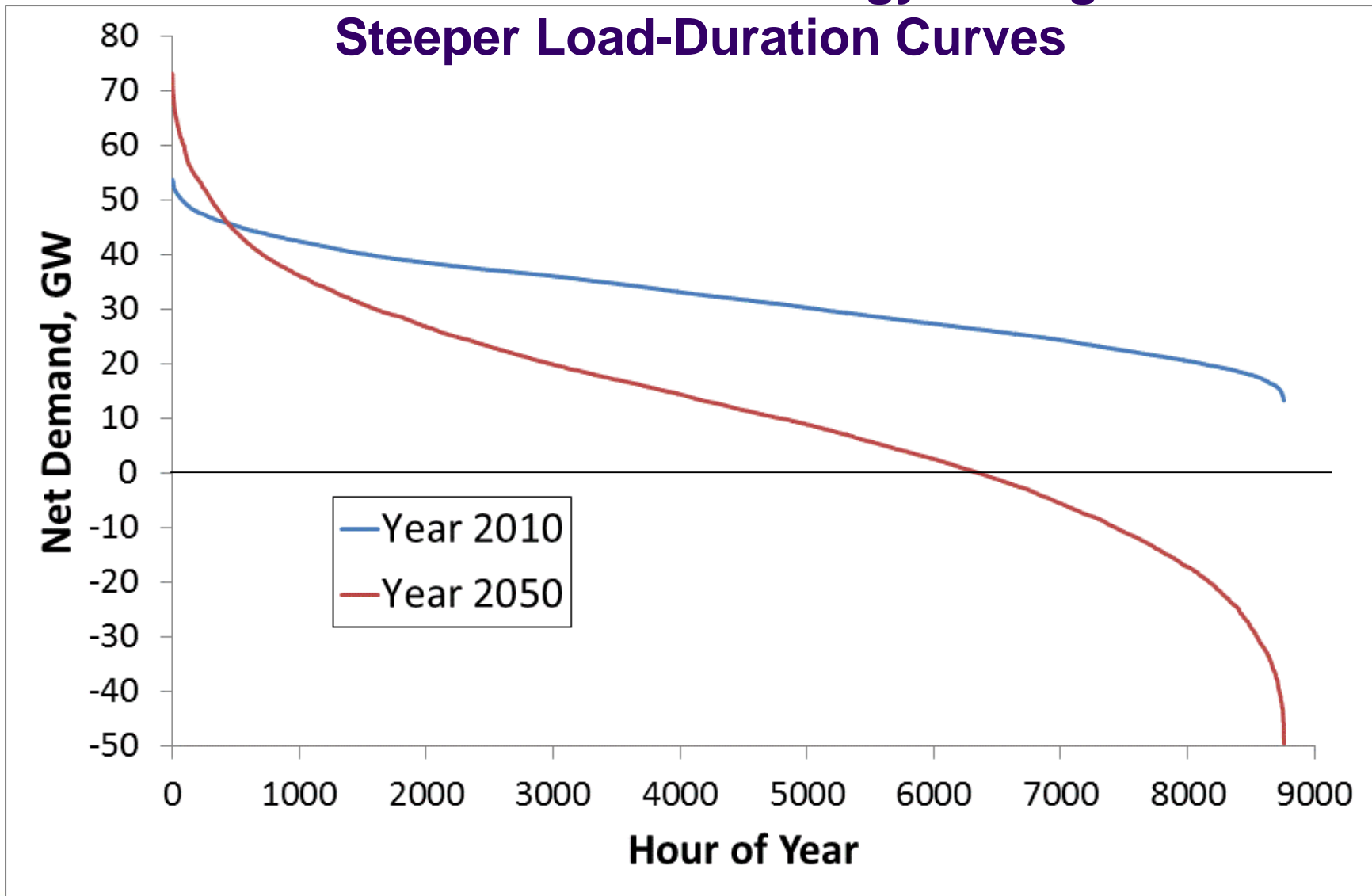# High-Temporal-Resolution Analysis of UK Power System Used to Determine the Optimal Amount and Mix of Energy Storage Technologies

John Barton, j.p.barton@lboro.ac.uk
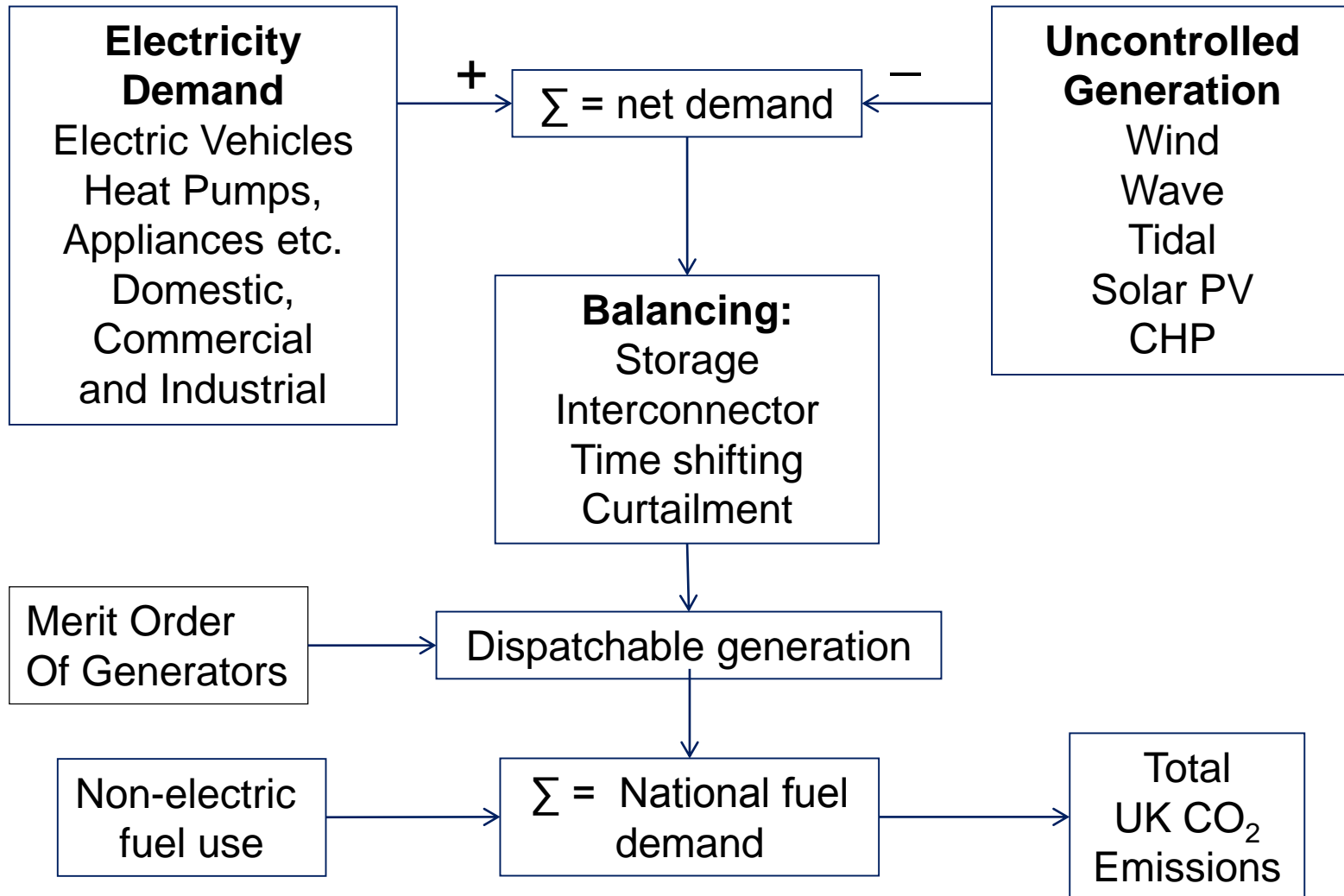
Murray Thomson, m.thomson@lboro.ac.uk

