The geographical distribution of UK energy system decarbonisation costs and the implications for utility companies, governments and communities

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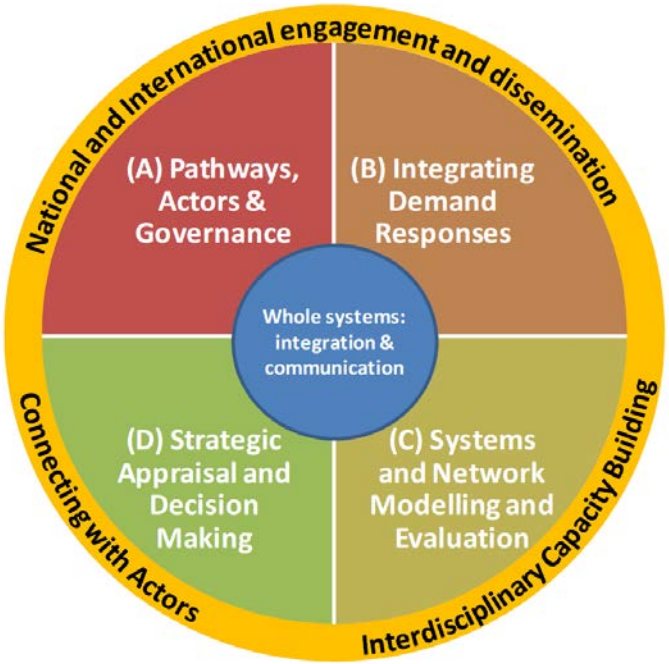
Overview

- Introduction to the Realising Transition Pathways Project
- Spatial Modelling of Decarbonisation Costs
- Insights for Policy and Modelling

Realising Transition Pathways (RTP)

- Interdisciplinary research consortium with 9 universities, running since 2008
- Exploring pathways to a decarbonised UK power sector through 4 main activities
- Emphasis on exploring socio-technical change



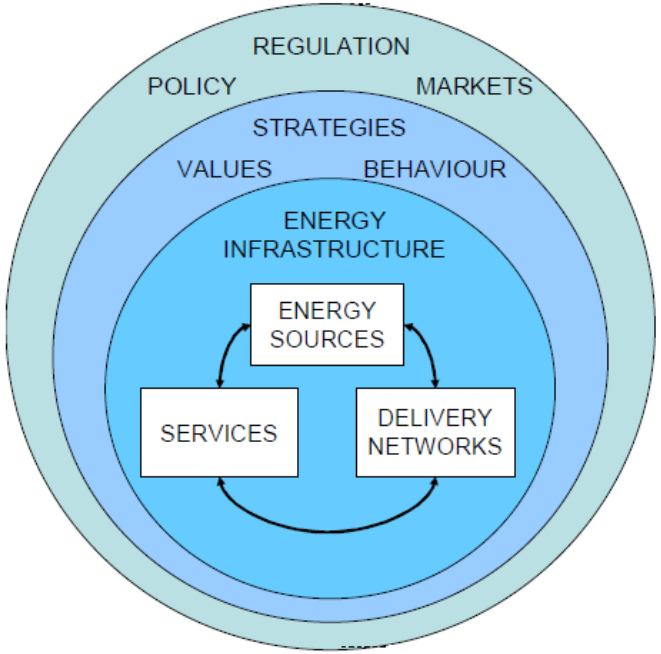


Image: Based on Foxon et al. 2010, Developing transition pathways for a low carbon electricity system in the UK

Transition Pathways

- Transition pathways follow 3 main narrative scenarios
- Exploratory in nature
- All achieve a low carbon electricity system consistent with UK 2050 targets, but do so through different governance arrangements

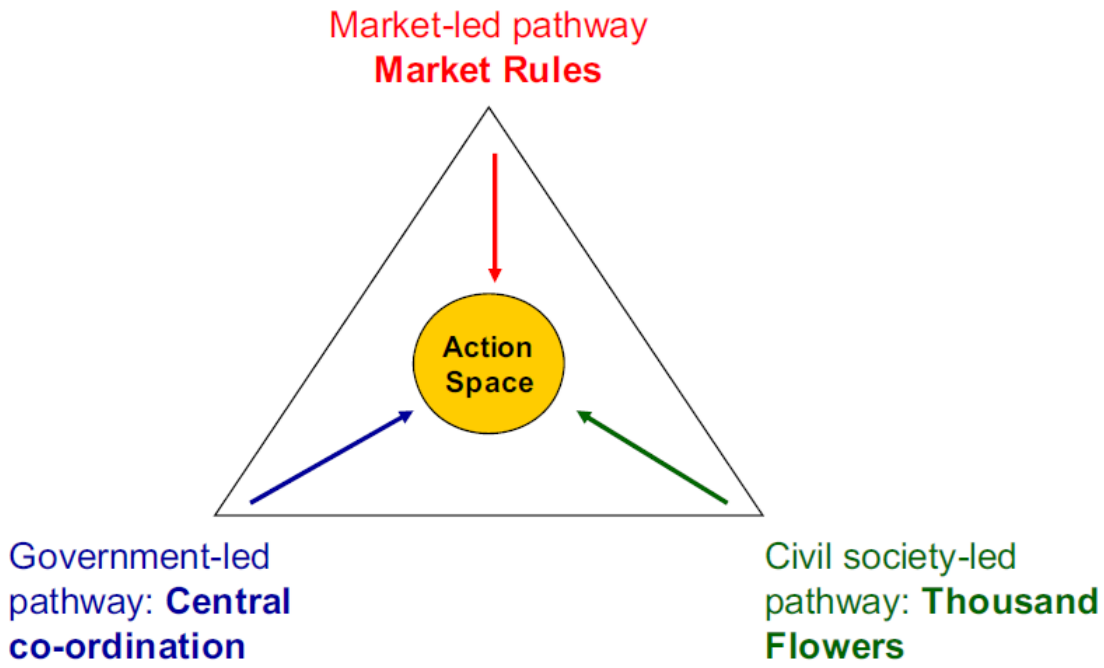
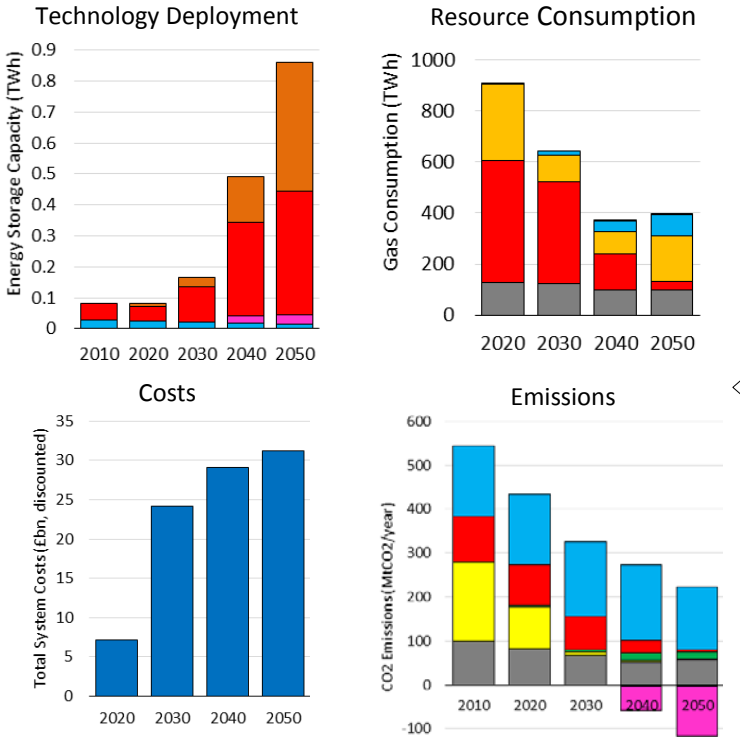
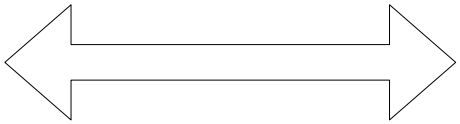


