Transition Pathways to a More Electric, Low Carbon Economy

Geoff Hammond

Professor and Director of *I•SEE*

University of Bath

[Email: G.P.Hammond@bath.ac.uk]

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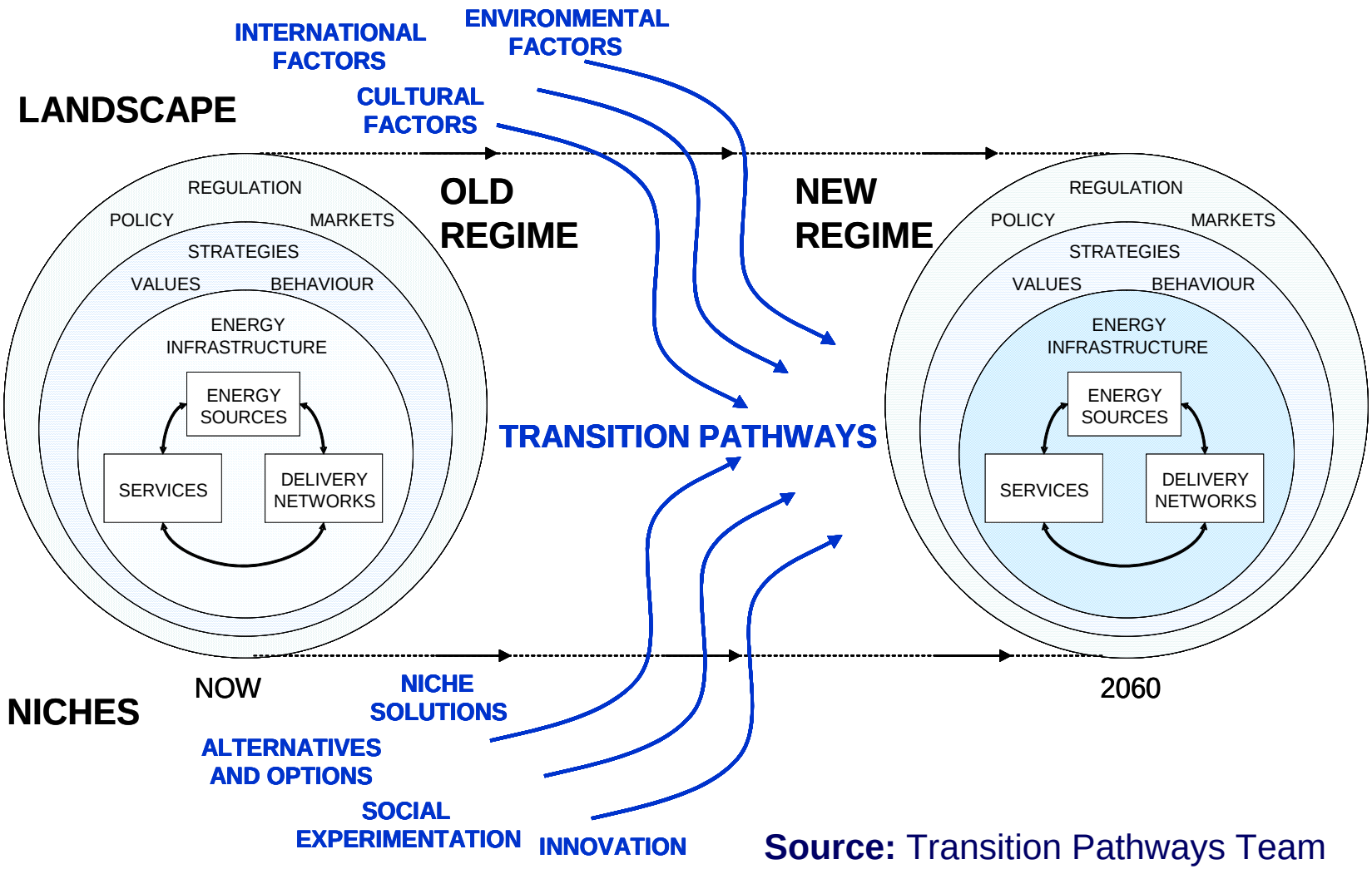
THE TRANSITION PATHWAYS PROJECT

- **E.On UK & *Research Council Energy Programme* (RCEP)-funded Consortium (May 2008 – April 2012)**
- **Multi-disciplinary Team – 9 Universities:**
  - Bath, Cardiff, East Anglia, Imperial College London, UCL, Leeds, Loughborough, Strathclyde, Surrey
  - Roughly 50% engineers and 50% economic & policy analysts
- **Mission –**
  - To undertake socially & scientifically engaged research into innovative technologies, policies & practices towards a low carbon energy system
  - To focus on the future of the electricity sector