Centre for Renewable Energy Systems Technology (CREST),
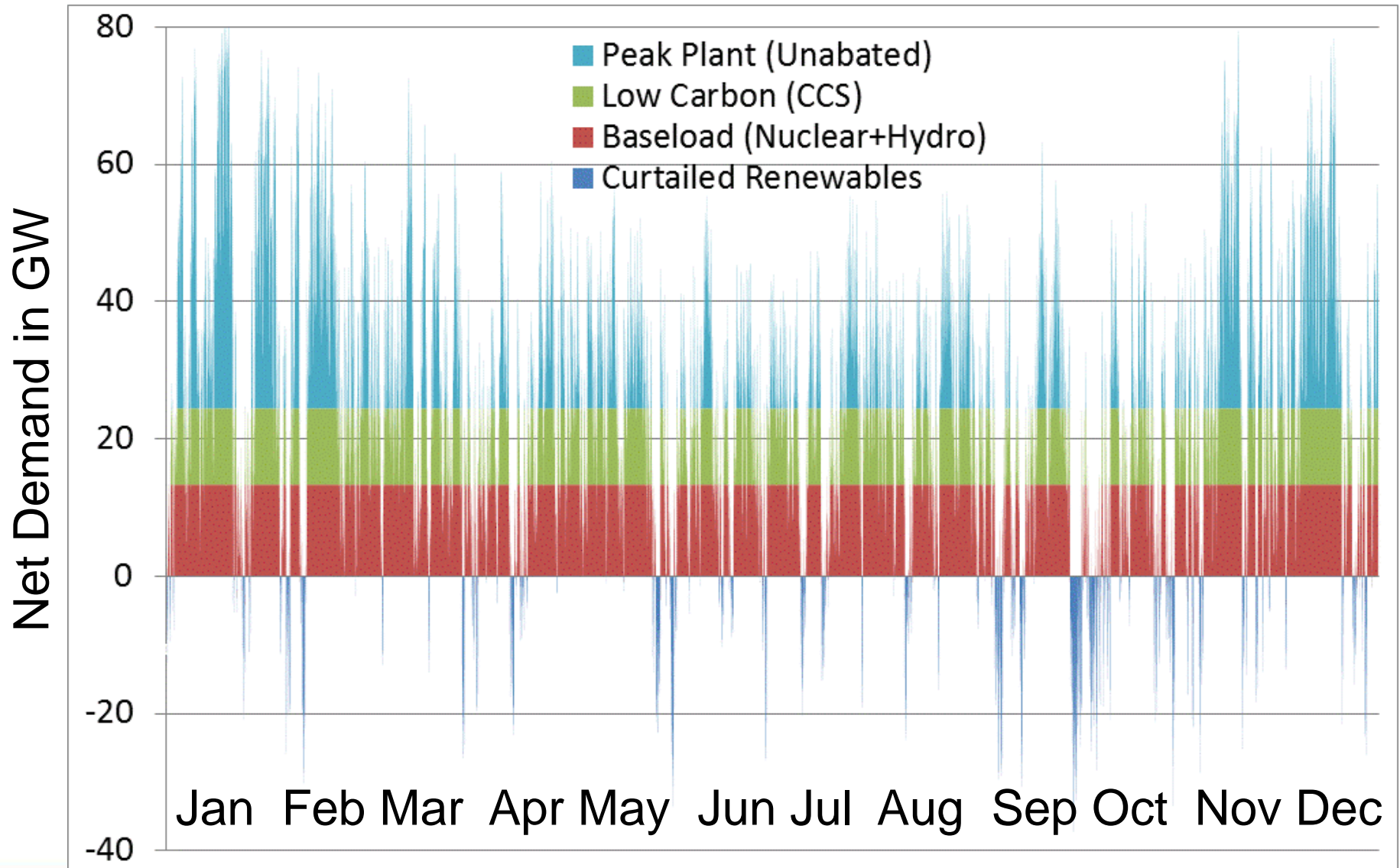
Loughborough University

