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***FAPESP, 12 May, 2014***

# DELIVERING FLEXIBILITY IN ENERGY SYSTEMS

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# UK Energy system need for flexibility

Main elements of UK energy system scenarios to meet 2050 GHG targets:

- Decarbonise power sector
- Increase energy efficiency
- Electrification of demand

Challenges will become more acute in pathways to 2050:

- Large proportion of intermittent generation by early 2020s
- Increase in demand for electricity for heating and transport in late 2020s

**Many scenarios which have guided policy not able to treat power system balancing effectively, nor the dynamic evolution of technology deployment.**

| Timescale | Challenge |
|---|---|
| **Seconds** | Renewable generation introduces harmonics and affects power supply quality. |
| **Minutes** | Rapid ramping to respond to changing supply from wind generation. |
| **Hours** | Daily peak for electricity is greater to meet demand for heat. |
| **Hours - days** | Variability of wind generation needs back-up supply or demand response. |
| **Months** | Increased use of electricity for heat leads to strong seasonal demand profile. |

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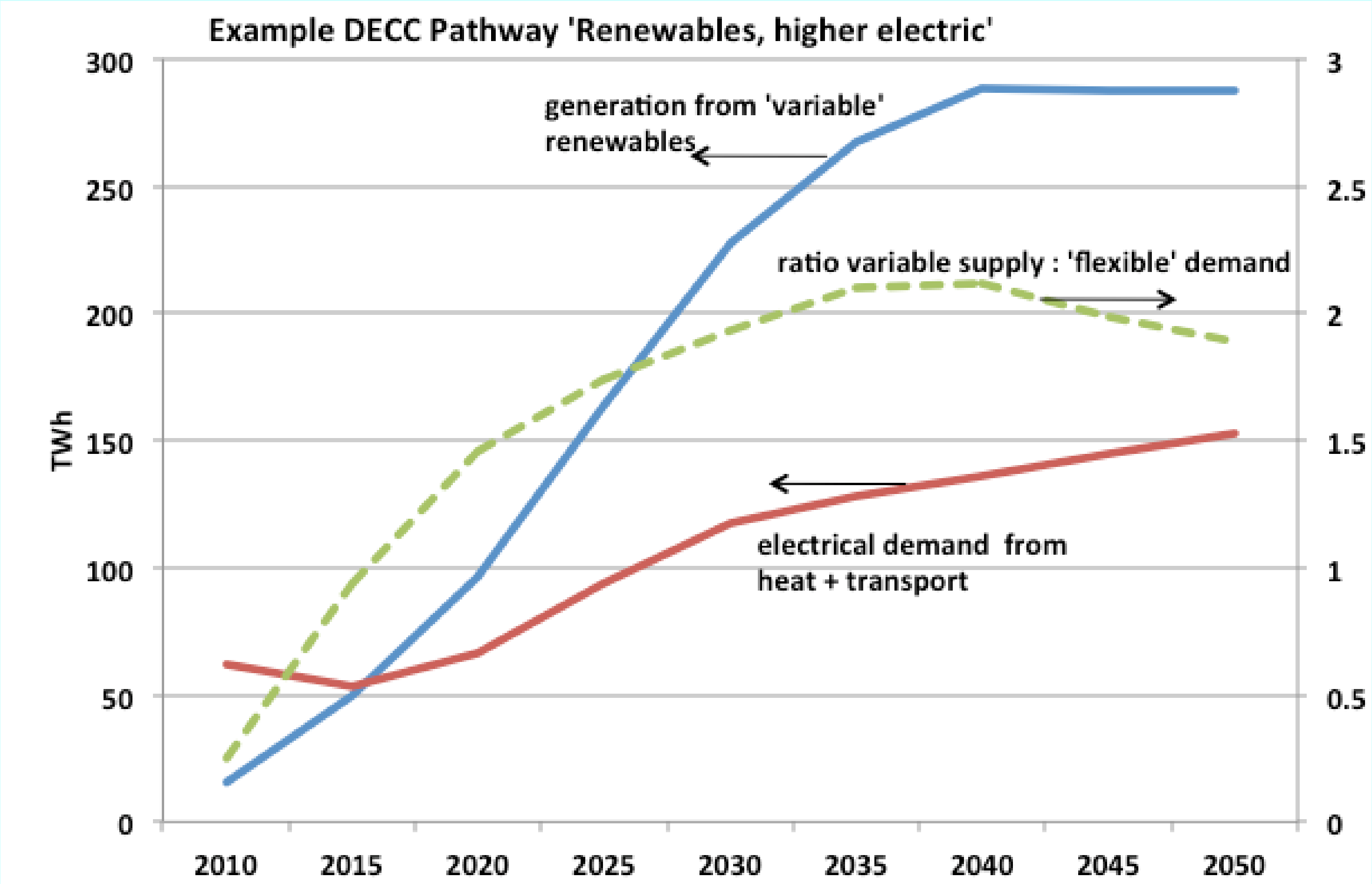
# Example pathway dynamics