Image: Based on Foxon et al. 2010, Developing transition pathways for a low carbon electricity system in the UK

Geographical Detail in Transitions

- Outputs from national-scale energy modelling can be difficult to relate to actors
- Relatively few energy system models are disaggregated at the sub-national level
- UK energy economic analysis to date has been mostly focused at the national scale

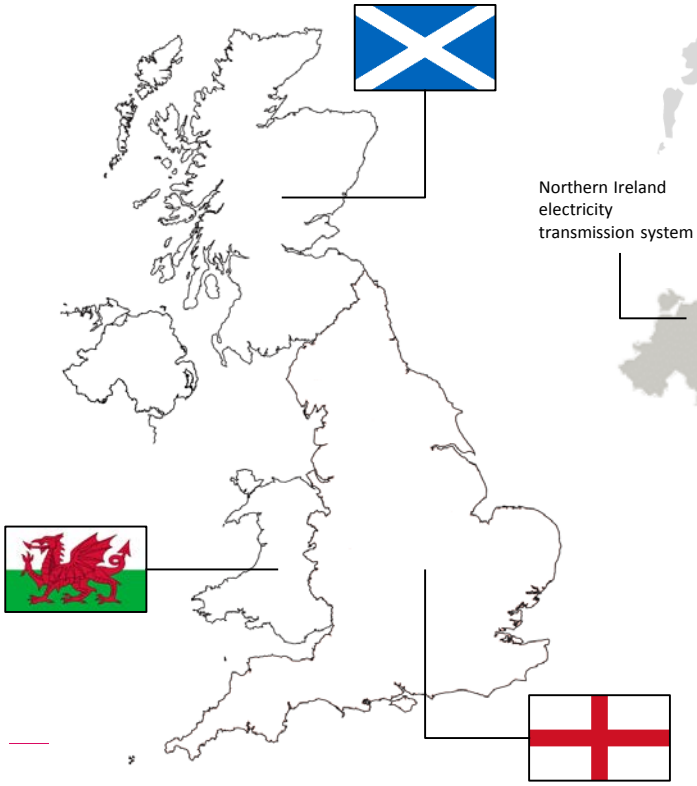




Geographical Detail in Transitions

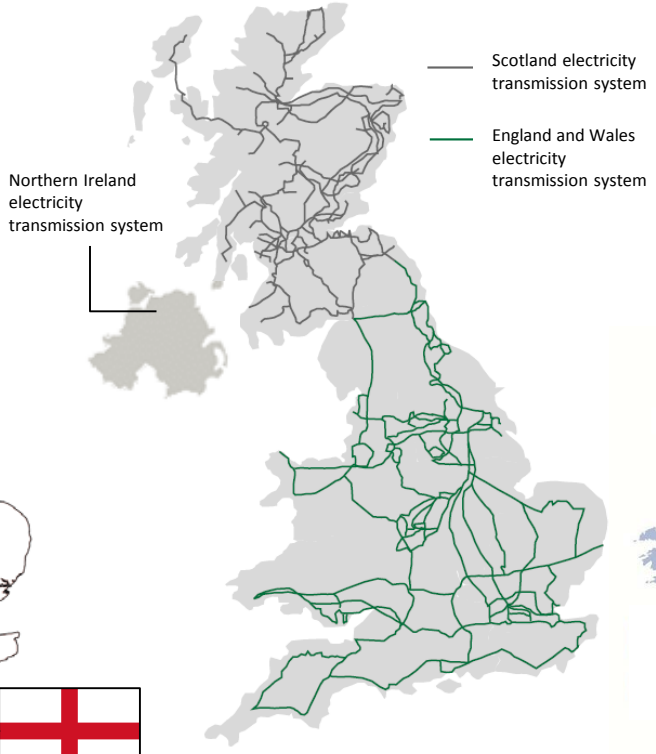
- UK is a "country of countries", with multiple governments with varying degrees of autonomy
- Liberalised electricity market with multiple transmission and distribution networks

UK Regions



Source: UK Office for National Statistics

UK Transmission Networks



Source: National Grid Plc

UK Distribution Networks

Source: Energy Networks Association (ENA)

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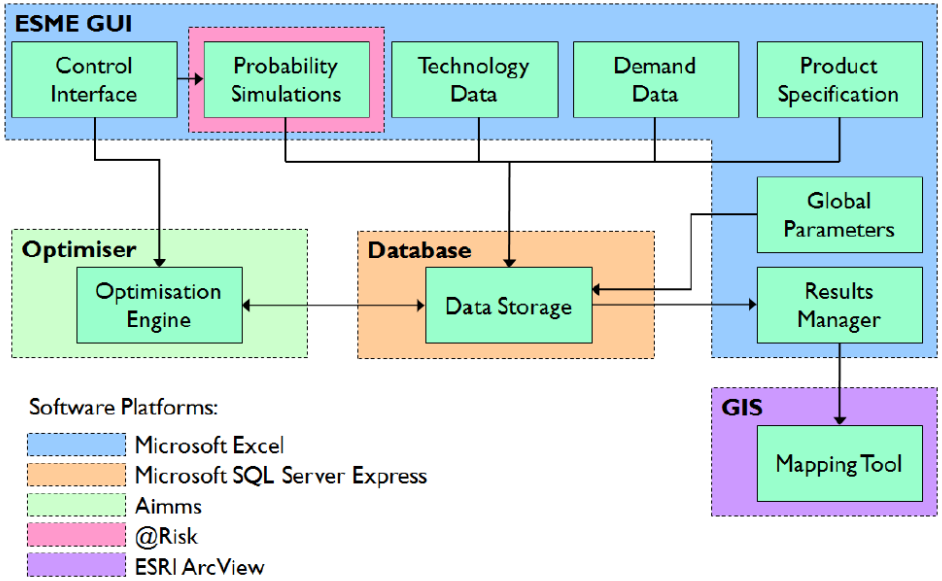
ESME (Energy Systems Modelling Environment) v3.4

- Pathway optimisation model, similar formulation to MARKAL/TIMES family i.e. partial-equilibrium, bottom-up model

- Notable distinguishing features:
  - Probabilistic inputs for exploring uncertainty
  - Multi-regional model with 24 spatial nodes

- Notable current/past users include:

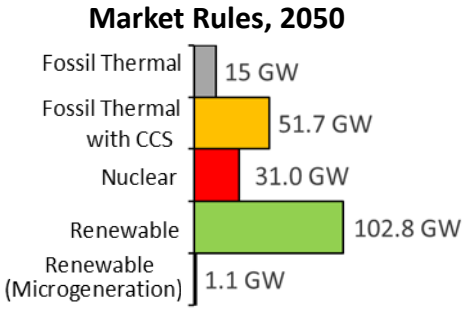


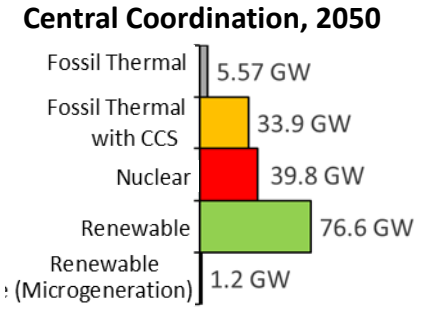
ESME
Energy System Modelling Environment

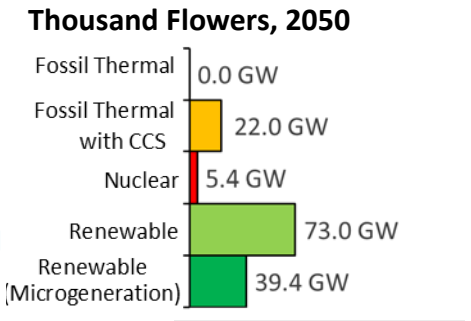
Image: Based on Heaton 2014, Modelling Low-Carbon Energy System Designs with the ETI ESME Model

Methodological Approach

- Generation capacity has been quantified to date using detailed engineering simulation models