The Future Need for Energy Storage: Steeper Load-Duration Curves

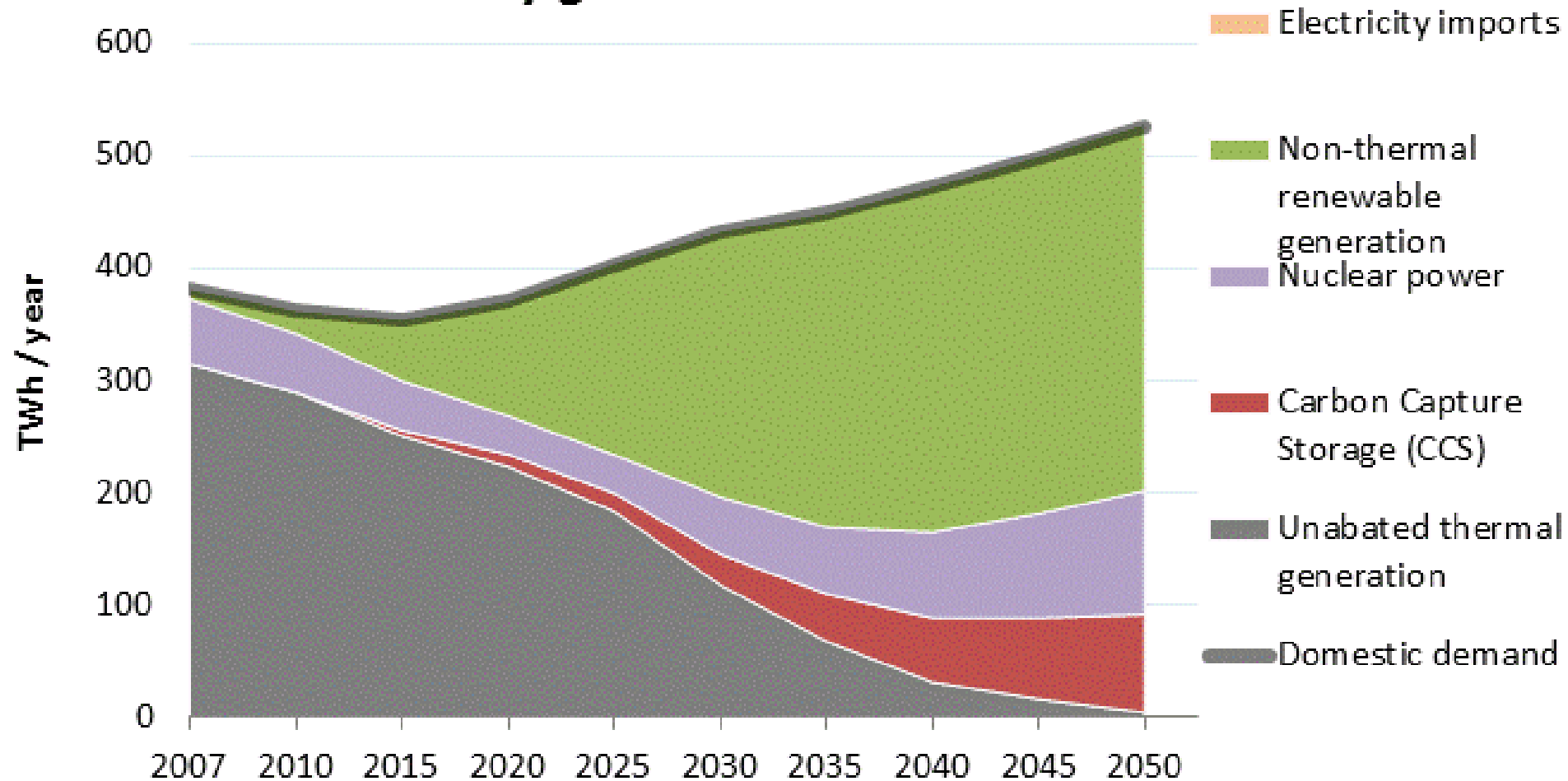# Overview of FESA, "Future Energy Scenario Analysis"

Electricity Demand
Electric Vehicles
Heat Pumps,
Appliances etc.
Domestic,
Commercial
and Industrial

+ → $\sum$ = net demand ← **−**

Uncontrolled Generation
Wind
Wave
Tidal
Solar PV
CHP

Balancing:
Storage
Interconnector
Time shifting
Curtailment

Merit Order
Of Generators → Dispatchable generation

Non-electric
fuel use → $\sum$ = National fuel demand → Total UK CO_2 Emissions

DECC 2050 Calculator (Higher Renewables Scenario)

DECC 2050 Calculator – (e.g. High Renewables)

