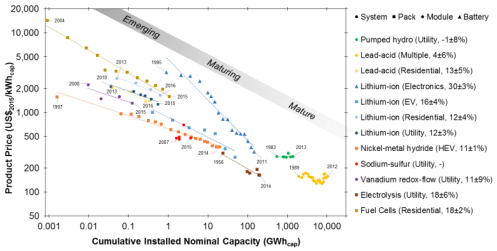
Capital cost projection (capacity)

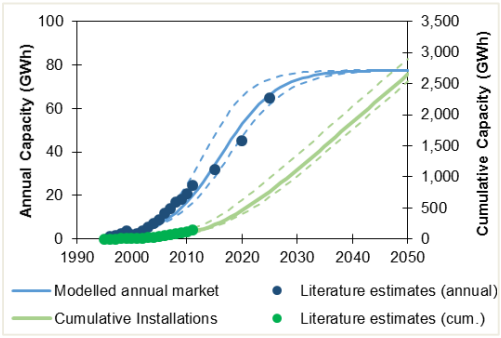


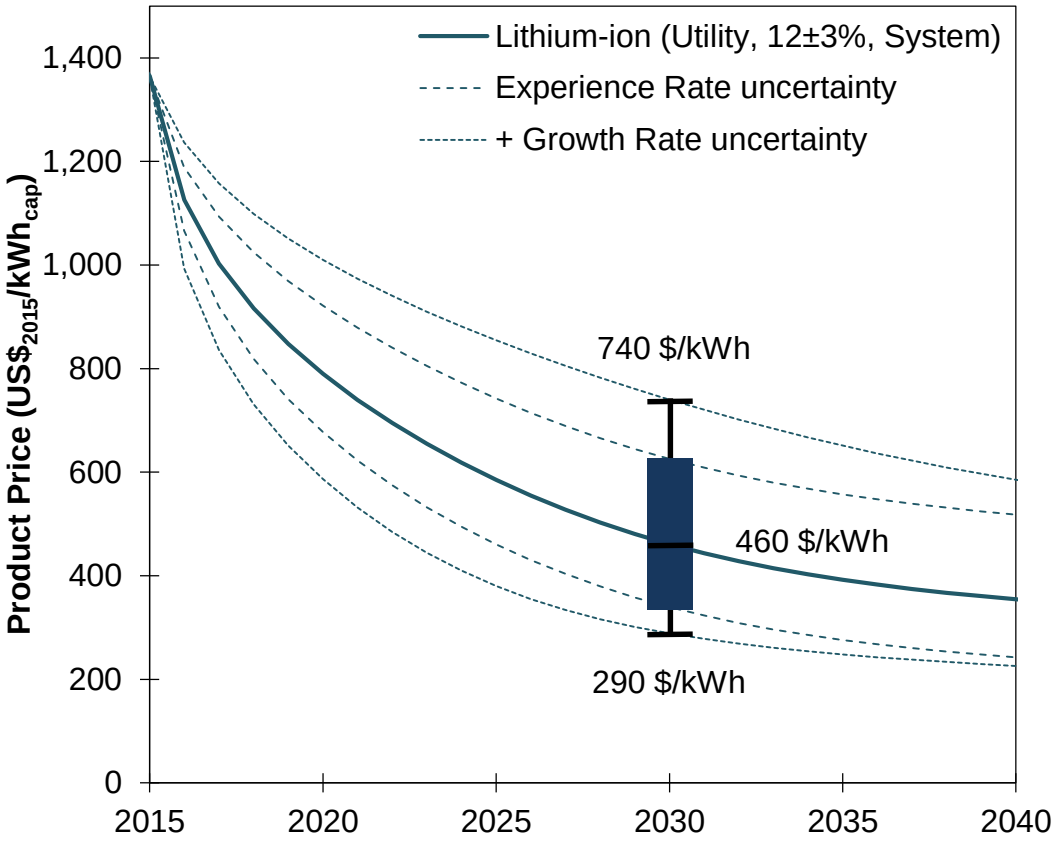
Source: O. Schmidt, A. Hawkes, A. Gambhir & I. Staffell. The future cost of electrical energy storage based on experience rates. Nat. Energy 2, 17110 (2017)