MULTI-LEVEL PERSPECTIVE ON TRANSITION PATHWAYS



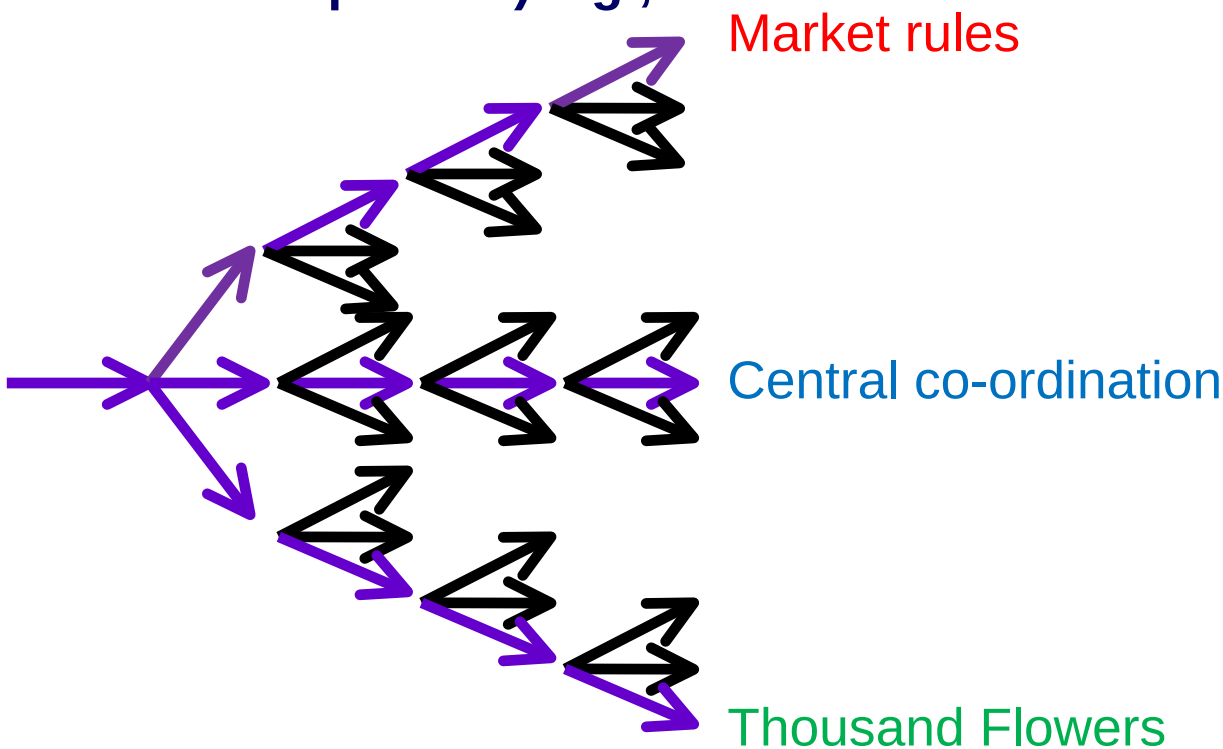
Source: Transition Pathways Team

CORE TRANSITION PATHWAYS

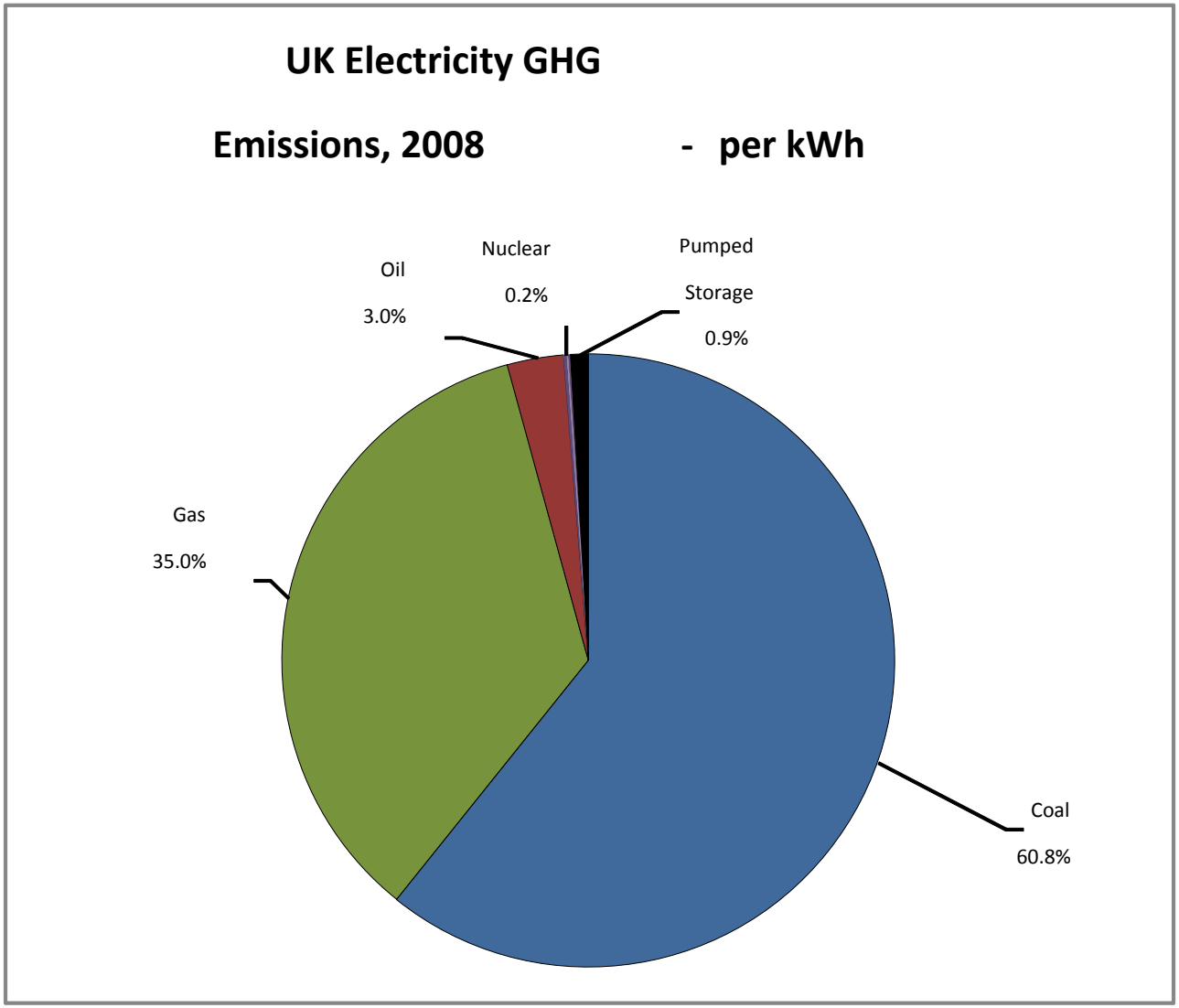
- ***Market Rules (MR)***
  - Energy companies focus on large-scale technologies: nuclear power, offshore wind & capture-ready coal
  - Minimal interference in market arrangements
- ***Central Co-ordination (CC)***
  - Greater direct government involvement in governance of energy systems, e.g., issuing tenders for tranches of low-carbon generation
  - Focus on centralized generation technologies
- ***Thousand Flowers (TF)***
  - More local, bottom-up diversity of solutions
  - Local leadership in decentralized options