3 Sources of Value from Storage

1. Peak Demand Lopping

2. Energy Arbitrage

3. Avoid Curtailment
Of Renewables (until Full)

Net Electricity Demand, GW

0

Time
(Hours)
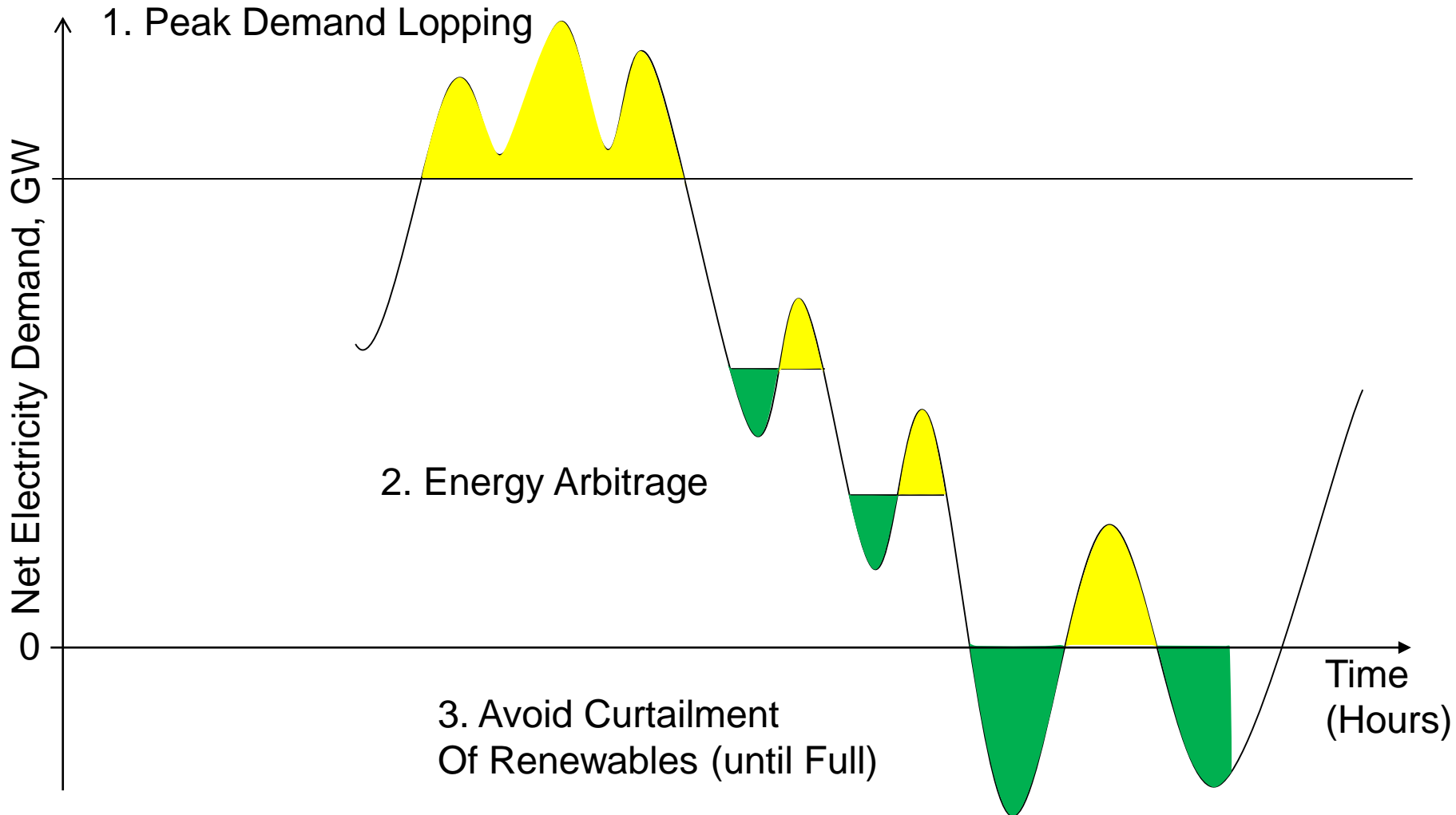
Store Sizing with Real Demand Data