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

Capital cost projection (time)







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)

We model storage in the power system where it reduces CO_2 emissions at a cost

Modelling scenarios

Baseline

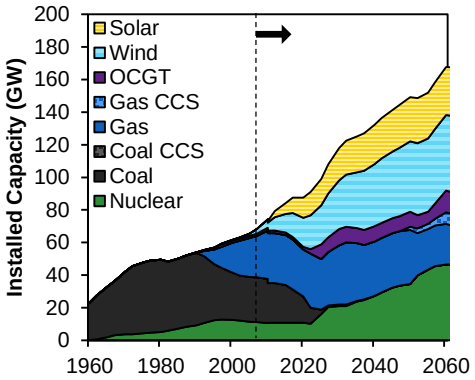
2050

Carbon Price:	200 £/ton
Strike Price:	89.5 £/MWh
Renewables:	70 GW

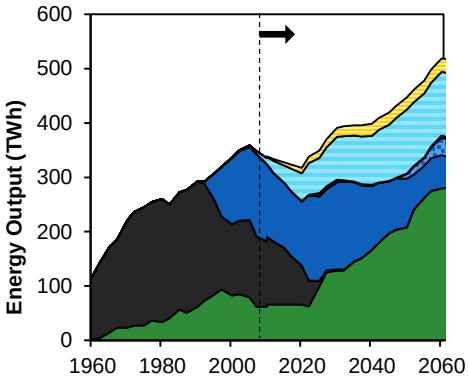
2010 - 2060

Curtailed:	159 TWh
Emissions:	3.14 GT
Net Spend:	£113 bn

Installed Capacity



Energy Output