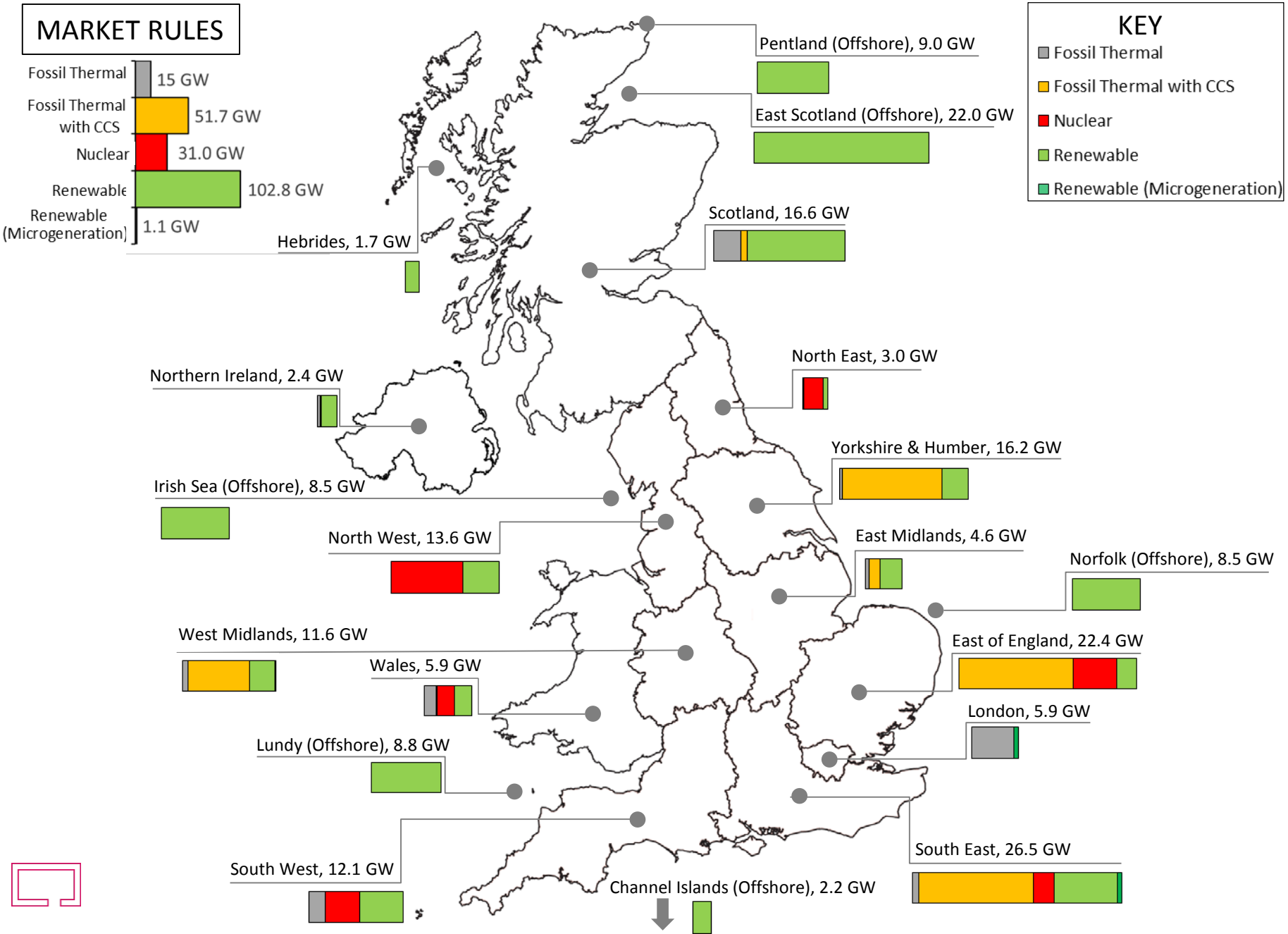




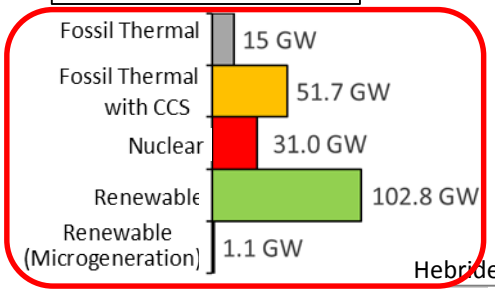
Methodological Approach

- Generation capacity portfolio for each narrative is included in ESME as constraints (minimum deployment, build rates, etc.) for 2030 and 2050

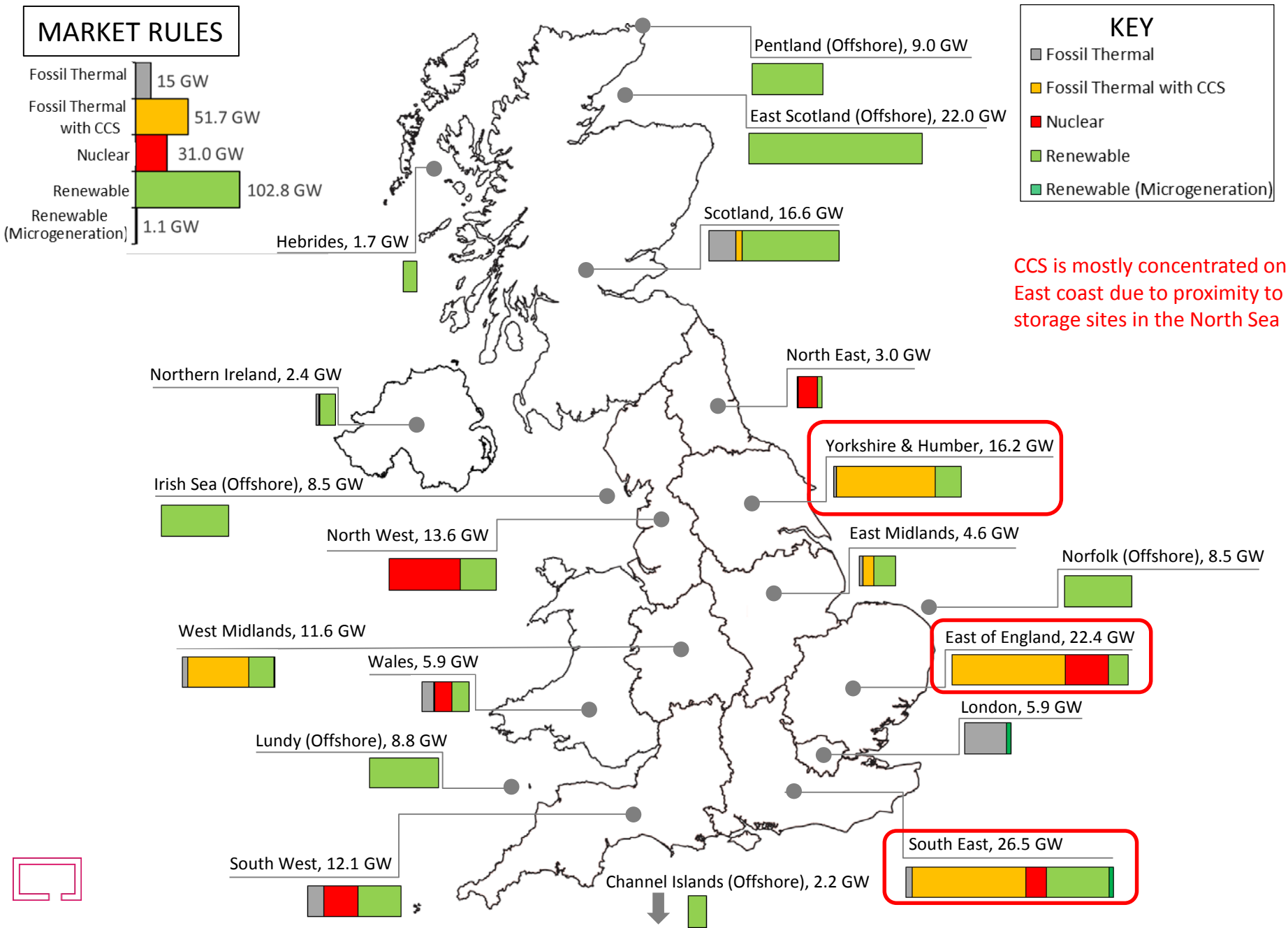
- Endogenous model outputs include:
    - Technology selection in buildings, transport, industrial sectors
    - Total system costs
    - Spatial disaggregation of national generation capacity portfolio, i.e. trade-off between:
        - Meeting demand locally with new generation capacity
        - Investing in transmission/distribution to connect to other resources