Annual Peak
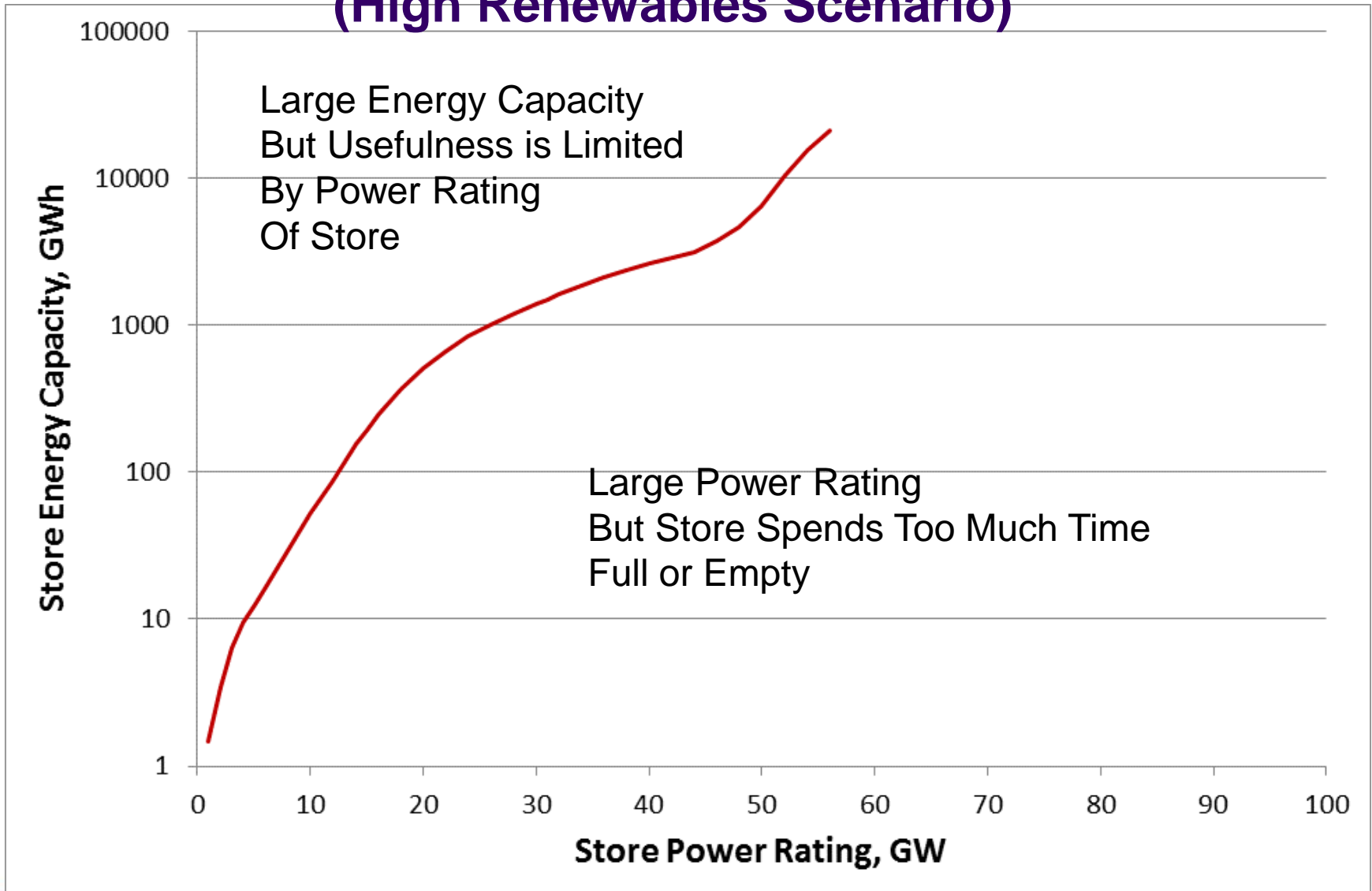
Area = Energy, E

Power, P

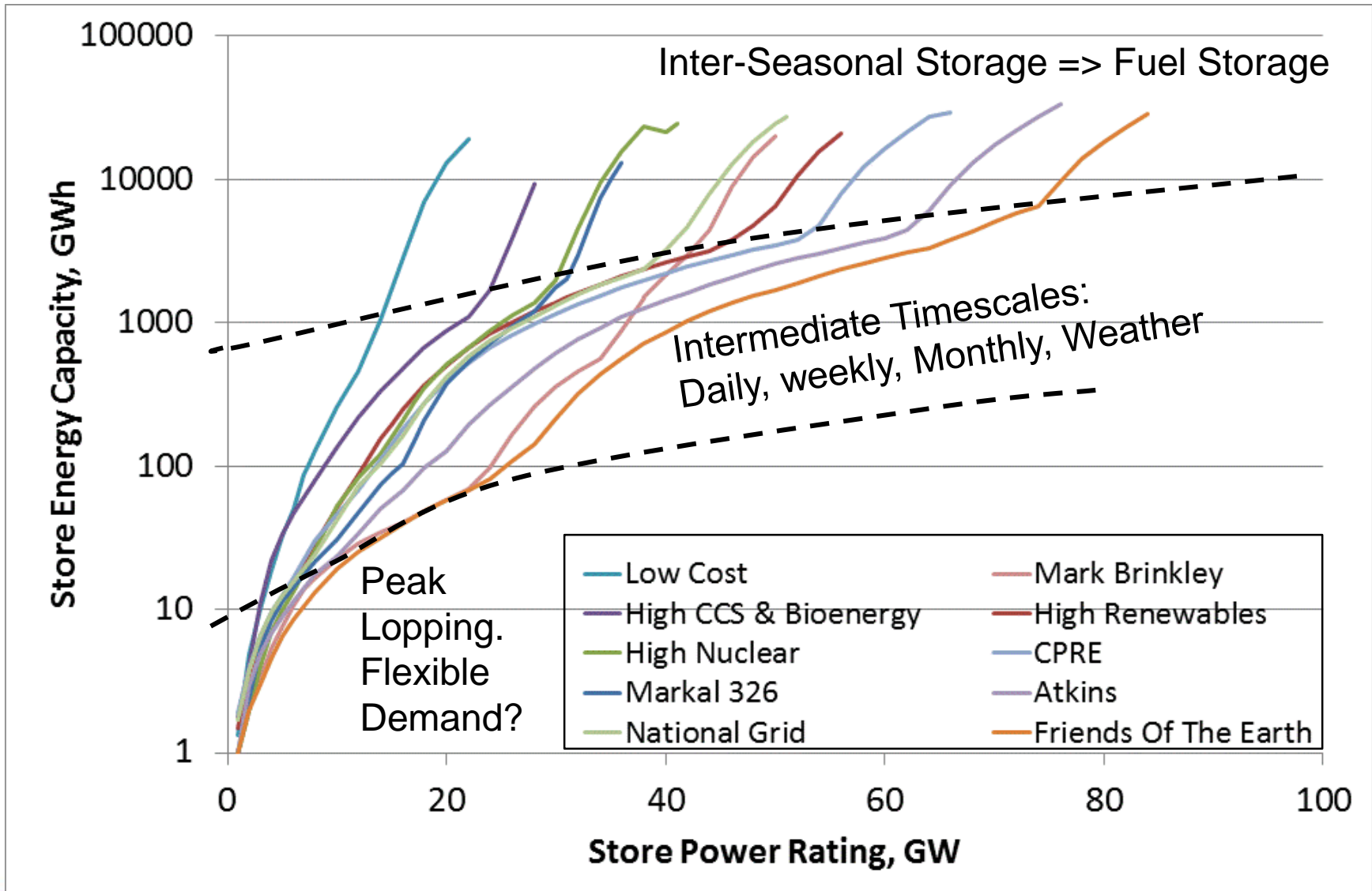Store ceiling

Time, t