EXPLORE, INTERROGATE & REVISE PATHWAYS

- **Quantitative, whole systems appraisal – energy, environmental & economic performance of the pathways**
- **Qualitative, branching point analysis (to test pathway sensitivity, resilience & responses) e.g.,**



CO_{2e} BASELINE – 2008



UPSTREAM EMISSIONS

- **Upstream from delivered fuel**
  - Extraction, refining, transport, …. etc.
- **Two main GHG burdens**
  1. Additional energy consumption to 'fuel' upstream activities
  2. Methane Leakage
     - Coal mining activities – quite significant contribution
     - Gas pipelines

Fuel	DEFRA GHG Combustion - per kWh	GHG Upstream – per kWh	Resulting Increase
Coal	0.33 kg CO_2e	0.06 kg CO_2e	+18%

TECHNOLOGY COMPARISON (per kWh)

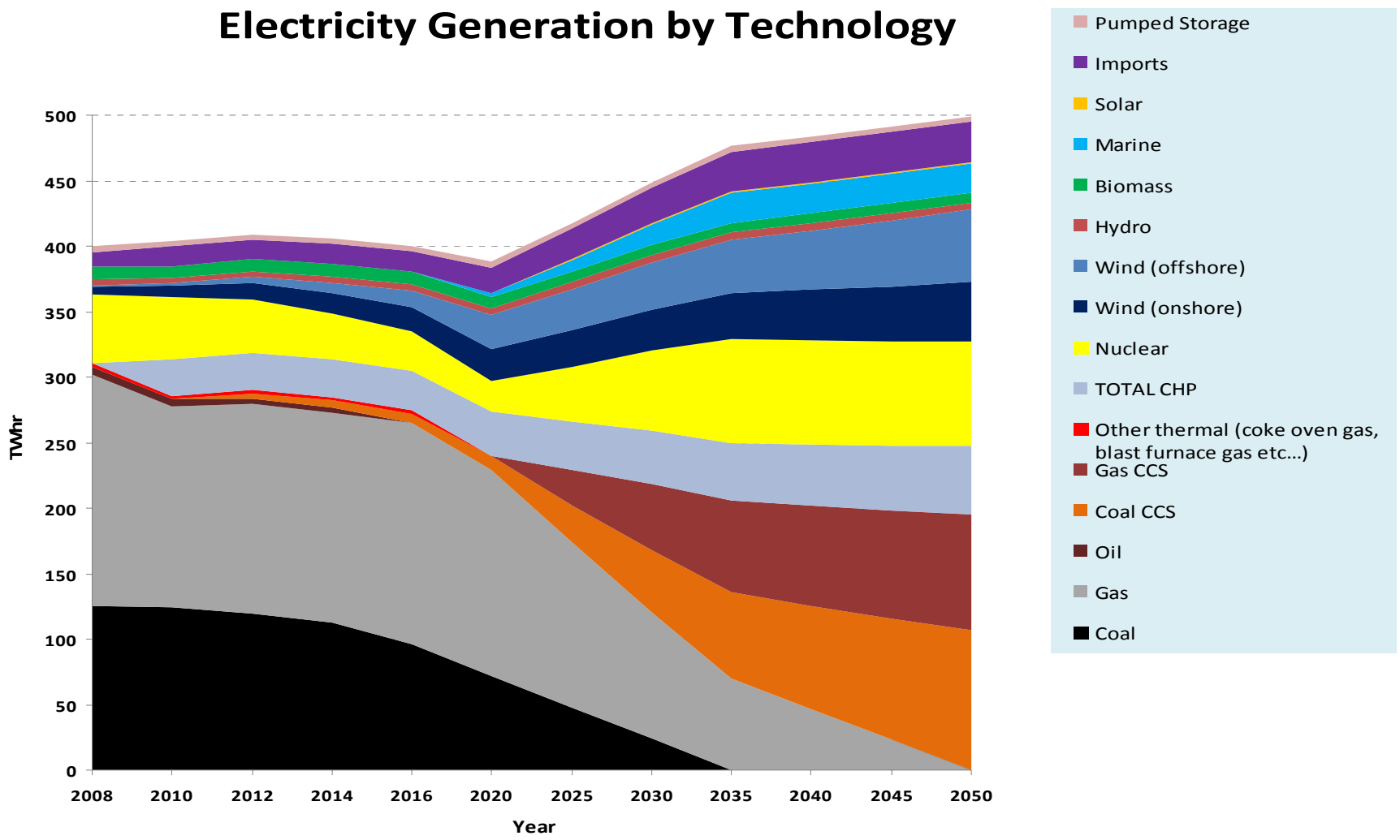
- Ranked by GHG emission order …
- Interesting to compare 'Gas' with 'Coal CCS'
  - Coal CCS only 1/3 lower GHG > would expect a much larger reduction??.....(high upstream emissions from coal mining aren't captured)
  - Coal CCS has a much higher NRE and single score LCA than 'Gas'
  - Is coal CCS an attractive environmental proposition??
    - But it's cheap fuel, available, flexible generation, …. etc.

Technology (mix)	GHG ($kg\ CO_{2e}$)	NRE (MJ)	Single Score LCA (!)
Coal	1.09	12.9	119
Grid Average, 1990	0.90	13.5	100
Grid Average, 2008	0.62	10.4	69
Gas	0.47	7.9	54
Coal CCS	0.31	15.5	85
Gas CCS	0.08	9.1	35
Nuclear	0.02	14.4	5 (!)