MARKET RULES
Fossil Thermal
15 GW
Fossil Thermal with CCS
51.7 GW
Nuclear
31.0 GW
Renewable
102.8 GW
Renewable (Microgeneration)
1.1 GW
KEY
Fossil Thermal
Fossil Thermal with CCS
Nuclear
Renewable
Renewable (Microgeneration)
Pentland (Offshore), 9.0 GW
East Scotland (Offshore), 22.0 GW
Scotland, 16.6 GW
Hebrides, 1.7 GW
Northern Ireland, 2.4 GW
North East, 3.0 GW
Yorkshire & Humber, 16.2 GW
Irish Sea (Offshore), 8.5 GW
North West, 13.6 GW
East Midlands, 4.6 GW
Norfolk (Offshore), 8.5 GW
West Midlands, 11.6 GW
Wales, 5.9 GW
East of England, 22.4 GW
London, 5.9 GW
Lundy (Offshore), 8.8 GW
South West, 12.1 GW
South East, 26.5 GW
Channel Islands (Offshore), 2.2 GW

MARKET RULES



Dominant technologies:
Offshore wind, marine power, fossil thermal with CCS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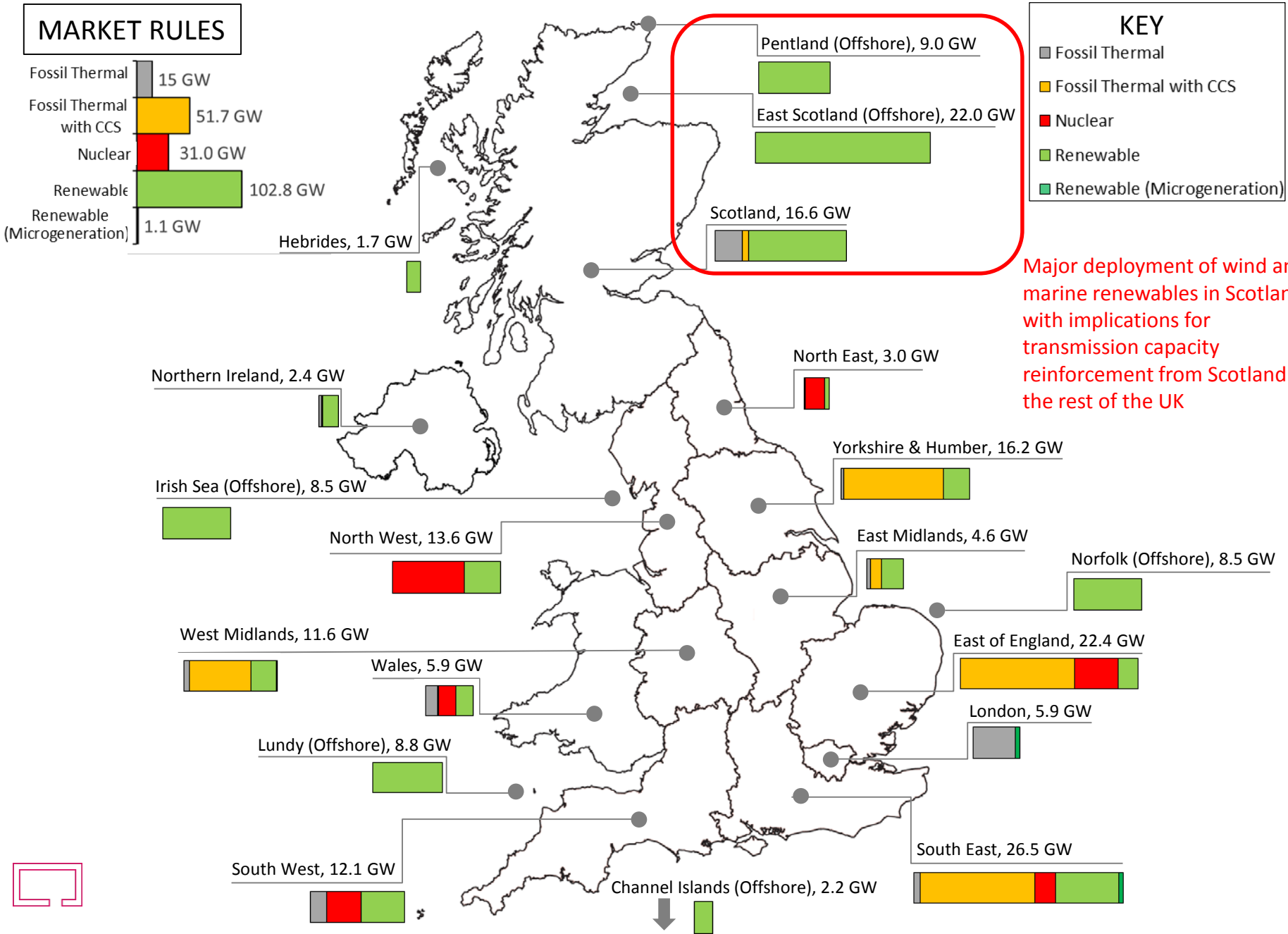
East of England, 22.4 GW
London, 5.9 GW
Lundy (Offshore), 8.8 GW
South West, 12.1 GW
South East, 26.5 GW
Channel Islands (Offshore), 2.2 GW
CCS is mostly concentrated on East coast due to proximity to storage sites in the North Sea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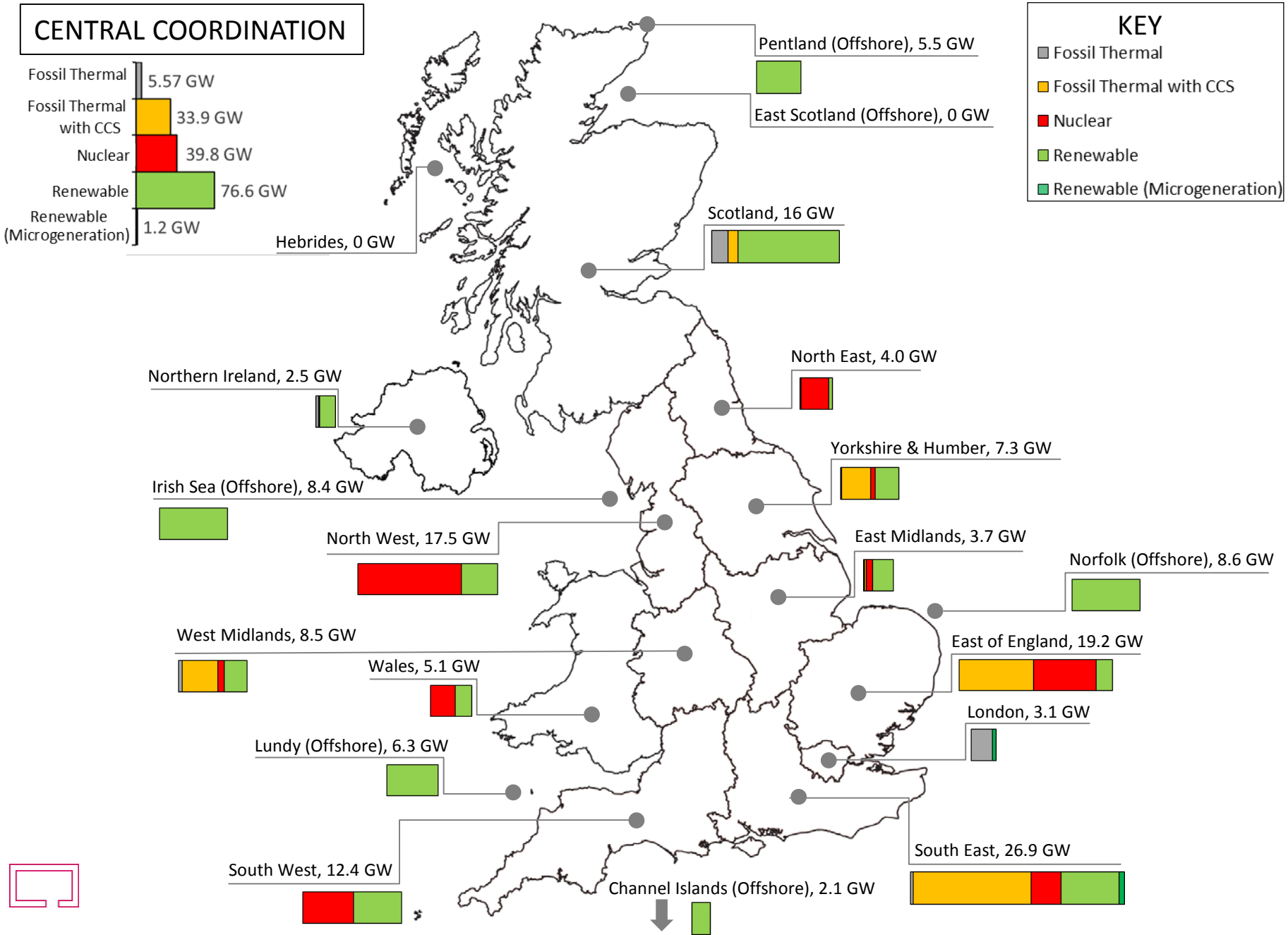
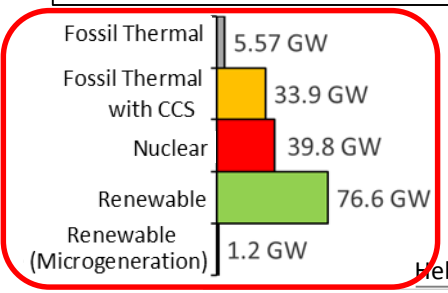
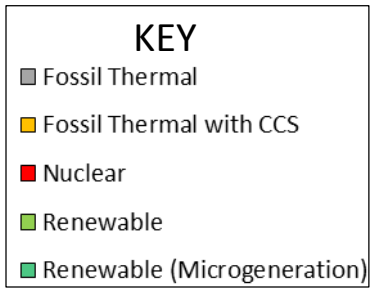
Pentland (Offshore), 9.0 GW
East Scotland (Offshore), 22.0 GW
Scotland, 16.6 GW
Hebrides, 1.7 GW
Major deployment of wind and marine renewables in Scotland, with implications for transmission capacity reinforcement from Scotland to the rest of the UK
Northern Ireland, 2.4 GW
North East, 3.0 GW
Yorkshire & Humber, 16.2 GW
Irish Sea (Offshore), 8.5 GW
North West, 13.6 GW
East Midlands, 4.6 GW
Norfolk (Offshore), 8.5 GW
West Midlands, 11.6 GW
East of England, 22.4 GW
Wales, 5.9 GW
London, 5.9 GW
Lundy (Offshore), 8.8 GW
South East, 26.5 GW
South West, 12.1 GW
Channel Islands (Offshore), 2.2 GW