- Dynamics of energy system transition could be critical to deployment of enabling technologies
- Likely that intermittent generation will expand before demand response from EV and HPs

# Flexibility options

With an increase in generation from ‘must run’ and intermittent sources, and rising demand for electricity with less predictable profiles, ***flexibility*** becomes a critical component of the energy system

There are various means of meeting the same general and specific challenges:

- ***Flexible plant*** – Gas CCGT/OCGT is the default option Future options may include nuclear and fossil fuel CCS with greater ability to flex generation cost-effectively.
- ***Demand side response*** – smart meters, heat pumps and EVs  deployed over the next decade can give consumers a mechanism to shift loads, but needs appropriate functionality and incentives.
- ***Interconnection*** – provides additional capacity or load for the UK, but operated on merchant basis is not solely for UK benefit, and relies on capacity being available elsewhere.
- <u>***Energy storage***</u> – can capture off-peak or excess generation and deliver at peak times, does not compromise national security of supply, does not require behavioural change from consumers.
  (Include consideration of alternative energy vectors – hydrogen, liquid air, heat…).
  But energy storage has its own challenges as an emerging disruptive technology: cost/performance; acceptance by the industry and wider energy community.

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# Growing recognition for role of storage

In November 2012, in a speech at the Royal Society, the Chancellor George Osborne said that the UK must take a global lead in developing a series of low carbon technologies, including energy storage:

- *Greater capability to store electricity is crucial for these power sources to be viable. It promises savings on UK energy spend of up to £10bn a year by 2050 as extra capacity for peak load is less necessary.*

**One of the UK Government's 'Eight Great Technologies':**

- *Energy storage has "the potential for delivering massive benefits – in terms of savings on UK energy spend, environmental benefits, economic growth and in enabling UK business to exploit these technologies internationally."*

From 2013 a number of new funding sources for storage demonstration and capital became available in the UK. Recently major new projects were announced including a major **Centre for Cryogenic Energy Storage at University of Birmingham**

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# Global application for energy storage

**Applications**

- Component of ‘smart grids’
- Meeting cooling demands in summer
- Managing rise in distributed generation from solar PV
- Maximising transmission line use
- Improving power quality with integration of renewables
- ‘Behind the meter’ arbitrage
- Increasing the efficiency of thermal plant
- Off-grid small-scale renewables

…

Multiple drivers, multiple applications, multiple technologies…

We need wide approach to technology development.

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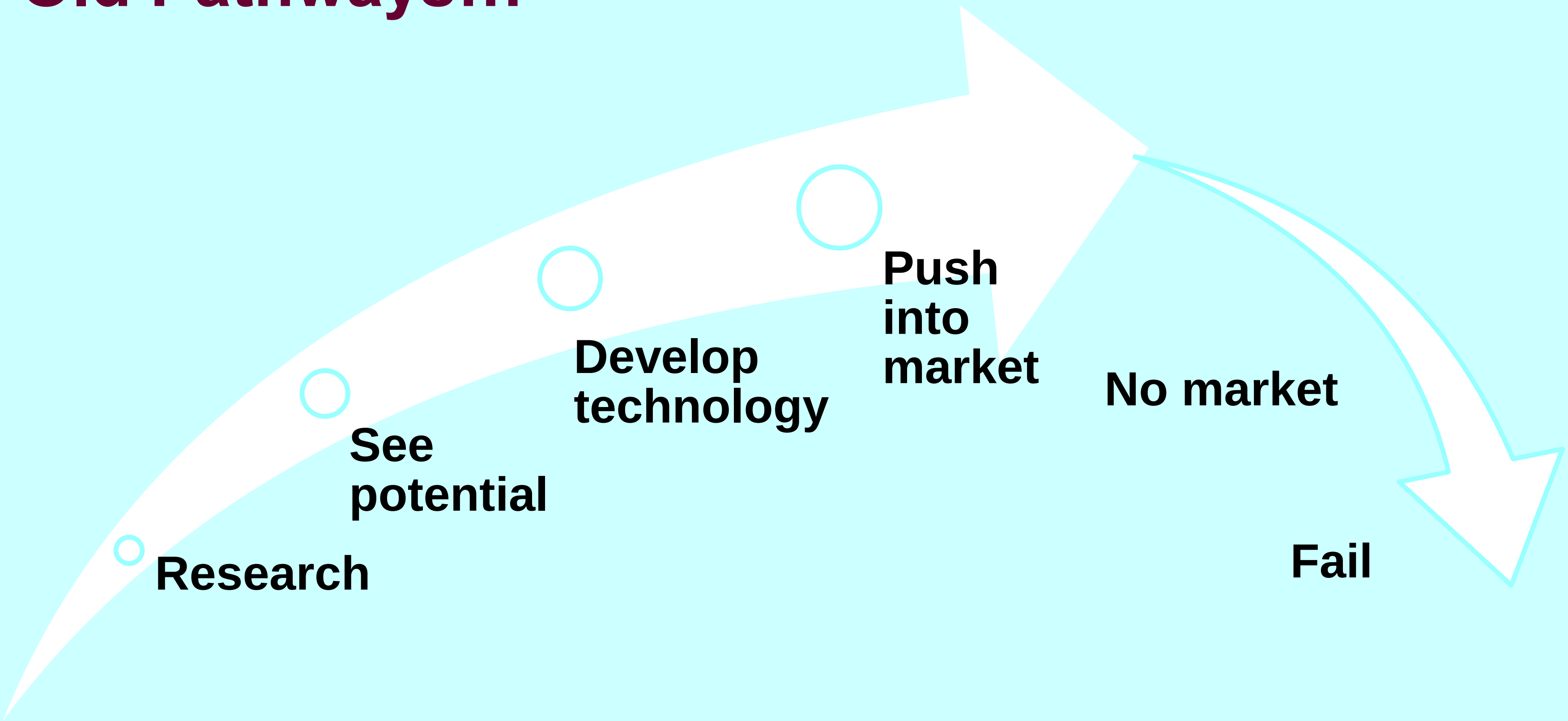
# Yet significant barriers to deployment