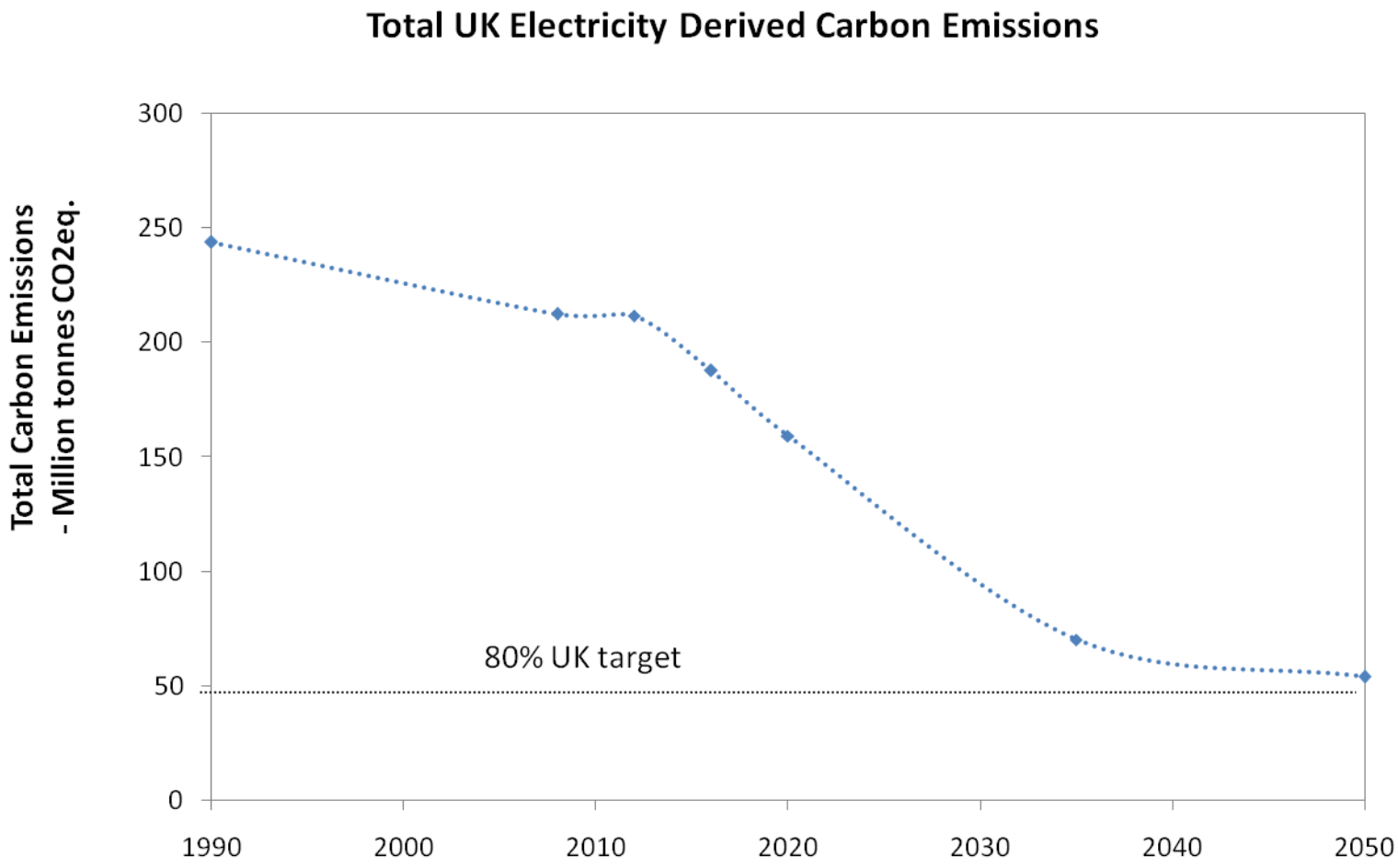
‘MARKET RULES’ PATHWAY OVERVIEW

Pathway aspect	Characteristics
Key technologies	**Coal and gas with carbon capture and storage (CCS); nuclear power; offshore wind**; onshore wind; imports; tidal barrage; wave and tidal power
Key concepts	Successful demonstration of CCS leads to high levels of deployment from 2020 onwards; **high carbon price makes CCS, nuclear and large-scale renewables economical to build**, and enables roll-out of retrofit of CCS to remaining coal and gas power stations; increasing electricity demand from heating and transport somewhat offset by technical efficiency improvements
Key actors	**Regime actors (large energy companies) dominate**; few new entrants
Key multi-level patterns	Landscape pressures (climate change and energy security) on regime actors leads to focus on carbon reduction and retrenchment around large-scale technologies; small-scale renewable technologies fail to emerge from niches
Key learning processes	Learning to achieve commercial deployment of CCS; **large energy companies see ‘high-electric’ future as a strategic business opportunity**, with increasing demand for electric heating and electric vehicles in a carbon-constrained world
Key infrastructure aspects	80% of generation still connected at high-voltage transmission level by 2050, with coal and gas CCS and new nuclear following siting of existing plants, and offshore wind concentrated around Scotland, implying need for high levels of transmission reinforcement