CENTRAL COORDINATION
Fossil Thermal
5.57 GW
Fossil Thermal with CCS
33.9 GW
Nuclear
39.8 GW
Renewable
76.6 GW
Renewable (Microgeneration)
1.2 GW
KEY
Fossil Thermal
Fossil Thermal with CCS
Nuclear
Renewable
Renewable (Microgeneration)
Pentland (Offshore), 5.5 GW
East Scotland (Offshore), 0 GW
Hebrides, 0 GW
Scotland, 16 GW
Northern Ireland, 2.5 GW
North East, 4.0 GW
Yorkshire & Humber, 7.3 GW
Irish Sea (Offshore), 8.4 GW
North West, 17.5 GW
East Midlands, 3.7 GW
Norfolk (Offshore), 8.6 GW
West Midlands, 8.5 GW
East of England, 19.2 GW
Wales, 5.1 GW
London, 3.1 GW
Lundy (Offshore), 6.3 GW
South West, 12.4 GW
South East, 26.9 GW
Channel Islands (Offshore), 2.1 GW

CENTRAL COORDINATION



Dominant technologies:
Nuclear power, fossil CCS, wind power



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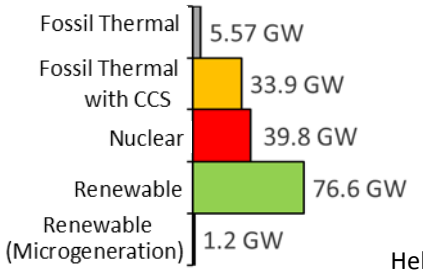
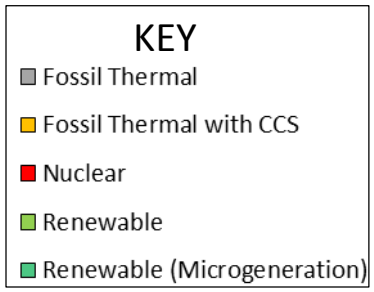
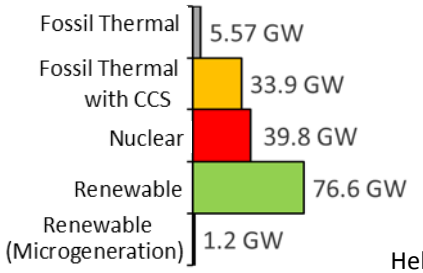
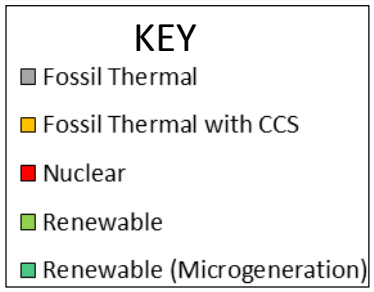




Nuclear power expands capacity in regions with existing sites, except Scotland, where existing assets are not renewed (reflecting Scottish Government moratorium)

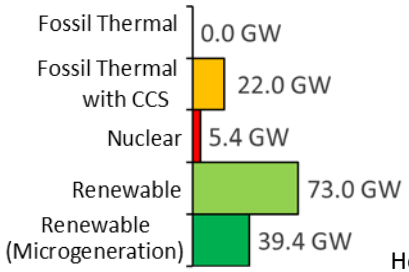
CENTRAL COORDINATION

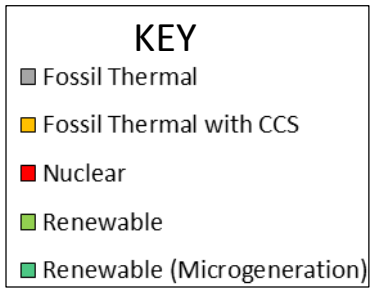




Gas/coal CCS deployed in similar locations to Market Rules narrative, but capacity levels are lower, also less emphasis on offshore wind and marine power

THOUSAND FLOWERS





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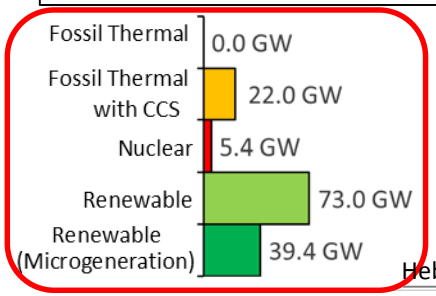

Dominant technologies:
Solar PV, bioenergy CHP, some large scale renewables

KEY
- Fossil Thermal
- Fossil Thermal with CCS
- Nuclear
- Renewable
- Renewable (Microgeneration)