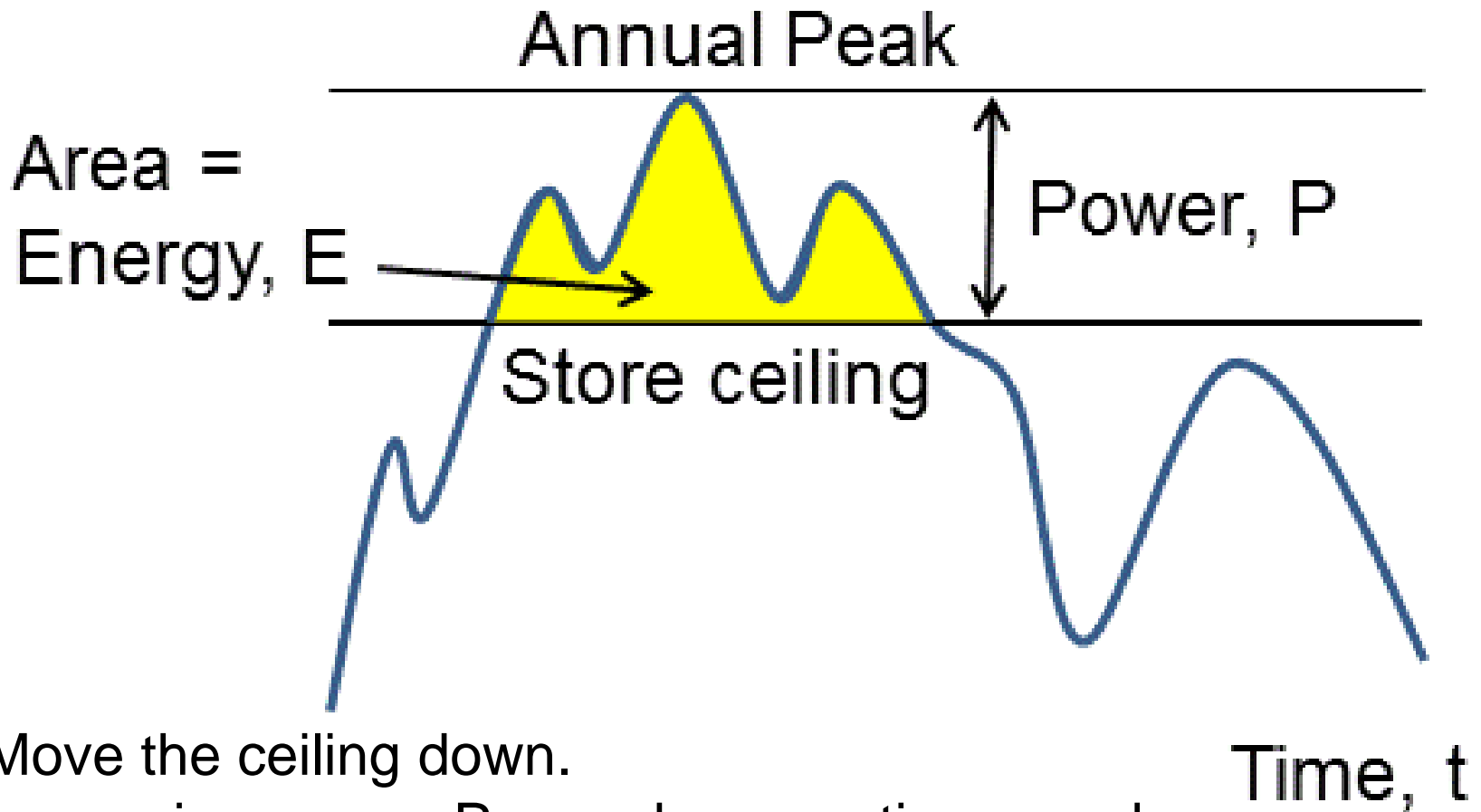
Move the ceiling down.
Increasing power, P = peak generation saved
Calculate the energy capacity, E = store capacity