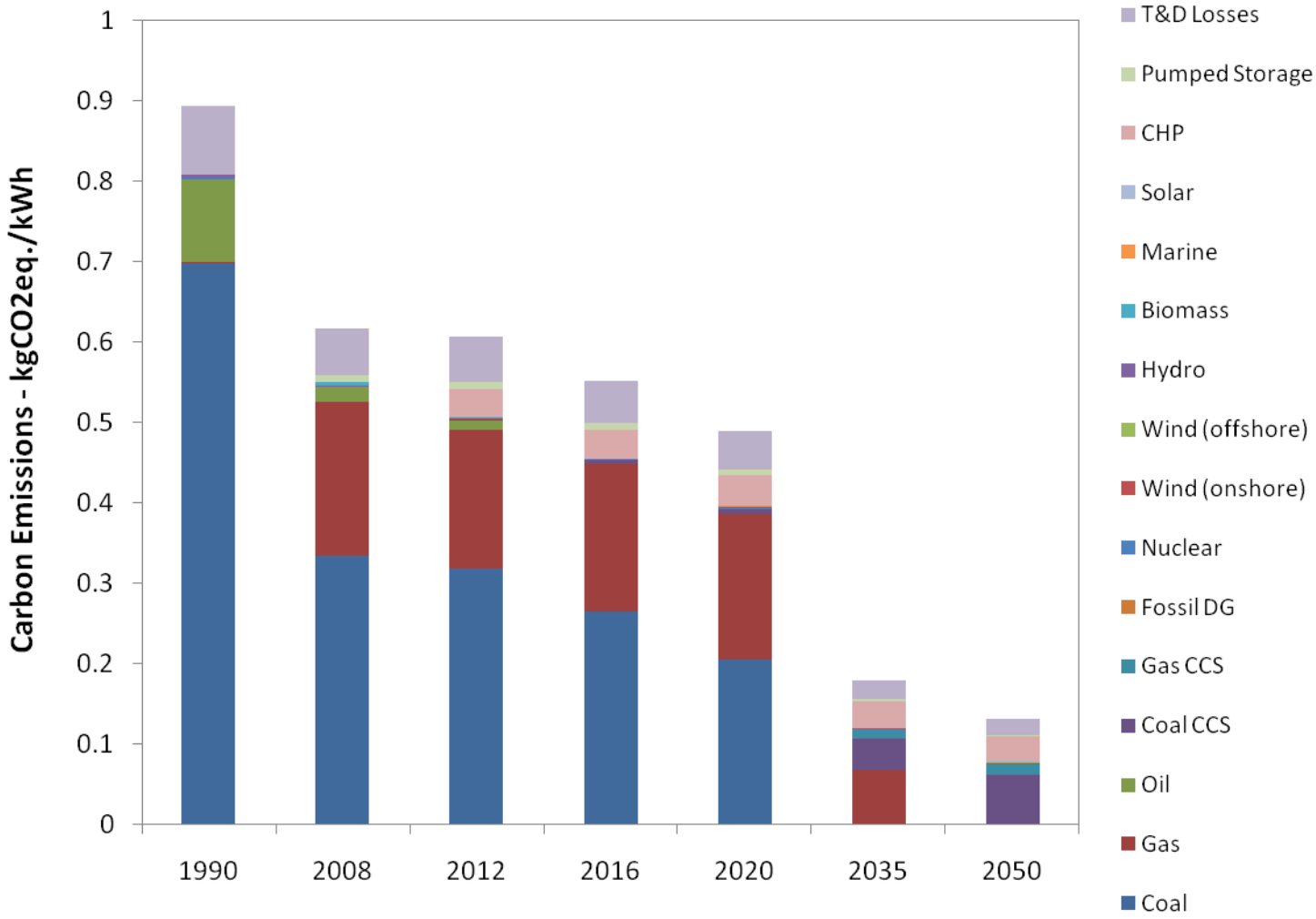
‘MARKET RULES’ – ELECTRICITY GENERATION MIX



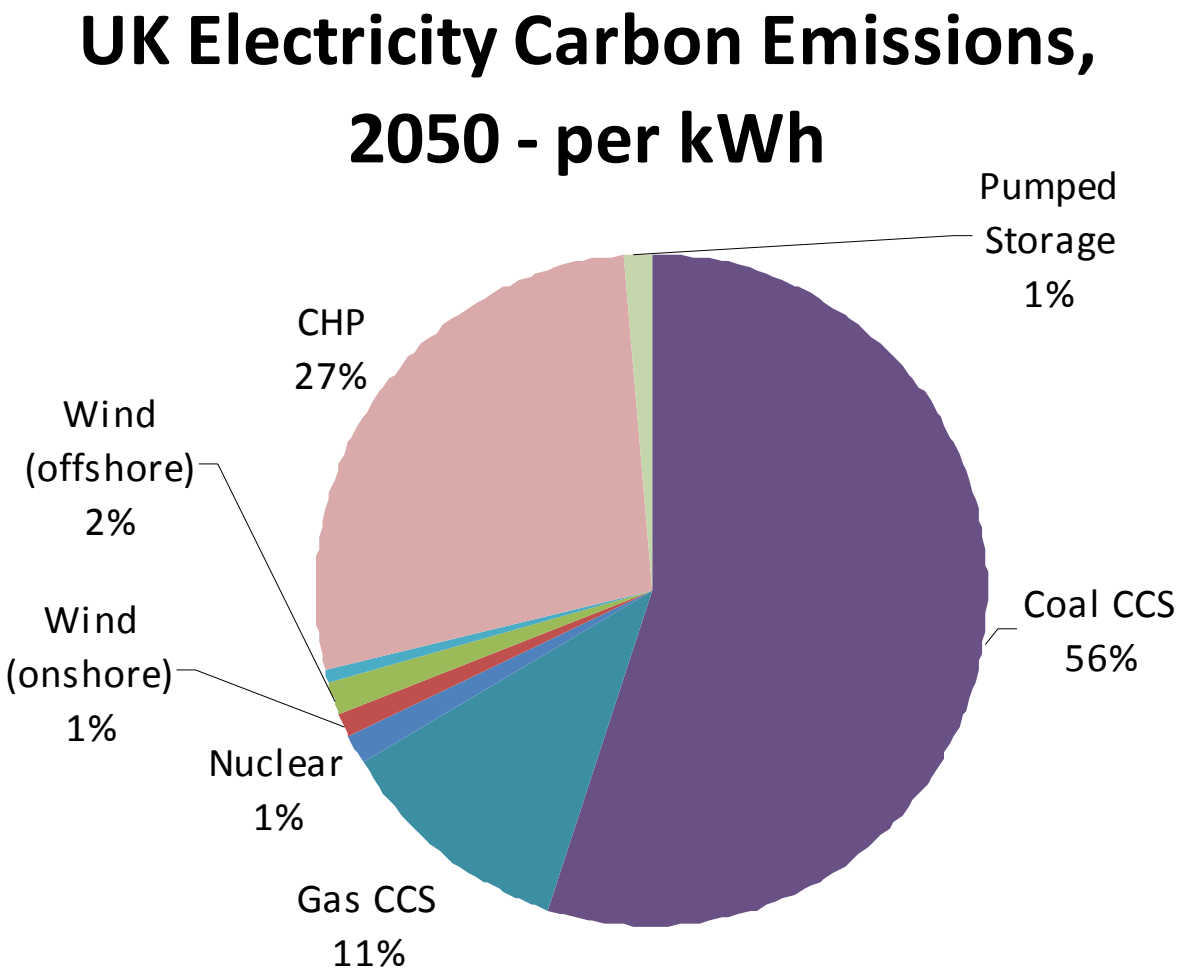
‘MARKET RULES’ (v1.1) PATHWAY - I



‘MARKET RULES’ (v1.1) PATHWAY - II



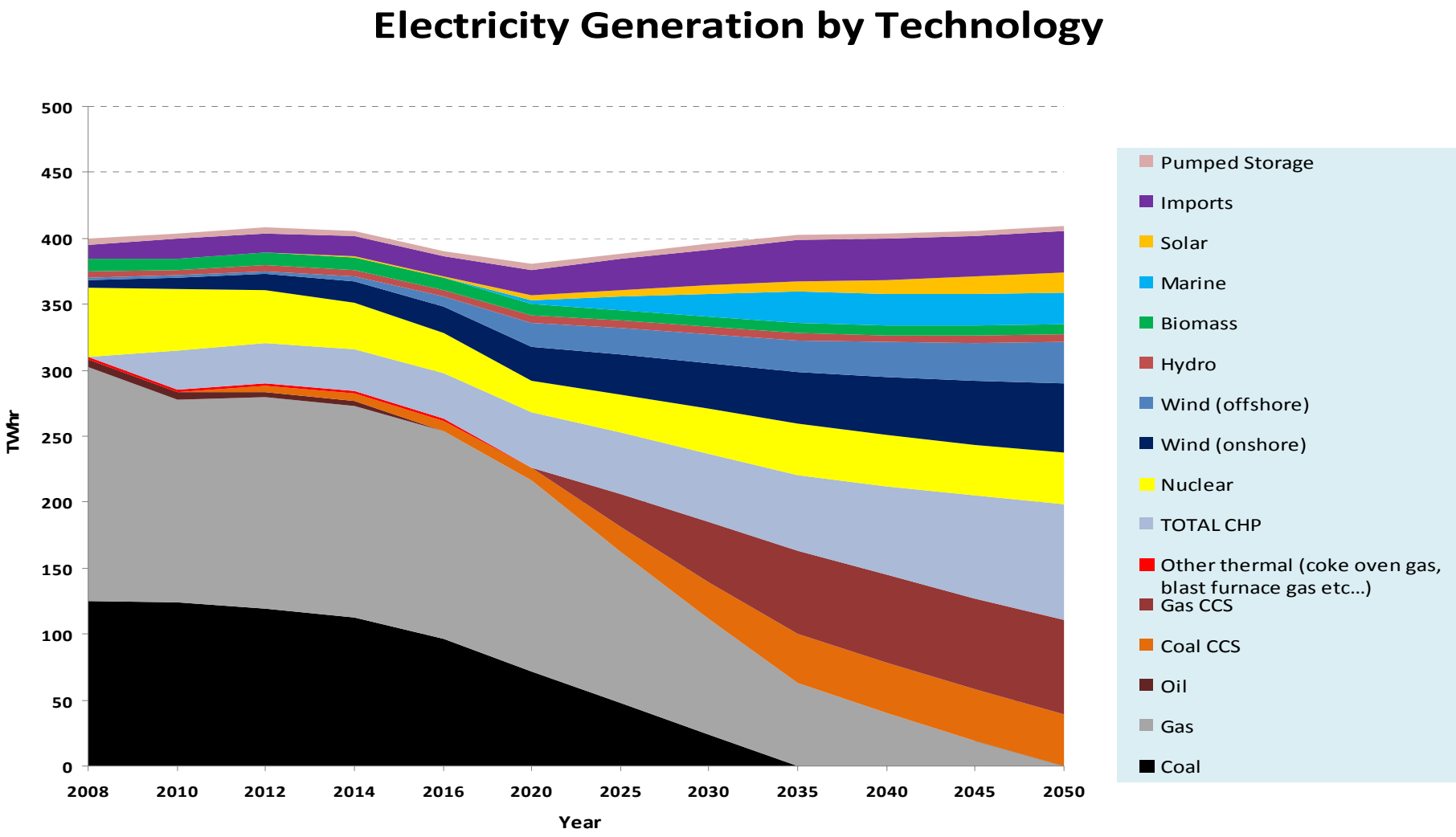
‘MARKET RULES’ (v1.1) PATHWAY - III



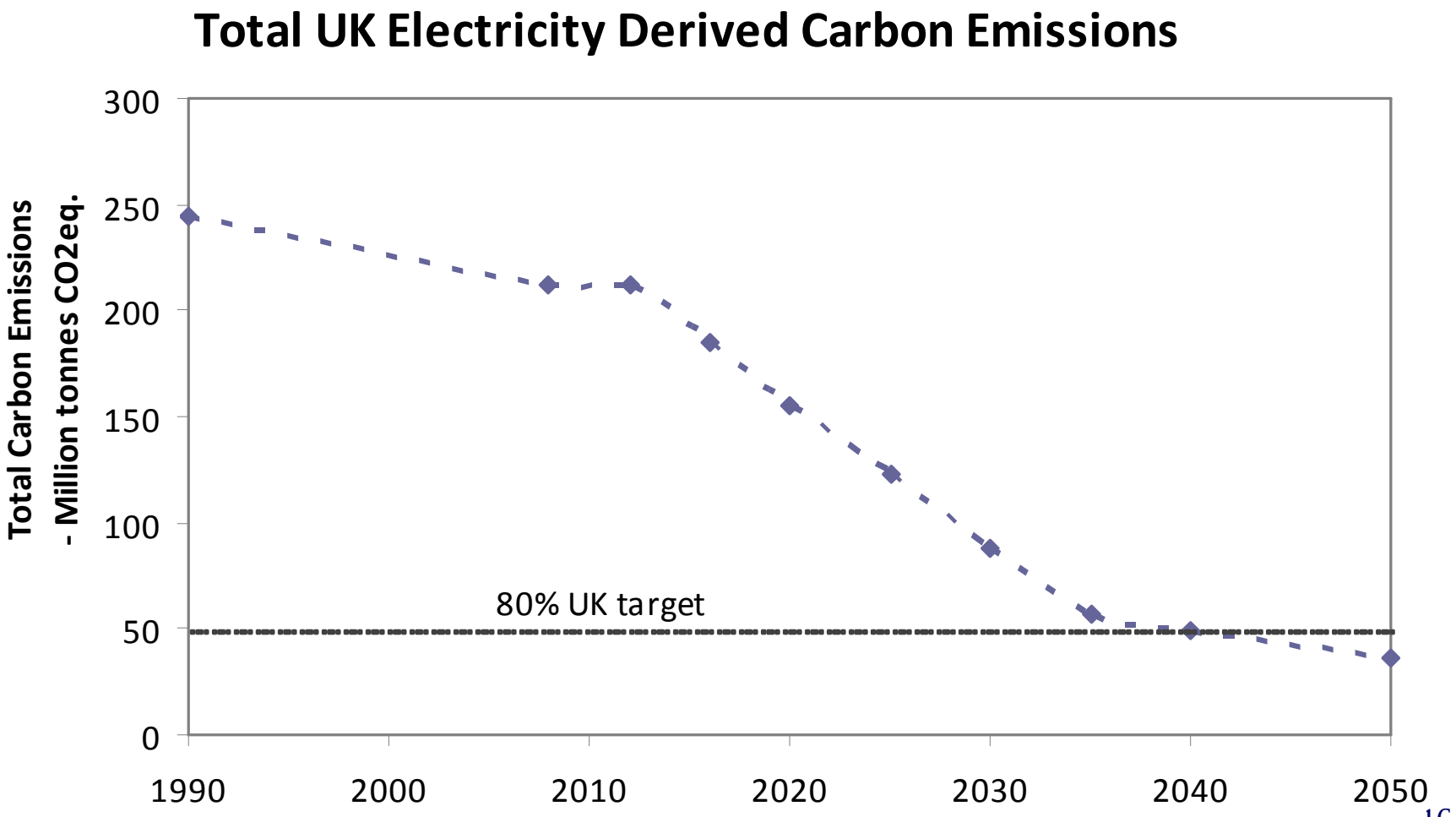
‘THOUSAND FLOWERS’ PATHWAY OVERVIEW

Pathway aspect	**Characteristics**
Key technologies	**Onshore wind; offshore wind; renewable CHP; solar PV**; imports; tidal barrage; wave and tidal power
Key concepts	**Move to ESCO business model**; **technological and behavioural changes lead to significant end-user demand reductions**; positive feedbacks lead to ‘virtuous cycles’ in deployment of small-scale distributed generation technologies; greater community ownership of generation, including onshore wind and biomass CHP.
Key actors	ESCOs (both new entrants and diversified existing energy companies); local communities; NGOs
Key multi-level patterns	Landscape pressures (climate change and energy security) on regime actors and government support for small-scale and community-level initiatives leads to focus on demand reduction and small-scale technologies; small-scale renewable technologies emerge from niches
Key learning processes	**Learning to achieve commercial deployment of range of distributed generation technologies**, with the emergence of a small number of ‘dominant designs’; large energy companies diversify into ESCO business model; focus on community-led renewable district heating schemes reduces the expected demand for electric heating, but rise in demand from electric vehicles
Key infrastructure aspects	50% distributed generation requires development of ‘smart grid’ technologies to handle two-way power flows; 50% still connected at high-voltage transmission level by 2050, dominated by high efficiency gas generation and offshore wind concentrated around Scotland and in the North Sea, implying need for significant levels of transmission reinforcement