- Uncertainty of value: the value is dependent on the energy system mix; models have so far been limited so estimates of value are still to be refined.
- Technology cost and performance: current price is too great to give a business model for deployment, even if the full system value could be extracted
- Business: capturing multiple revenue streams is difficult to establish, both for a potential business and the market in which it will operate.
- Markets: the true value of energy is not reflected in the price; more fundamentally, the future long-term value of storage cannot be recognized in today's market.
- Regulatory/policy framework: e.g. restrictions on ownership; high network charges affect storage operators; market reforms not considering storage.
- Societal: wider community acceptance.

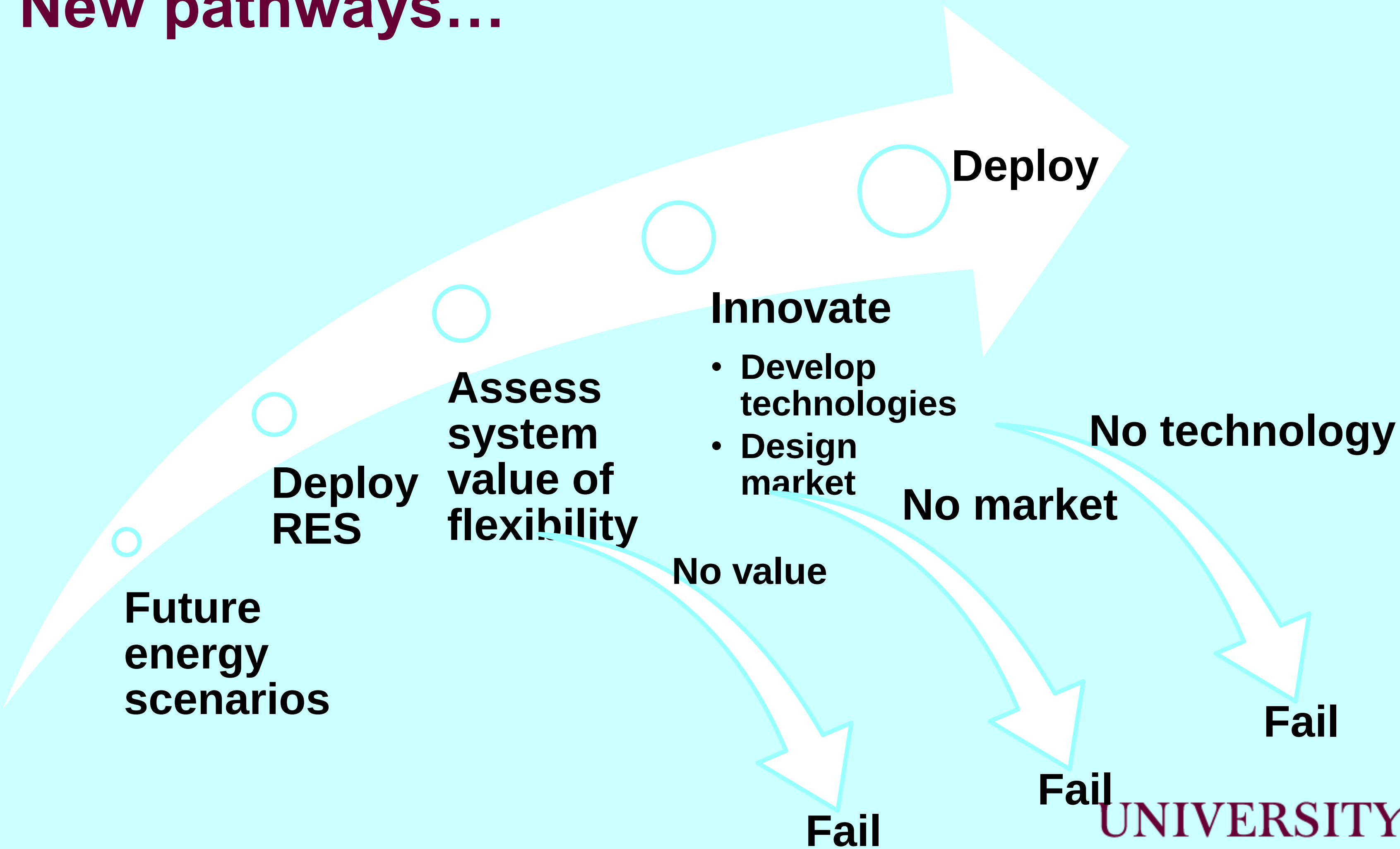
- Long term view needed to see future value of technologies, with mechanisms to bring forward that value of energy storage