# Optimum Ratio of energy Capacity to Power (GWh/GW) (High Renewables Scenario)

# Optimum Ratio of energy Capacity to Power (GWh/GW)

The Value of Energy Storage

| Function of Energy Storage	Benefits to Grid & Economy	Method of Evaluation
Meet peak demand (Takes priority)	Peak plant not needed ➔ Capital cost saving	CAPEX saved, DECC numbers
Energy arbitrage	Fuel saved or cheaper fuel substituted	Costs saved using DECC fuel costs Coal £9.5/MWh Gas £23.2/MWh
Avoid curtailment of renewables or nuclear	Lower carbon generation used ➔ Carbon saved	Costs saved using DECC CO_2 price, £76/tonne
Hour-to-hour ramp rates reduced	Cycling of backup generators is reduced	Not yet evaluated

Value of Storage vs. Store Power
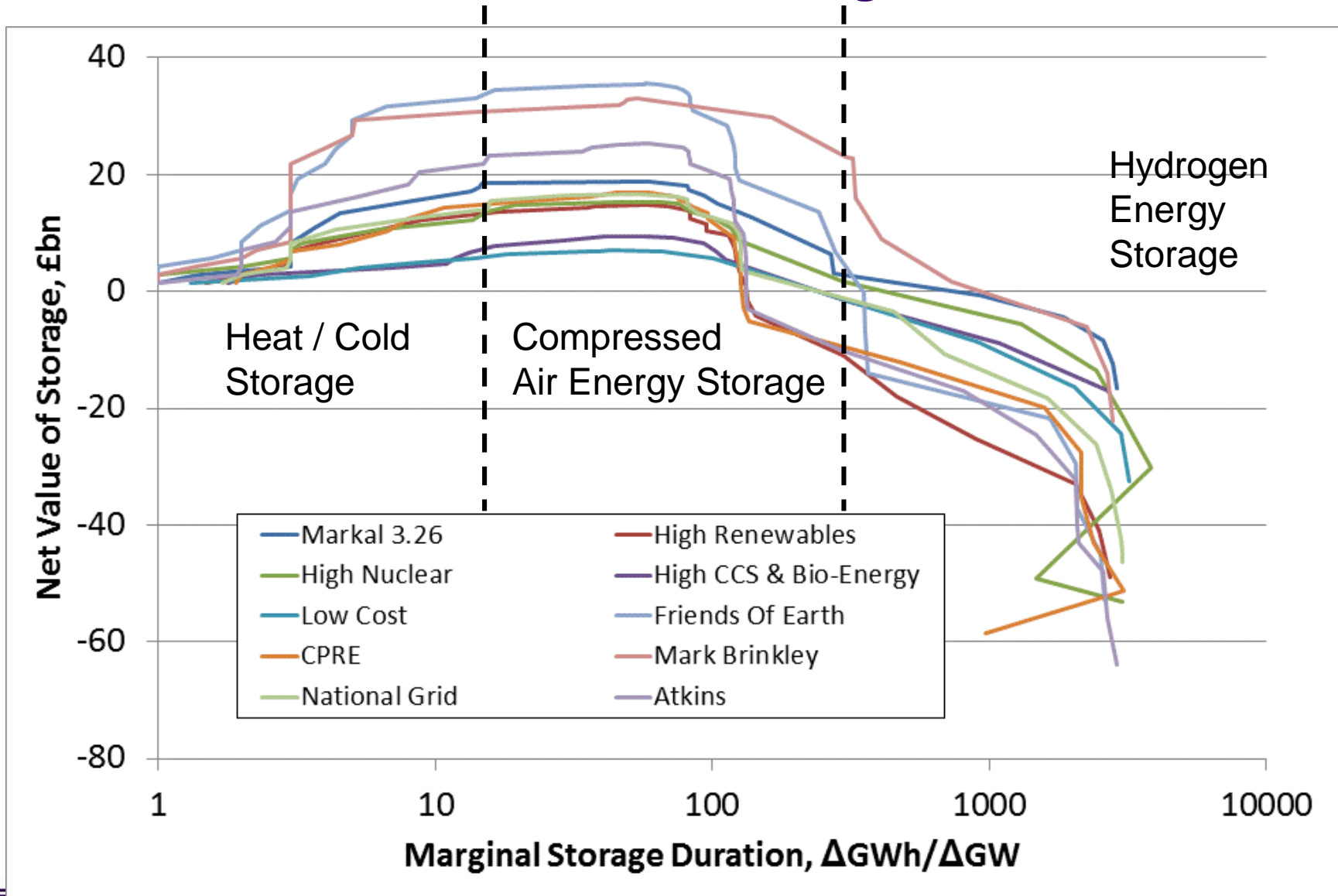
Value of Storage vs. Storage Capacity