‘THOUSAND FLOWERS’ – ELECTRICITY GENERATION MIX



‘THOUSAND FLOWERS’ (v1.1) PATHWAY - I



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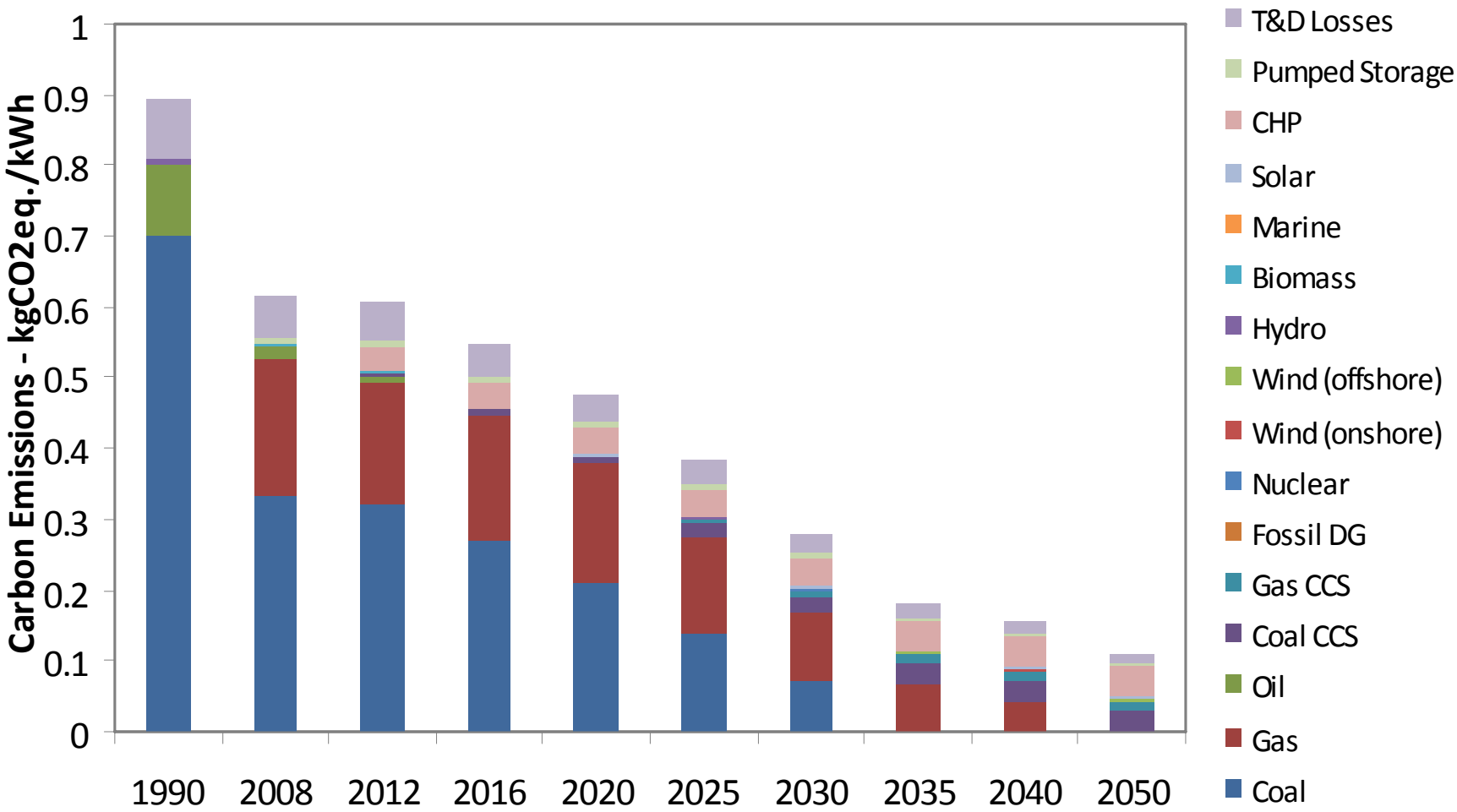

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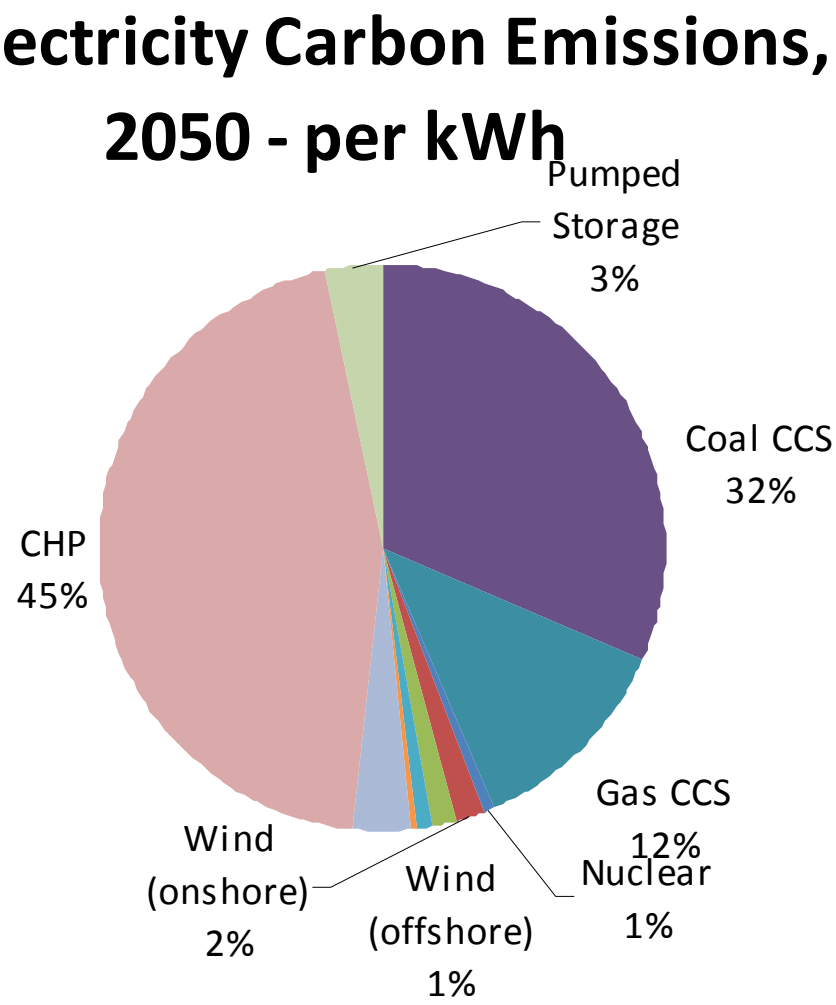

OVERALL SUMMARY OF THE v1.1 PATHWAYS

- MR is the highest carbon impact pathway
- CC and TT achieve similar carbon emissions reductions by 2050, but get there in different ways
- The impact of 'upstream emissions' on the carbon performance of both technologies (such as CHP and CCS) and the pathways distinguish the present findings from those of other analysts, e.g., the CCC and DECC
- Particulate Matter Formation (PMF) and Human Toxicity (heavy metal emissions) may need attention; although pathways are only required to deliver carbon reductions
  - Especially with CCS technologies
  - Coal, even with CCS, exhibits significant emissions

VALUE OF 'TRANSITION PATHWAYS' ANALYSIS

- **Specification & analysis of transition pathways & branching points could inform actions needed & consensus building for a shared vision**
- **Analysis shows implications of uncertainties, including**
  - Future progress in different energy technologies
  - Role of ICTs to help facilitate change through a 'smart grid'
  - Role of changes in actors' habits, practices & wider social values
  - And how they might interact with techological change
- **Shows pathways with different/shifting roles for large & small government, market & civil society actors**
  - & how they might lead to alternative visions & realities of a low-carbon society
- **Throws light on opportunities & challenges of a 'more electric' future**

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Thank You For Your Attention