- Policy/regulation, technology development, and systems analysis must work together to create new pathways

# Old Pathways…



# New pathways…

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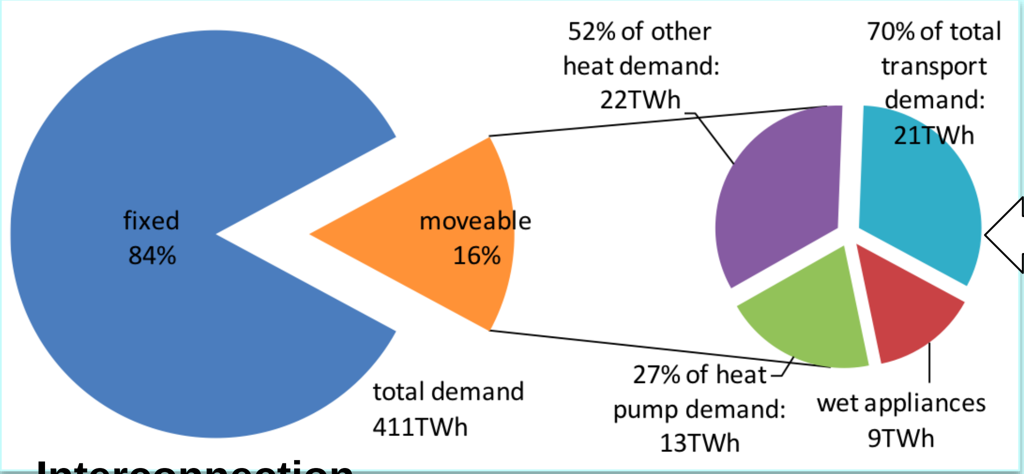
# Progress in analysis (1/3): CCC 50% RES in 2030 - Low cost to manage intermittency?




## Demand side

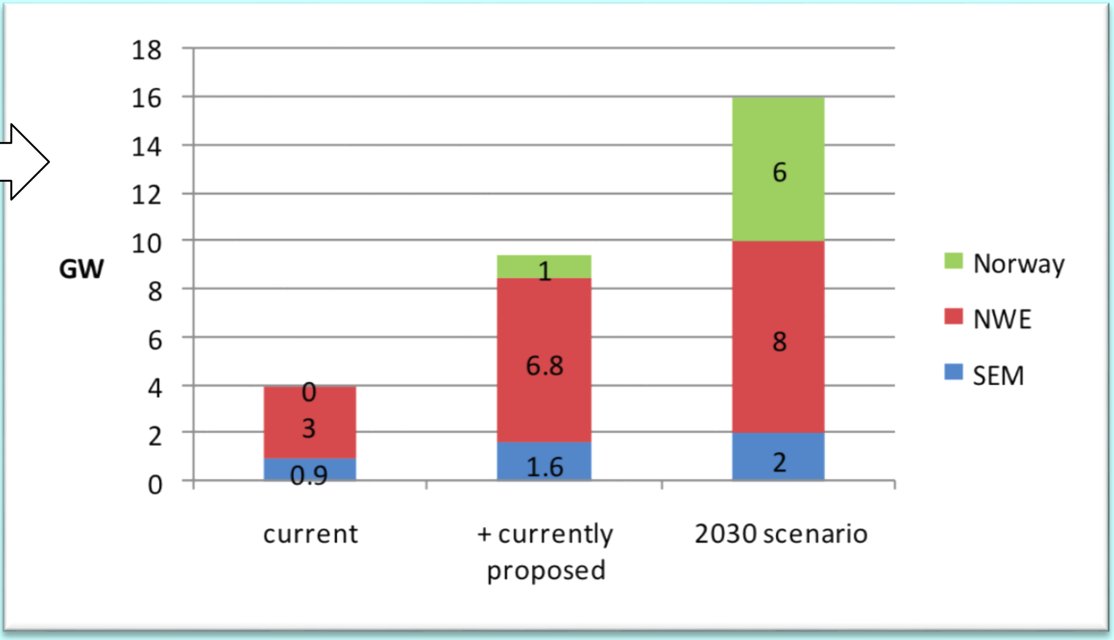
- 16% of demand moveable, primarily thermal storage and EV batteries.
- Dependency on deployment of heat pumps and EVs; with smart meter system capability.