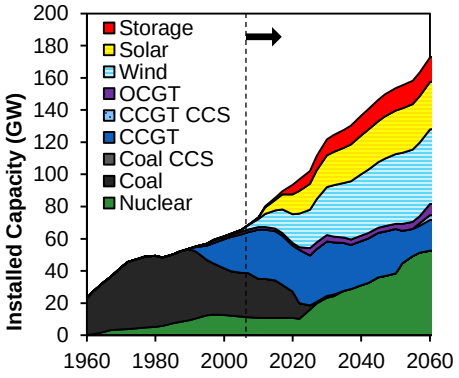
Storage

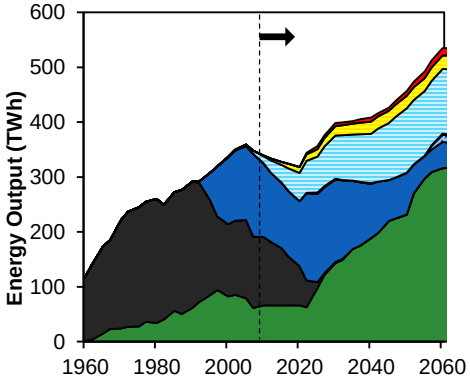
2050

Storage capacity:	14 GW (20%)
Storage duration:	6 hours
Storage efficiency:	75%

2010 - 2060

Curtailed:	117 TWh (-25%)
Emissions:	2.94 GT (-6%)
Net Spend:	£130 bn

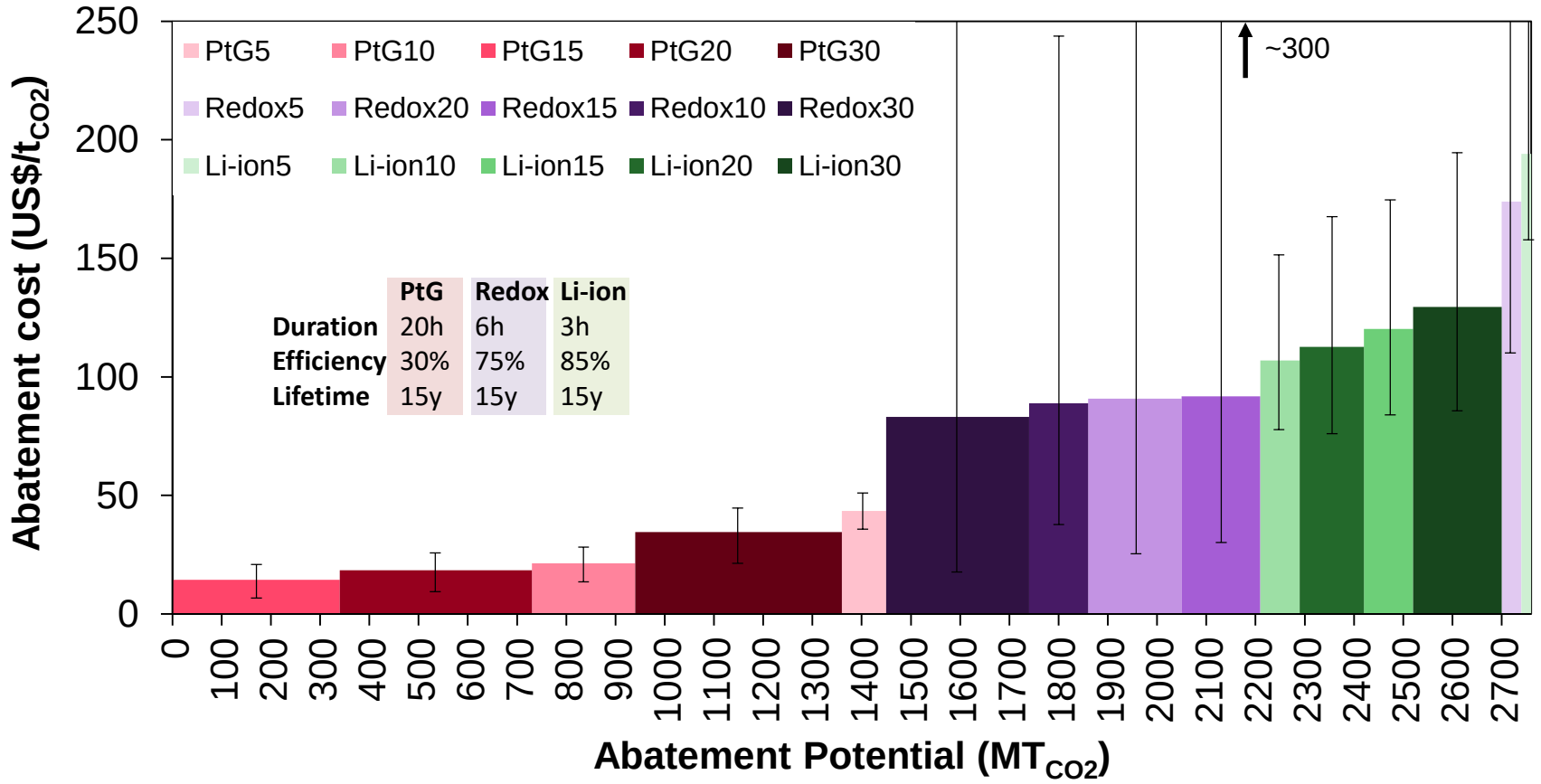




Source: Own analysis

Emission reduction relative to its cost reveal the abatement cost for storage

Abatement cost curve



Source: Own analysis

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Questions?