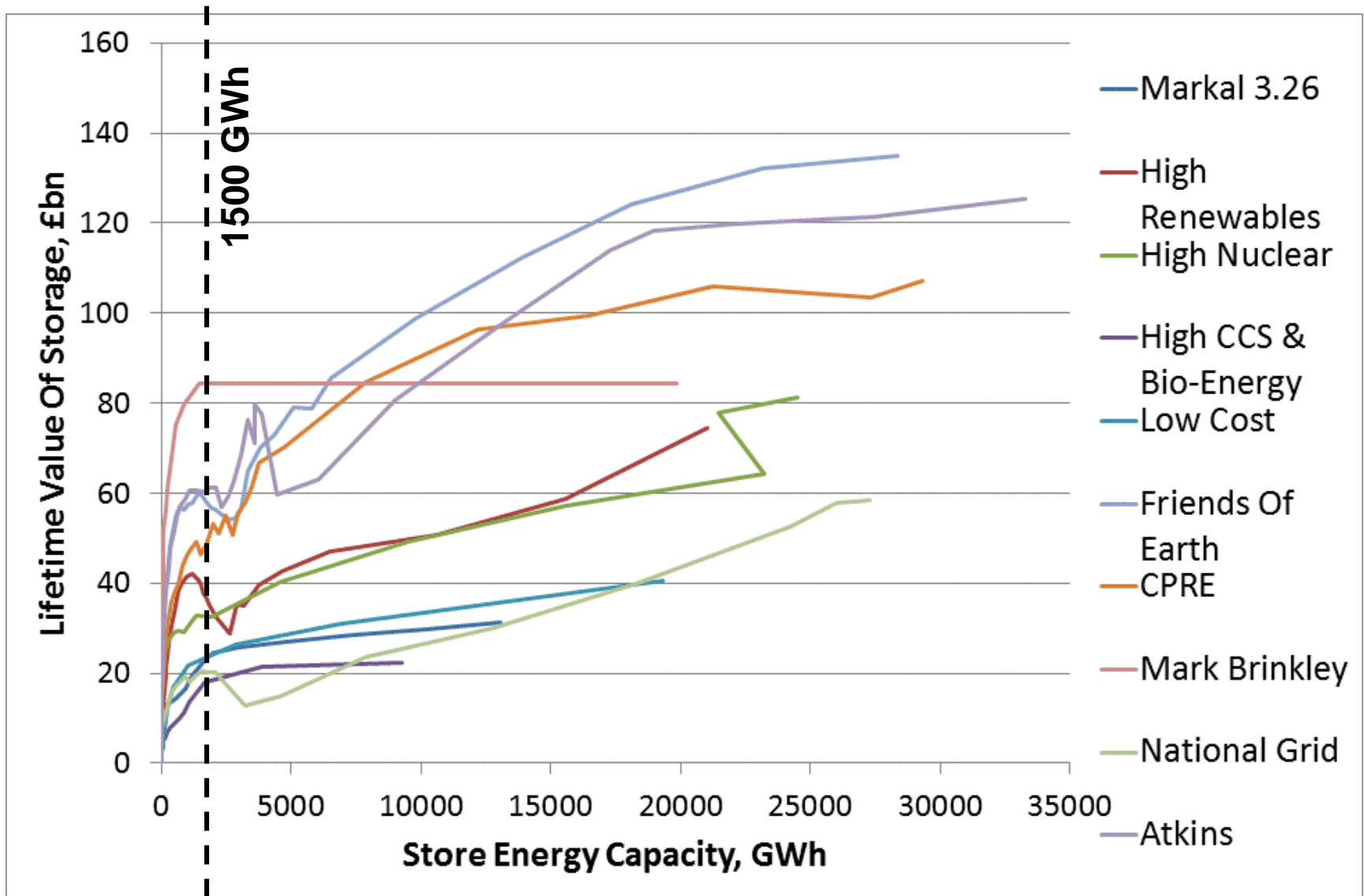
Capital Costs Per Power and Energy for Energy Storage
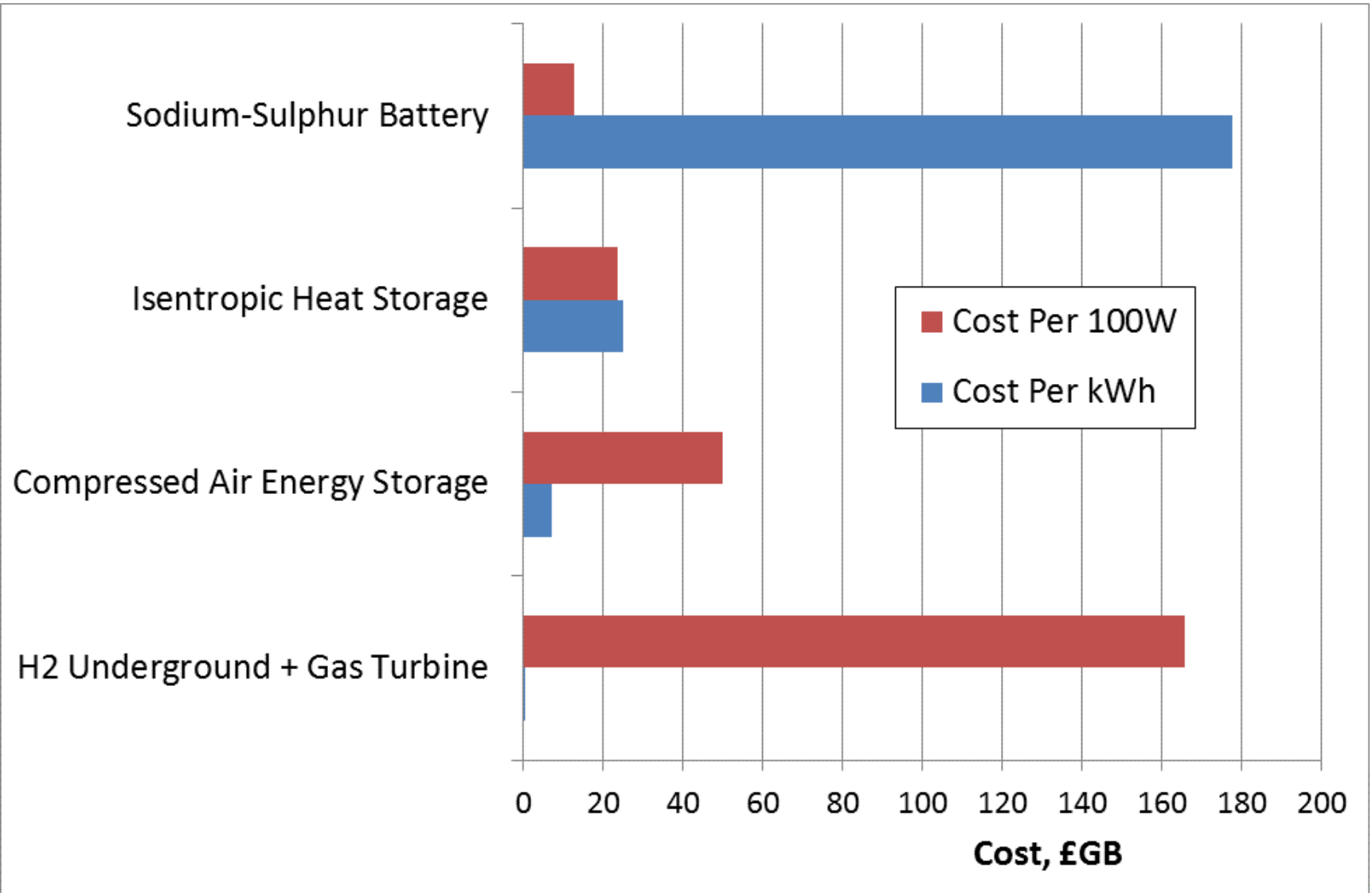
Sizes of Storage and Appropriate Technologies
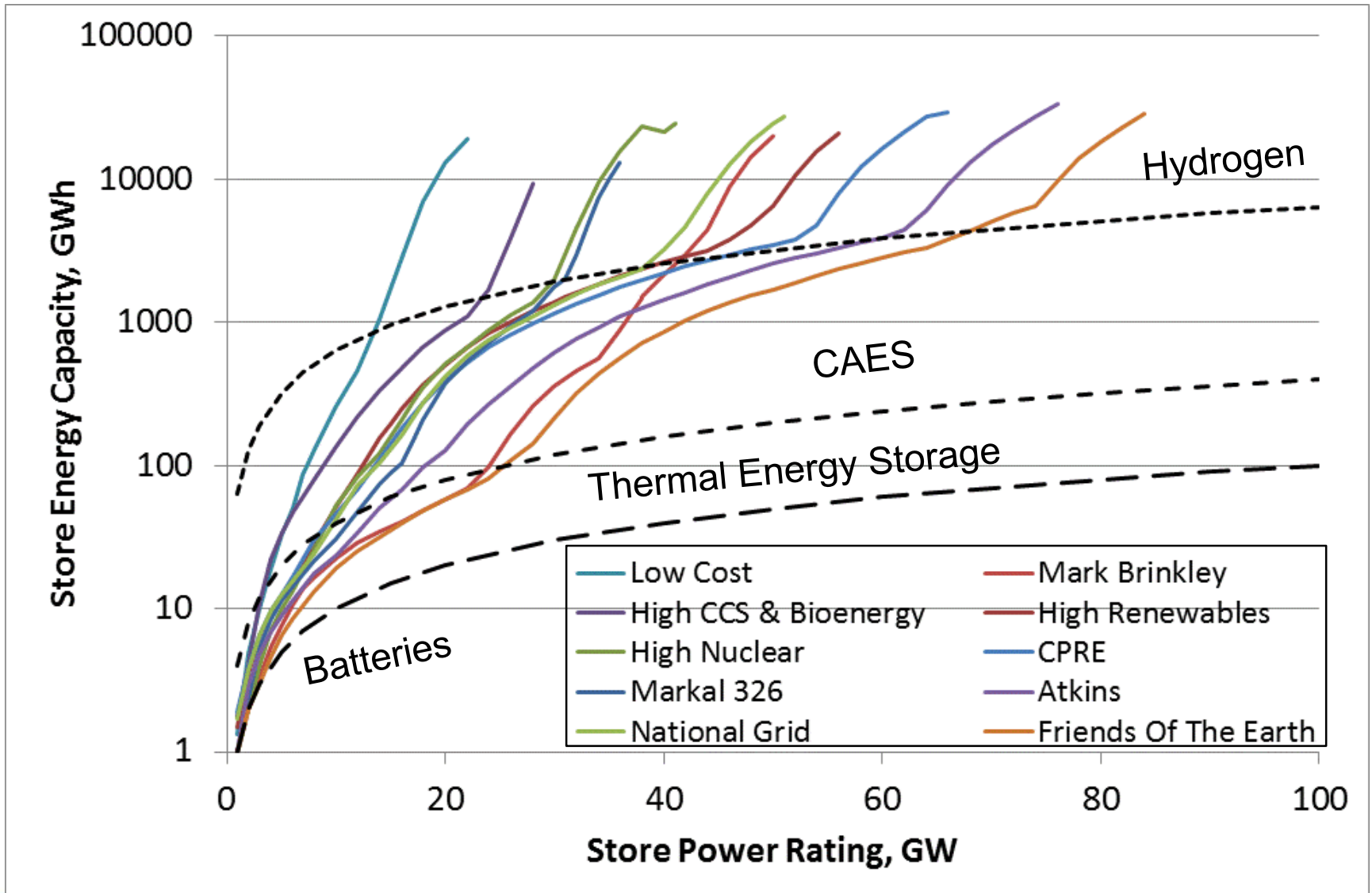
Net Total Lifetime Value of Storage = Value - Cost

Conclusions

- The need for energy storage is increasing

- The optimum ratio of GWh/GW (time constant) increases exponentially with power rating

- Strong law of diminishing returns with energy capacity, GWh

- The cost-effective technologies appear to be heat/cold storage and Compressed Air (CAES)

- Storage is cost-effective for daily or weekly smoothing and some weather-related variations but not inter-seasonal storage

Cost of Storage with Increasing Timescales

Energy Storage Control Algorithm