## Storage

- Modest increase in capacity to 4GW.

## Interconnection

- Increase capacity 4GW → 16GW, with Norwegian PHS key role.
- Valuable system balancing role.
- Questionable whether can provide reliable supplies in wind lull.




## Flexible generation

- No new thermal generation beyond currently planned
- Operating at low load factors <20%

***Committee on Climate Change (2011) 'Renewable Energy Review'***

# Progress… in analysis (2/3)

**‘Value of storage’**, report by Strbac et al*****, find that in scenarios with high renewables:

- the value of storage increases markedly towards 2030 and further towards 2050;
- a few hours of storage are sufficient to reduce peak demand and capture significant value;
- storage has a consistently high value across a wide range of cases that include interconnection and flexible generation;
- deployment of bulk storage occurs at lower levels than distributed storage.
- <u>The values tend to be higher than previous studies suggest.</u> But “split benefits” of storage pose significant challenges for policy makers to develop appropriate market mechanisms to ensure that the investors in storage are adequately rewarded for delivering these diverse sources of value.

→ Begin to consider ***which*** technologies will have most value in a systems context and ***when*** they need to be deployed.

*http://www.carbontrust.com/resources/reports/technology/energy-storage-systems-strategic-assessment-role-and-value

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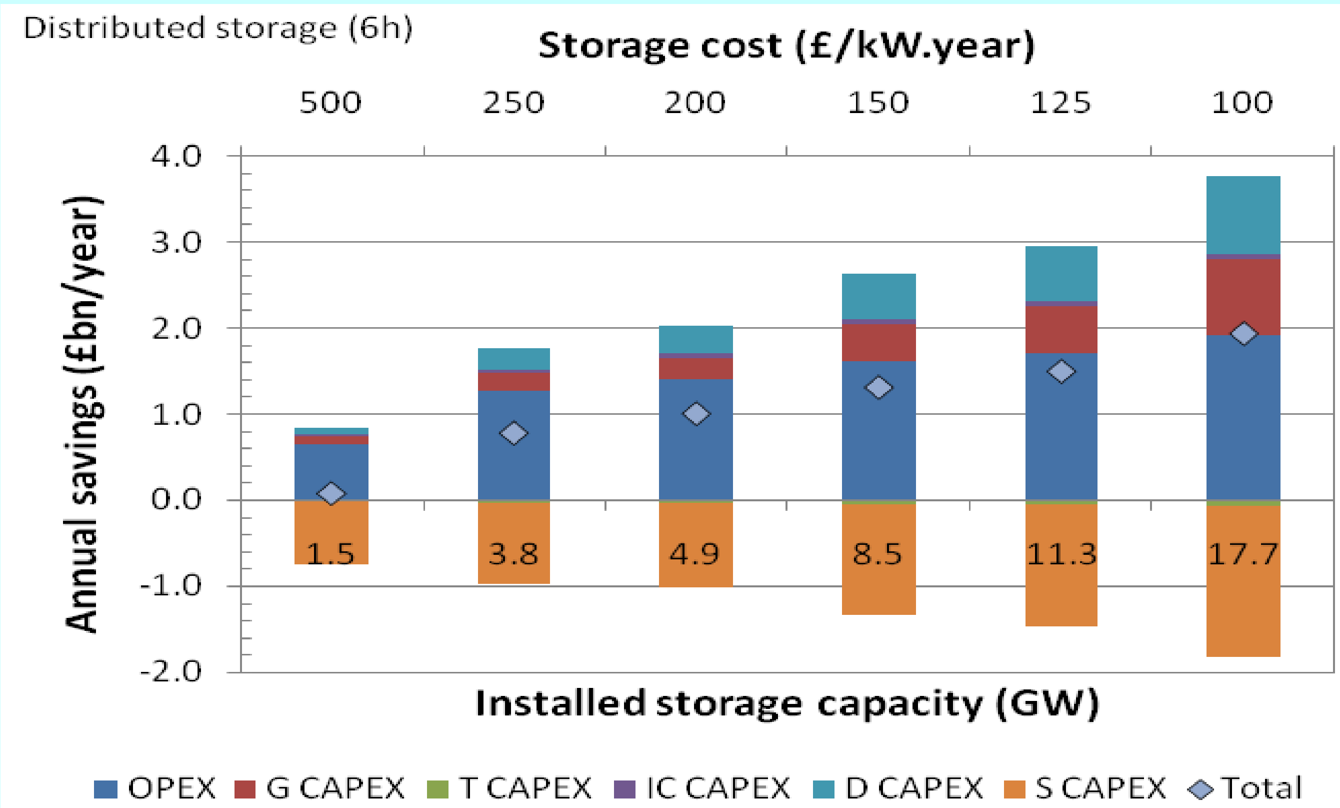
# Progress… in analysis (3/3)