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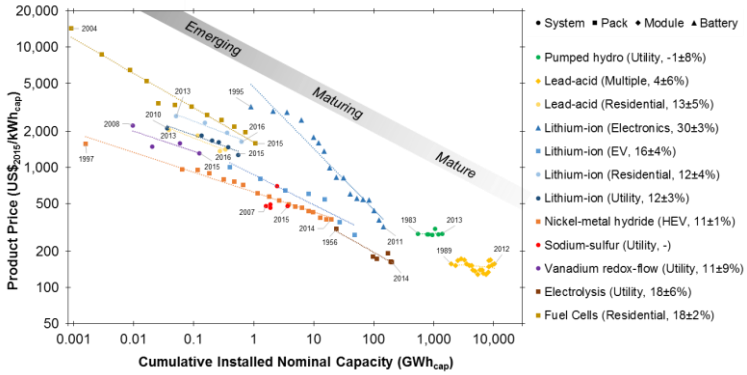
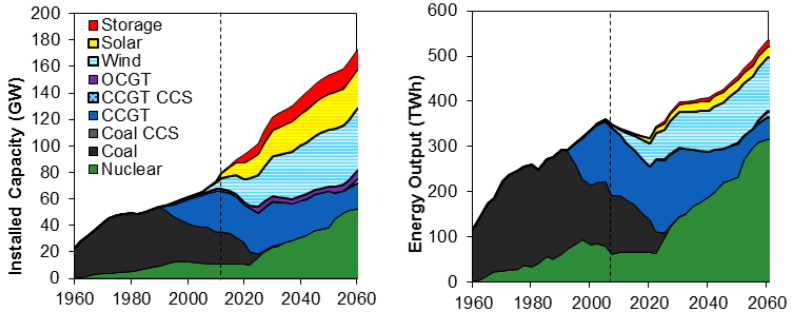
Including storage cost forecasts in power system models informs on abatement cost

Methodology

Experience Curves



Power System Model (UK)

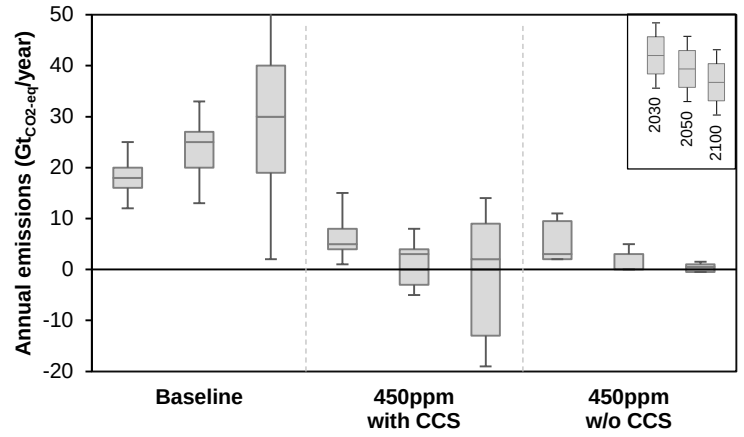


1. Determine experience rates for storage technologies
2. Combine with market forecasts to project future cost of three storage technologies
   - Lithium-ion 15y, 3h, 85%$_{AC\text{-}AC}$
   - Redox-flow 15y, 6h, 75%$_{AC\text{-}AC}$
   - Power-to-Gas 15y, 20h, 30%$_{AC\text{-}AC}$

1. Model baseline scenario for 80% emission reduction by 2050
2. Model storage scenario for three technologies at 5-30% share of Ren.
3. Determine marginal abatement cost for 80%+ emission reduction with storage

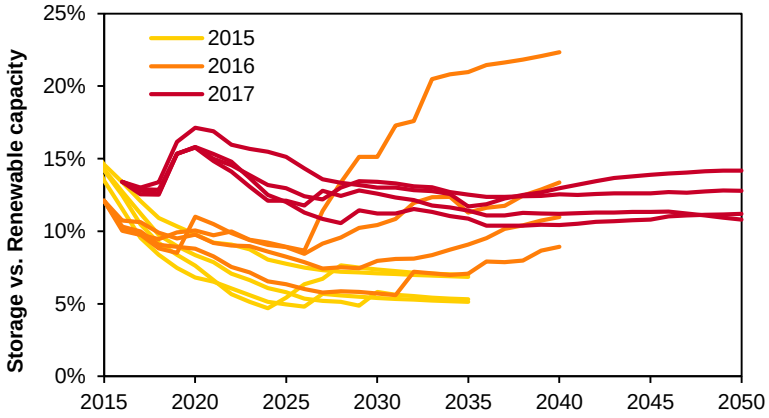
The power sector needs to be close to complete decarbonisation by 2050