Pentland (Offshore), 8.7 GW
East Scotland (Offshore), 0 GW
Scotland, 12.7 GW
Hebrides, 1.0 GW
North East, 2.0 GW
Northern Ireland, 2.7 GW
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North West, 5.1 GW
East Midlands, 10.2 GW
Norfolk (Offshore), 6.2 GW
West Midlands, 10.2 GW
East of England, 10.6 GW
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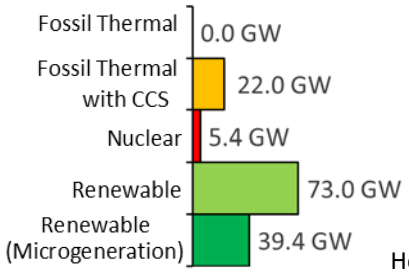
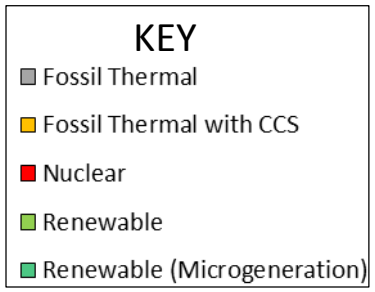
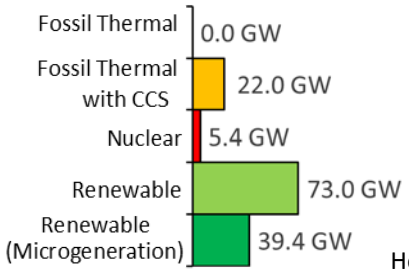
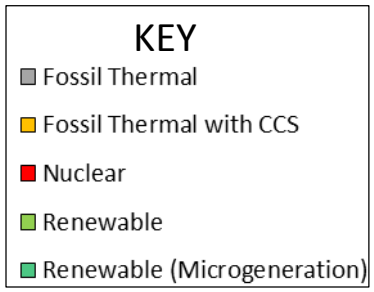




Notable concentrations of microgeneration found in the South and East of England

THOUSAND FLOWERS

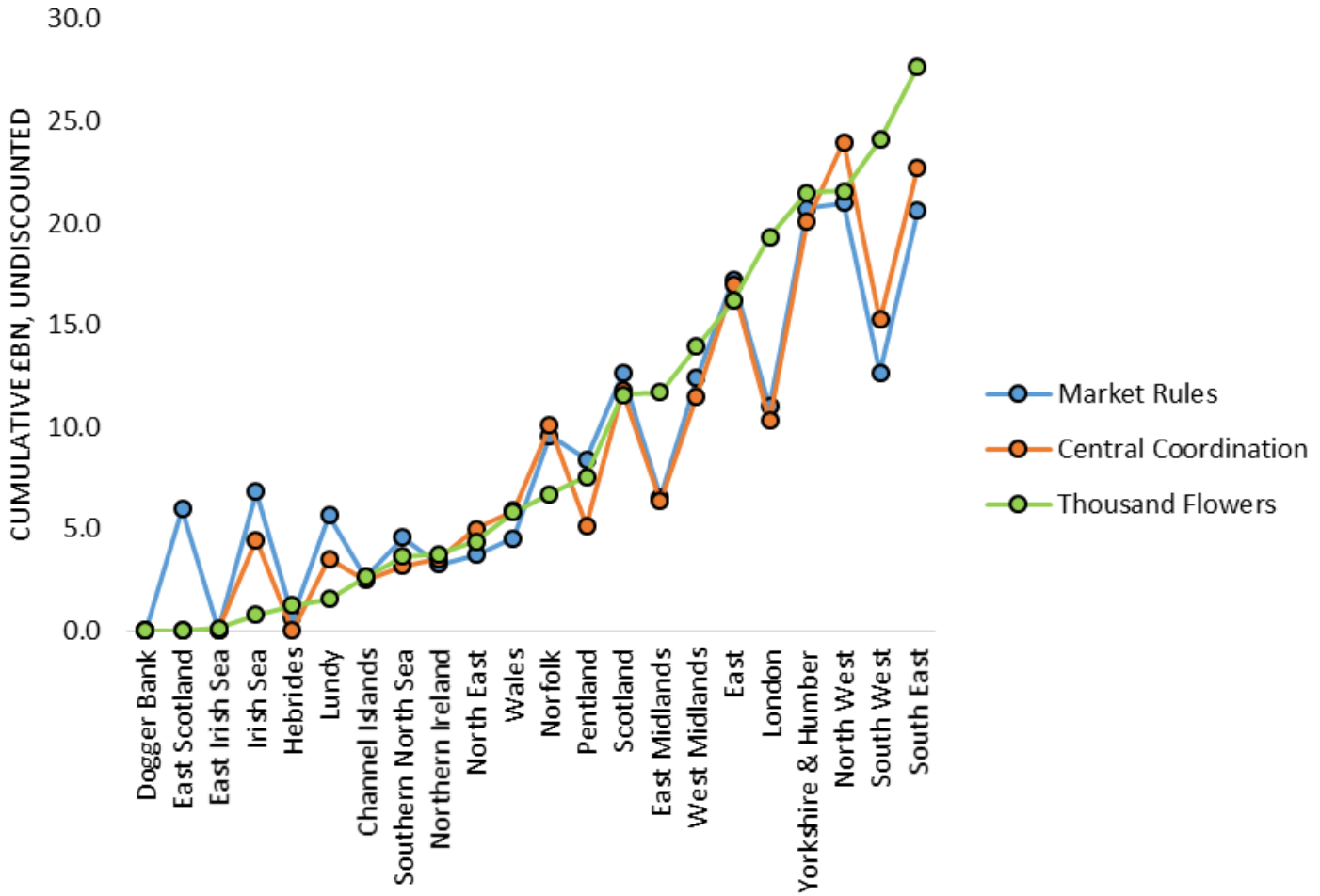




CCS plant distributed in nearly all regions for balancing intermittency – implies possible requirement for national capture network?

Spatial Insights

- Spatial distribution of electricity system investments varies significantly between pathways



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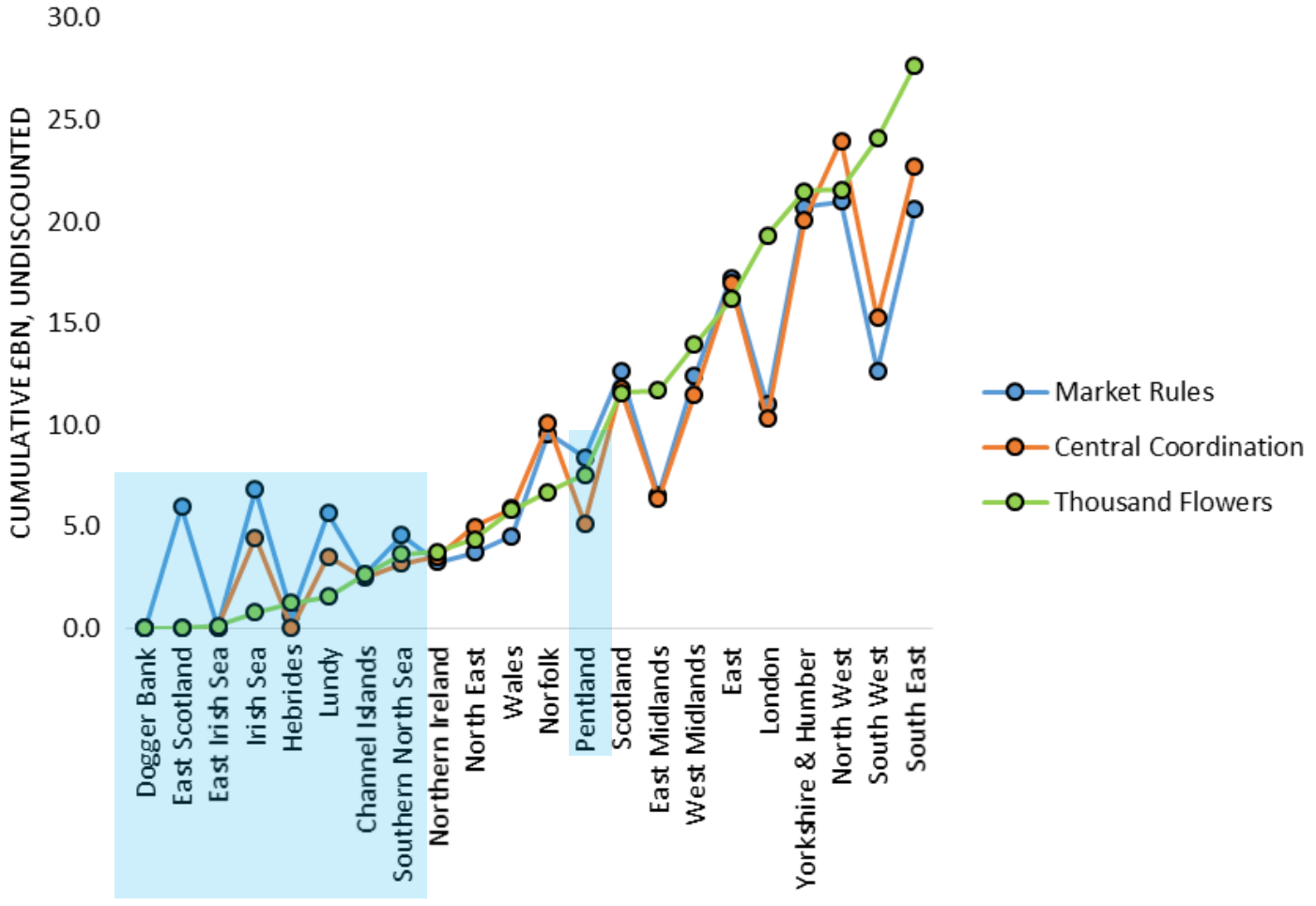