*Annual net benefit of distributed storage for the Grassroots scenario in 2030*. Strbac et al (2012)

***Key storage technology characteristics required:***

- Low cost solutions are needed as energy requirements increase, decouple power & energy.
- Significant value for fast storage, but limited market
- Ability to cycle frequently for distributed storage with 6 hours capacity
- Efficiency not as important at low levels of deployment: consider overall costs, scaleability, and lifetime.

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# UK Electricity Market Reform

Energy Act 2013 included provisions for:

*Capacity market*

- An “insurance policy against the possibility of future blackouts”

*Feed-in-Tariffs with Contracts for Difference*

- Long-term contracts for price stability
- Generators receive the price they achieve in the electricity market plus a ‘top up’ from the market price to an agreed level (the “strike price”).

*Emissions performance standard*

- Regulatory backstop to limit CO2 emitted from new fossil fuel plant
- Won’t impact new gas generation

Also introduced in 2013 – *Carbon price floor*

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# Progress… in policy?

Paper from Department of Energy and Climate Change (DECC), published August 2012, 'looks at whether there are more cost effective ways to operate the system in the future':

> *The need for a more flexible electricity system with more widespread deployment of balancing technologies and a smarter network appears to crystallise in the 2020s, nevertheless it is important that we ensure we are facilitating its development today.*

Followed-up in November 2012 with proposals for the Capacity Market:

> *Given the advantages of DSR and storage, Government is keen to help the industries develop and play an increasing role in ensuring security of supply.*

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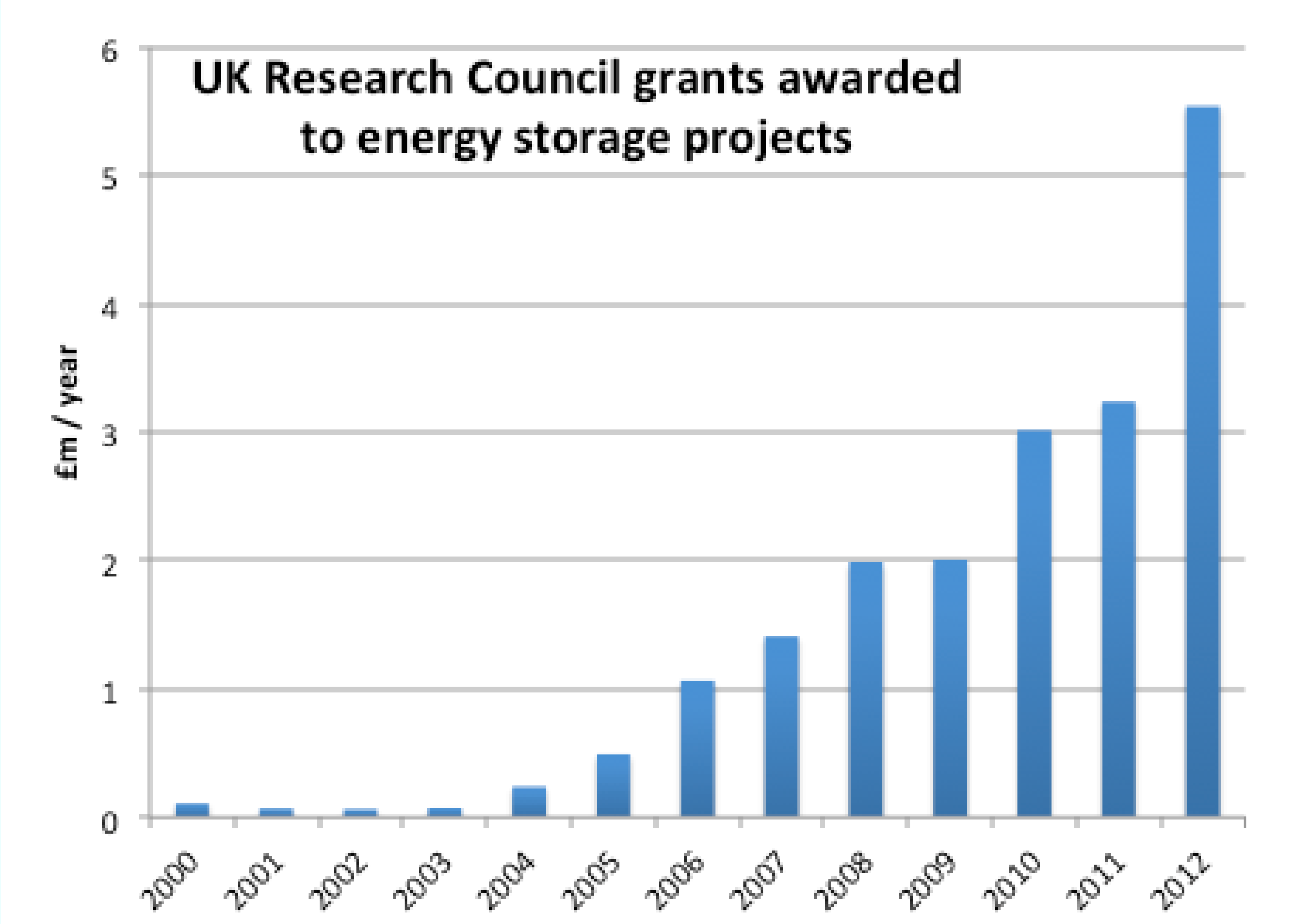
# Growing commitment to energy storage R&D