Introduction



IPCC Fifth Assessment Report

- Annual emissions from power generation must reduce to max. 5 Gt_{CO2} by 2050 (glob.)
- The power sector is among the first energy sectors to completely decarbonize



National Grid – Future Energy Scenarios

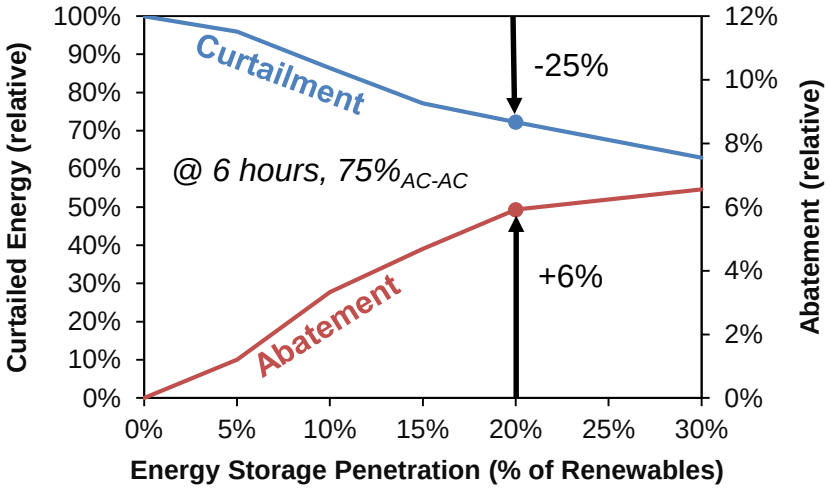
- The UK targets an 80% reduction of emissions by 2050 compared to 1990 levels
- National Grid foresees storage capacity at 5-25% of renewable capacity to succeed

Source: Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Core Writing Team, R.K. Pachauri and L.A. Meyer (eds.)], IPCC, Geneva, 2014.); Future Energy Scenarios, National Grid, 2017.

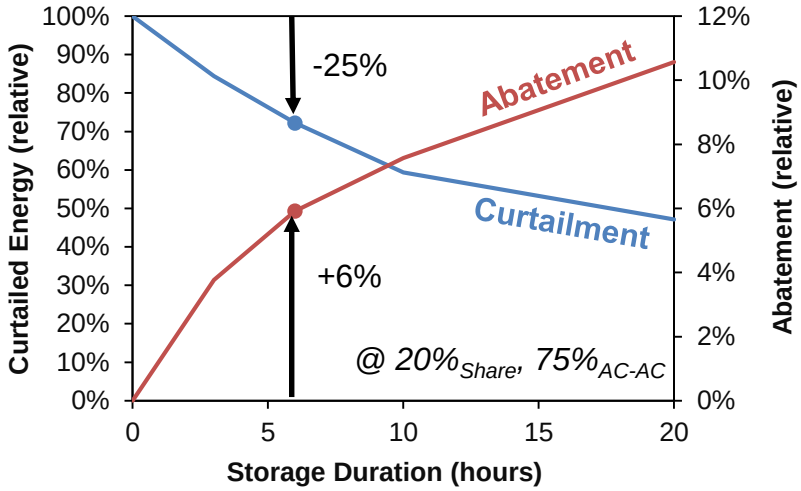
Storage duration and penetration affect RE curtailment and CO_2 abatement