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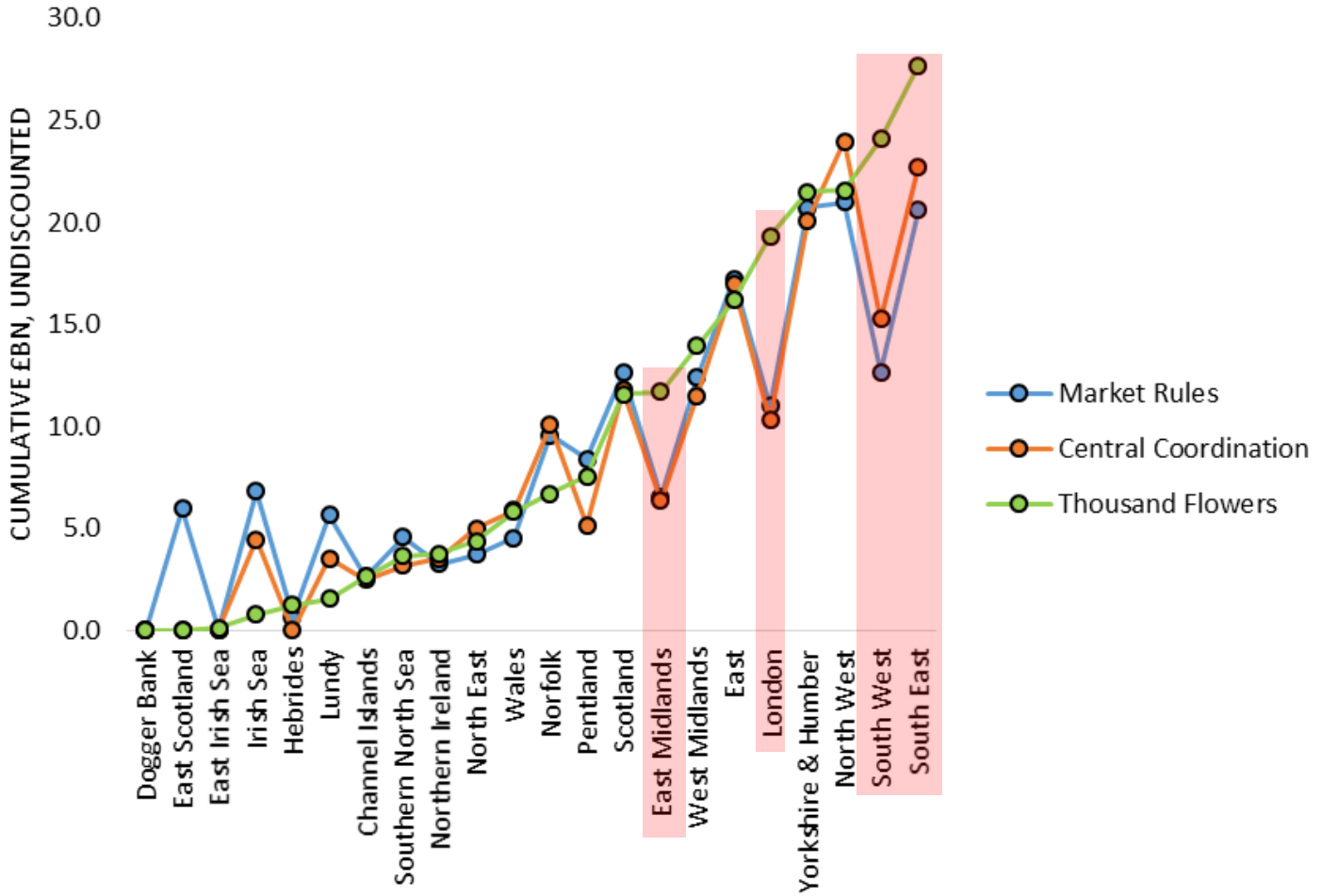
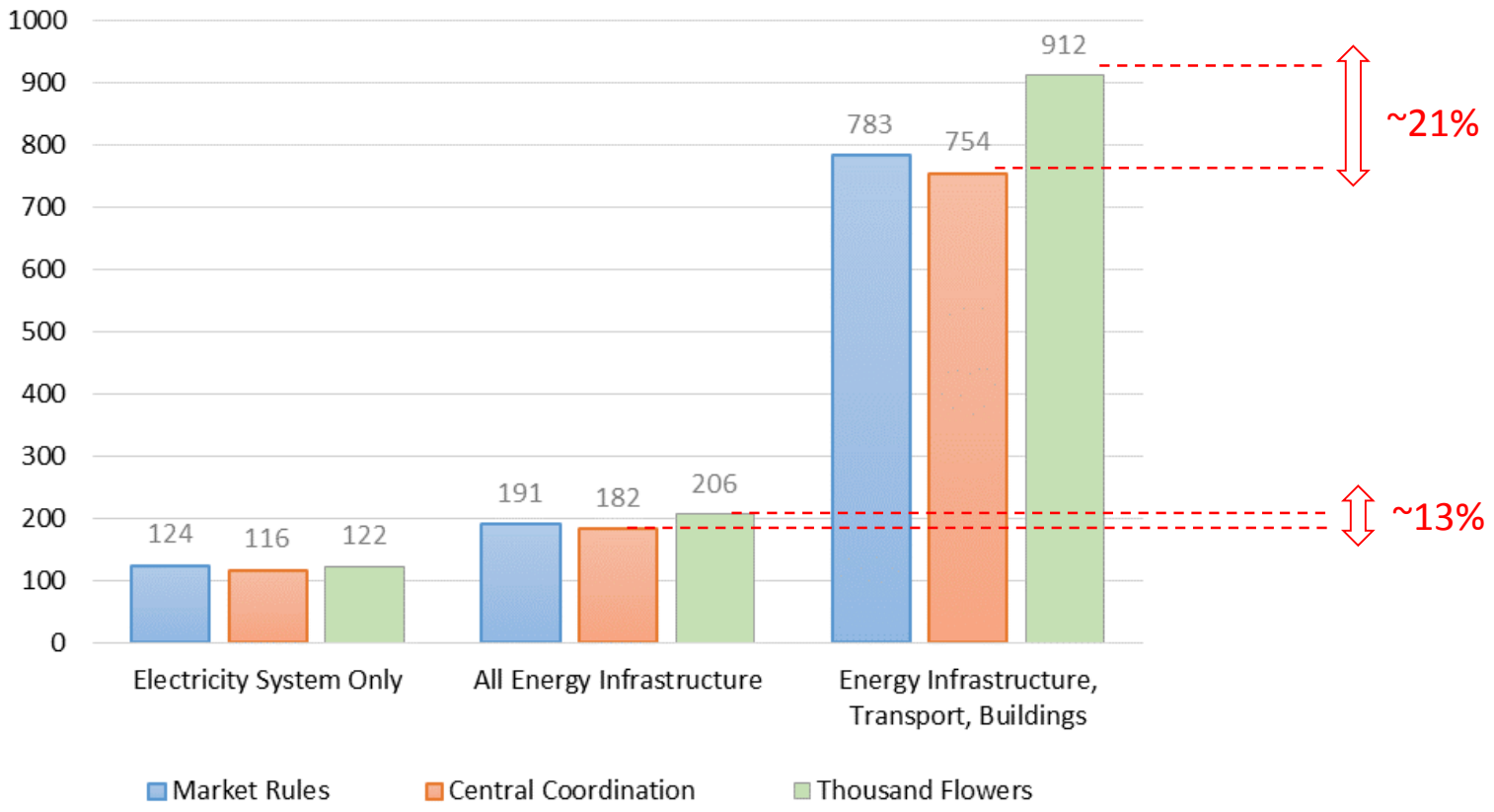