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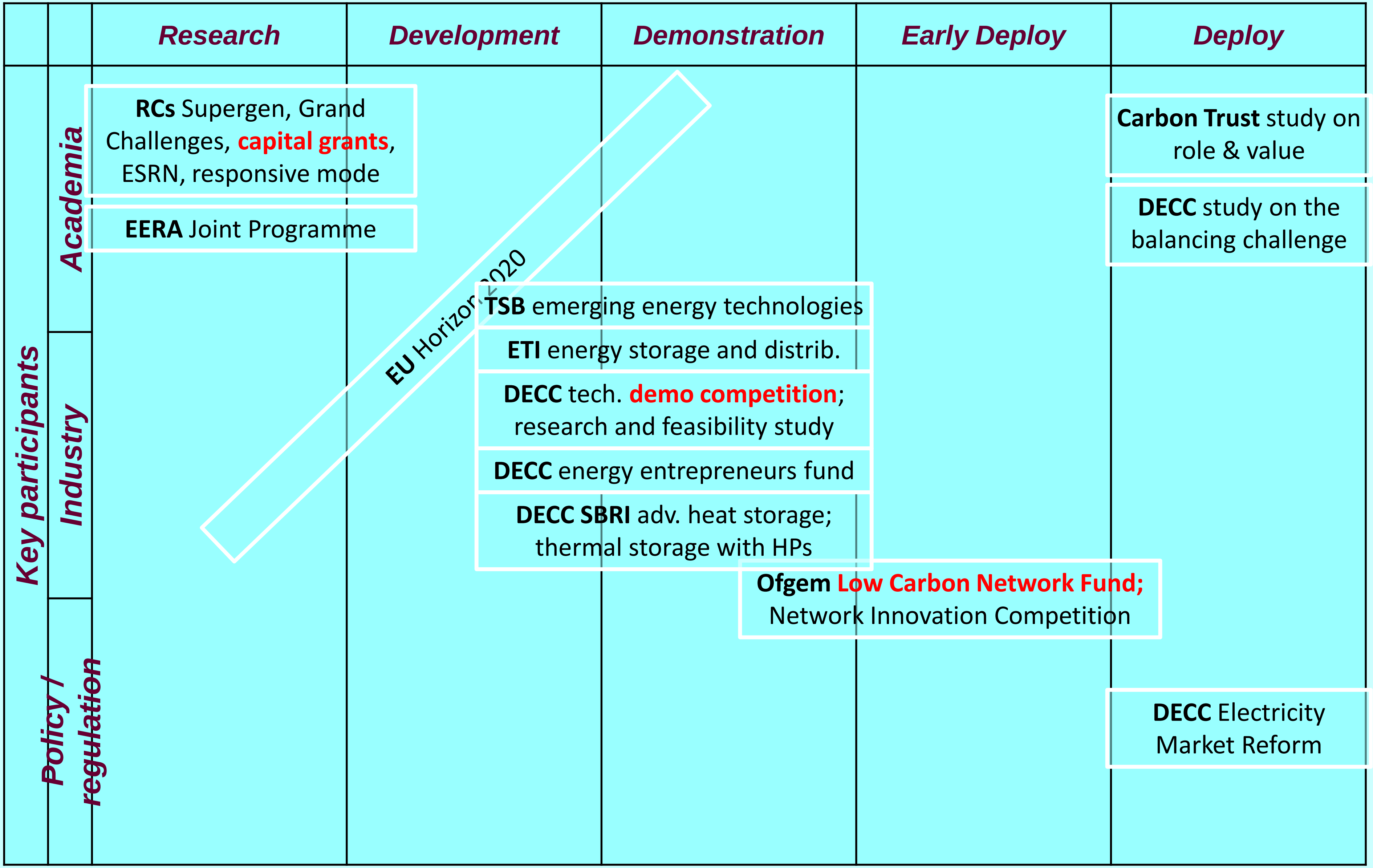
Source: UKERC Research Register