Impact of Energy Storage

Penetration



Storage duration

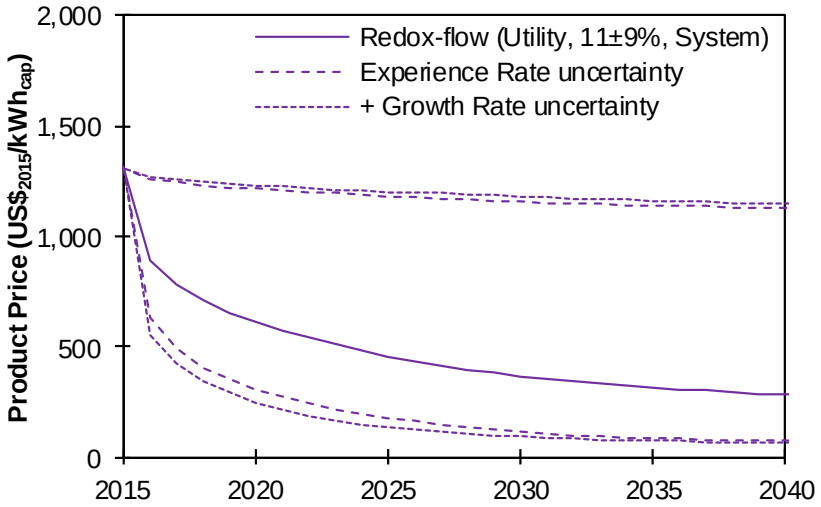


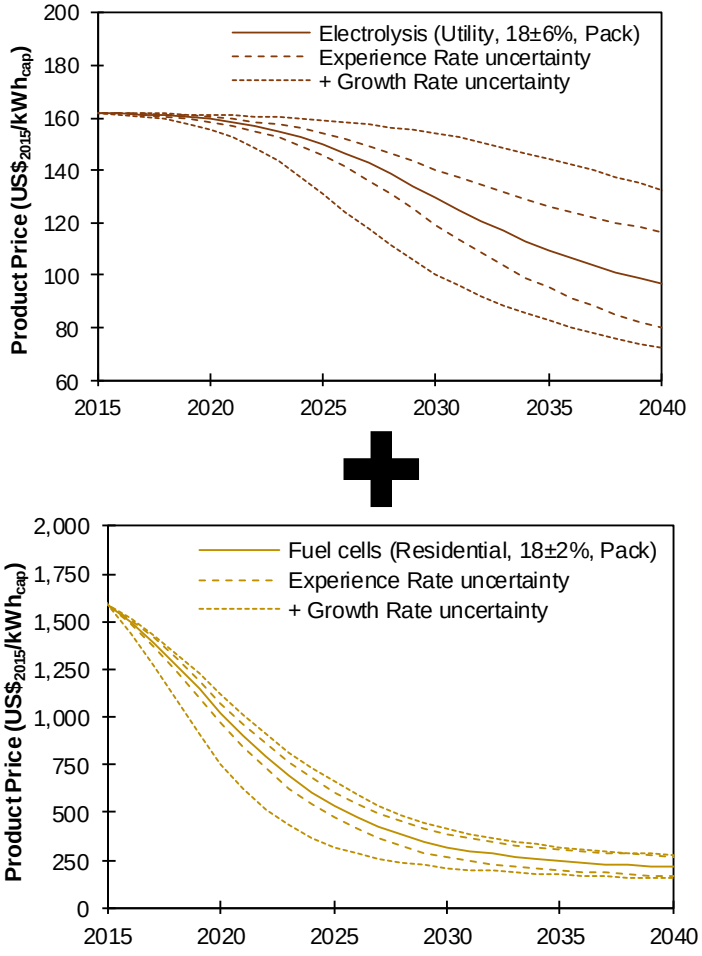
Stronger impact of storage duration on RE integration