System Boundaries vs. Investment Costs

- Cumulative investment to 2050 (£bn) in national aggregate terms
- Nuclear dominated pathway has lowest costs, distributed energy pathway has highest costs
- However, relationship to actors important – balance of costs/benefits differs



Overview

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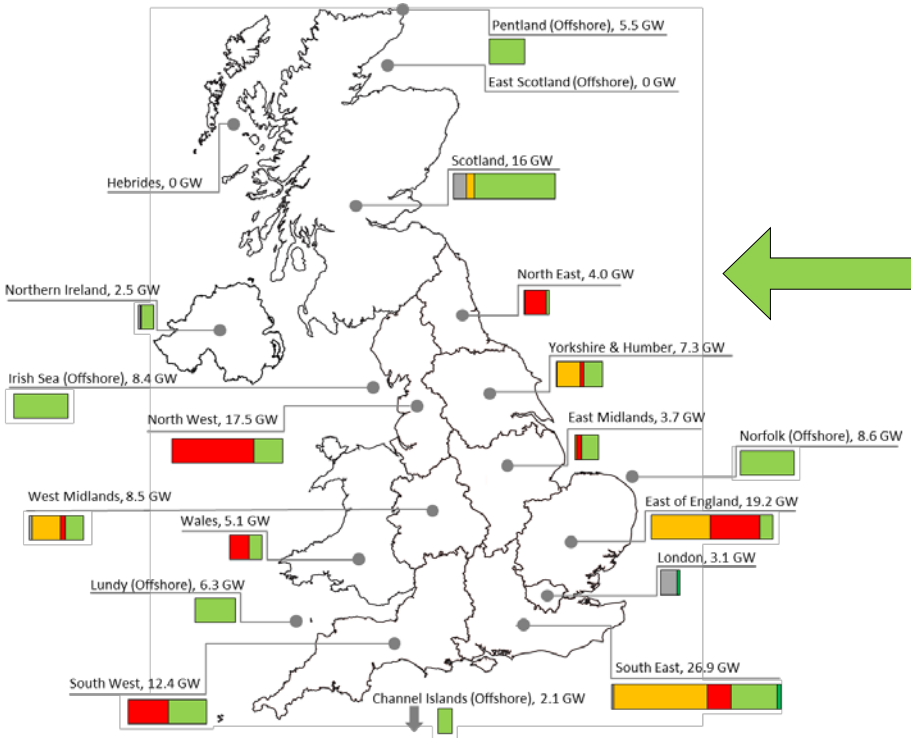
Insights for Policy and Modelling

- Spatial distribution of investments does vary significantly between future energy pathways, with implications for regional actors in the UK's liberalised energy market

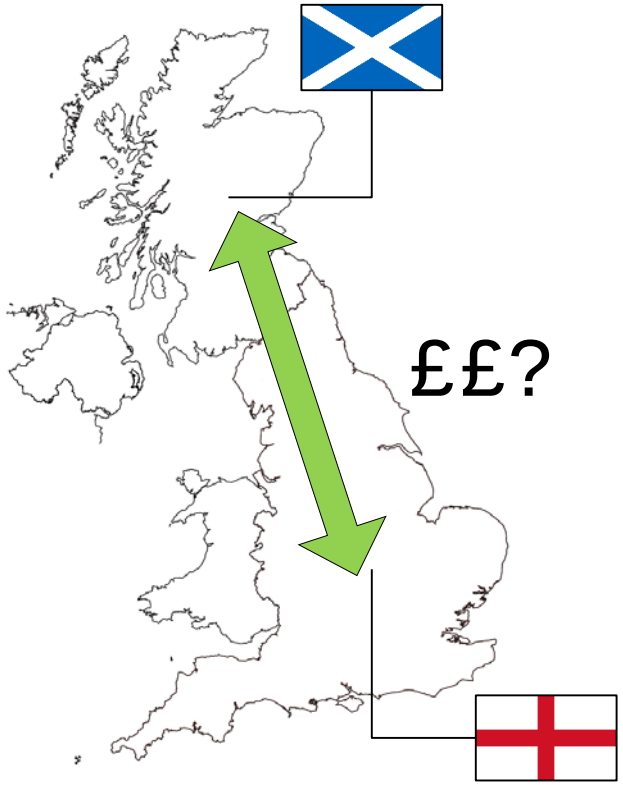


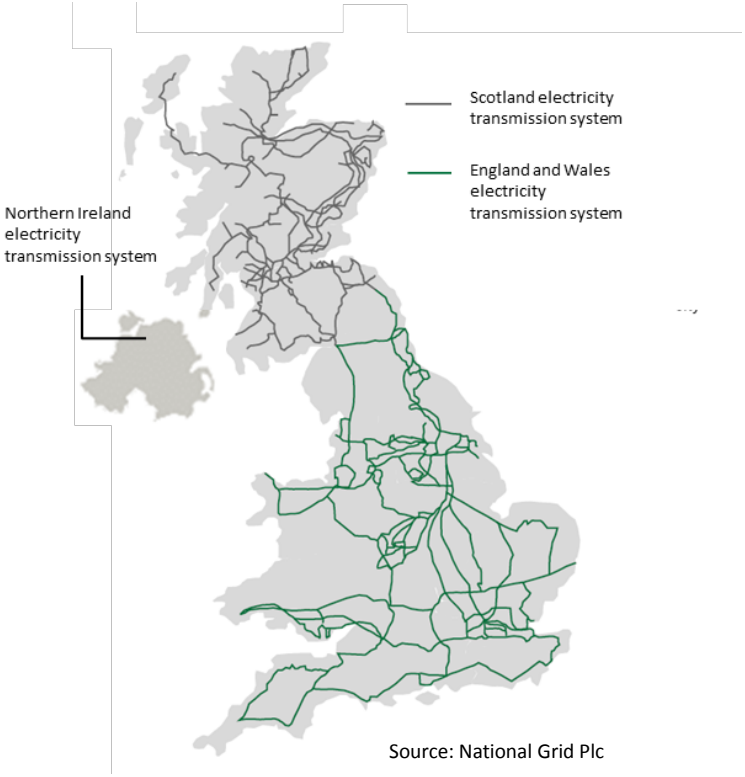
Source: Energy Networks Association (ENA)

Insights for Policy and Modelling

- Future role of offshore Scottish renewable energy has major implications for investment in transmission infrastructure to supply England (x2 under high offshore/marine energy pathway)

- Implies coordination between governments and key transmission system operators





Source: National Grid Plc

Insights for Policy and Modelling

- Spatially explicit modelling introduces significant additional complexity:
    - Additional set-up time needed for model constraints (spatially indexed)
    - Additional requirements for visualisation and interpretation
- "Who pays and who benefits" is potentially more interesting than total costs in different scenarios, particularly when assets are not owned/operated under a vertically integrated monopoly structure
- Future work will focus on actor dynamics and the constraints on capital availability for financing energy transitions

Insights for Policy and Modelling

- Useful Links:
  - Realising Transition Pathways: http://www.realisingtransitionpathways.org.uk/
  - UCL Energy Models: https://www.ucl.ac.uk/energy-models/models

Questions?