# Energy storage innovation landscape



# Key elements of centre for cryogenic energy storage

University of Birmingham-led initiative with University of Hull; both part of Centre for Low Carbon Futures, with major energy storage programme

BCCES industry partners: Highview Power Storage, Dearman Engine Company, Air Products, EG&S KTN; Arup and ETI on advisory board

PI – Prof. Richard A Williams; Director – Prof. Yulong Ding

**Total £12.3m**:

£5.9m EPSRC equipment grant; £1.2m institution; £5.2m industry

Integrated innovation:

- Research → develop → demonstrate
- Cross-disciplinary, whole-system
- Academia + business + policy

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# Cryogenic energy storage – key development challenges

Research themes:

1. Novel materials: address key materials challenges, inc. performance of deep cold and low to medium temperature heat storage materials
2. Thermodynamic and generation processes: address process challenges, develop high efficiency hot & cold exchange devices
3. Systems integration, control and optimization: address energy management challenges of an operational CES plant

Pilot scale test-bed for full CES system and generation-only

Next steps:

- Equipment procurement by Q1/Q2 2014
- Lab refurbishments by Q2 2014
- CES test-bed relocation by Q2 2015
- Policy / markets analysis alongside technical RD&D
- Seek opportunities to support further development and commercialisation of the technology

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# Current energy storage technology projects

- **EPSRC: £3.906M**, Energy Storage SuperGen Hub (led by Oxford University in collaboration with Imperial College, Cambridge, Warwick, Birmingham, Southampton and Bath Universities), July 2014 – June 2019.
- **EPSRC: £984,845**, Next Generation Grid Scale Thermal Energy Storage Technologies (NexGen-TEST), in collaboration with Nottingham & Warwick (together with three Chinese academic organisations and industrial partners), March 2014 – February 2017.
- **EPSRC: £5.9M**, Birmingham Centre of Cryogenic Energy Storage, December 2013 – December 2023.
- **EPSRC: £1.06M**, Thermal energy storage (part of a £14.283M consortium led by Imperial College in collaboration with Cambridge, Oxford, St Andrews, Newcastle, UCL, Sheffield and Cardiff) on Capital for great technologies - Grid scale energy storage), October 2013 – 2015.
- **Joint Centre with Chinese Academy of Sciences (Chinese side: about £3.5M),** Energy storage materials and processes, March 2010 – June 2015.
- **EPSRC: £5.59M**, Energy storage for a low carbon grid, a consortium led by Imperial College in collaboration with Oxford, Cambridge, UCL, Leeds, St Andrews, Sheffield and Cardiff), October 2012 – September 2017.

With proposals for projects from other sources

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# Current non-technology projects

- **EPSRC**: Will be undertaking a national energy storage roadmap for the UK as part of Supergen Hub; considering research requirements, and strategic-level
- Modelling heat and power system to assess value of energy storage at local level; with Birmingham City Council and other stakeholders
- **CLCF/Chatham House** project on international market opportunities and investment for energy storage
- **FCO**: Comparative analysis of UK and Korea energy systems and opportunities for energy storage, with survey of key stakeholders

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# Survey of stakeholders

- Interviews with a variety of stakeholders to understand their perspectives on the needed for greater system flexibility, the role of storage and barriers to its implementation.
- Government, regulators, electricity companies, R&D funders, technology manufacturers.
- Part of a larger study led by CLCF and funded by the FCO looking at opportunities for storage in the UK and Korea and areas for co-operation.

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# Key messages from the interviews

Agreement on:

- Need for additional energy system flexibility
- Key drivers of the need for flexibility: renewables, electric vehicles and heating
- Storage durations < 1 day most likely
- Storage cost and performance, plus current market structure and regulations are important barriers

Less agreement on:

- Whether any particular flexibility option likely to win out
- If a lack of business models poses a barrier

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# Priorities for innovation in energy storage

- Further **analysis** of the value of energy storage and other flexibility options in the energy system:
  - in the transition period
  - under different scenarios
  - showing value from multiple streams
- More systems thinking in **policy**.
- Further **demonstrations** and understanding of results.
  - Especially at distributed level, and considering thermal storage
  - ‘Smart’ metering systems need to demonstrate effectiveness
  - Ensure strong links between EV pilots and energy system analysis; investigate benefits of vehicle-to-grid
- **R&D** needed to develop lower cost alternatives
  - Coordinated UK RD&D effort, with international engagement.

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# THANK YOU

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