Source: Own analysis

Investment cost reductions for Vanadium redox-flow & Power-to-Gas storage

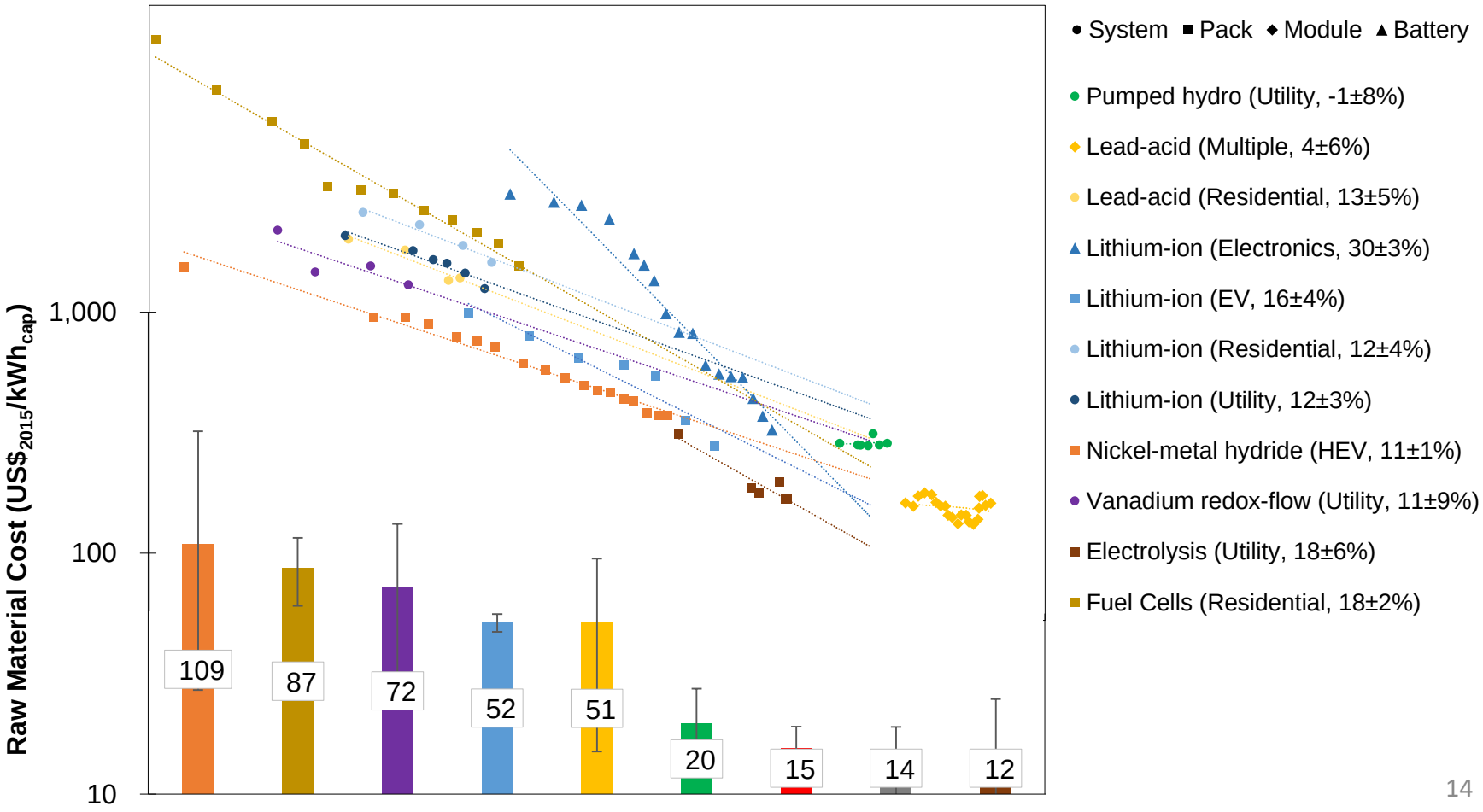
Cost projections





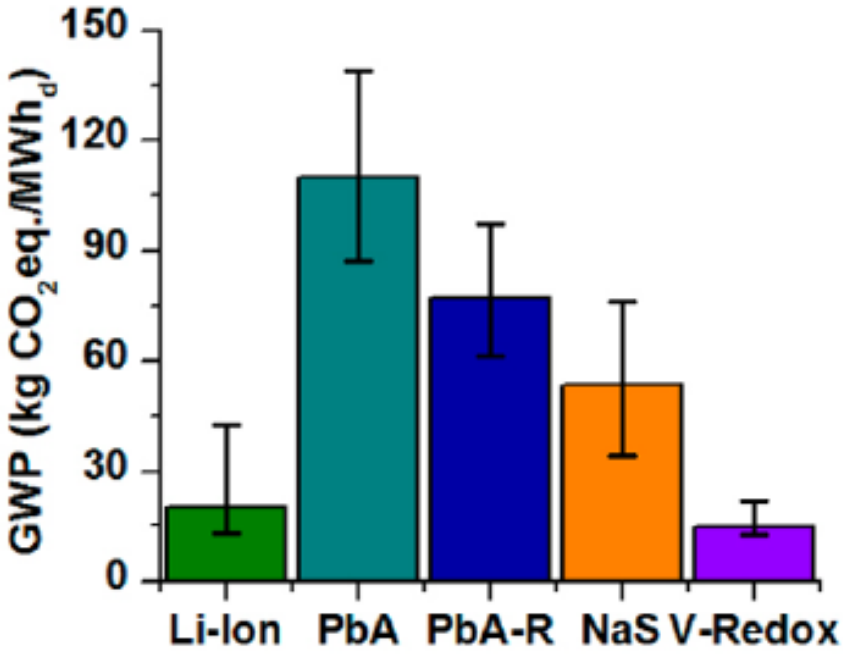
Raw material costs suggest that these cost projections are not infeasible

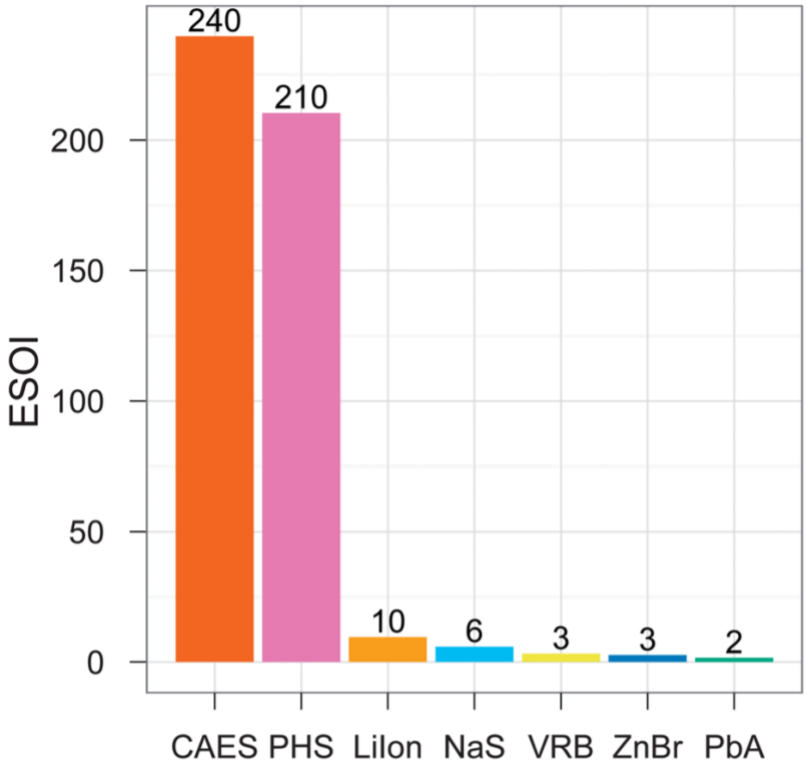
Sanity Check 1 – Raw material cost



Environmental characteristics of storage technologies

GWP and ESOI





Source:
M. Hiremath, K. Derendorf, T. Vogt, Comparative life cycle assessment of battery storage systems for stationary applications., Environ. Sci. Technol. 49 (2015) 4825–33;
Barnhart, C. J., & Benson, S. M. (2013). On the importance of reducing the energetic and material demands of electrical energy storage. Energy Environ. Sci., 6, 1083–1092.