Transition Pathways to a Low Carbon Electricity System in the UK: Key findings and policy messages

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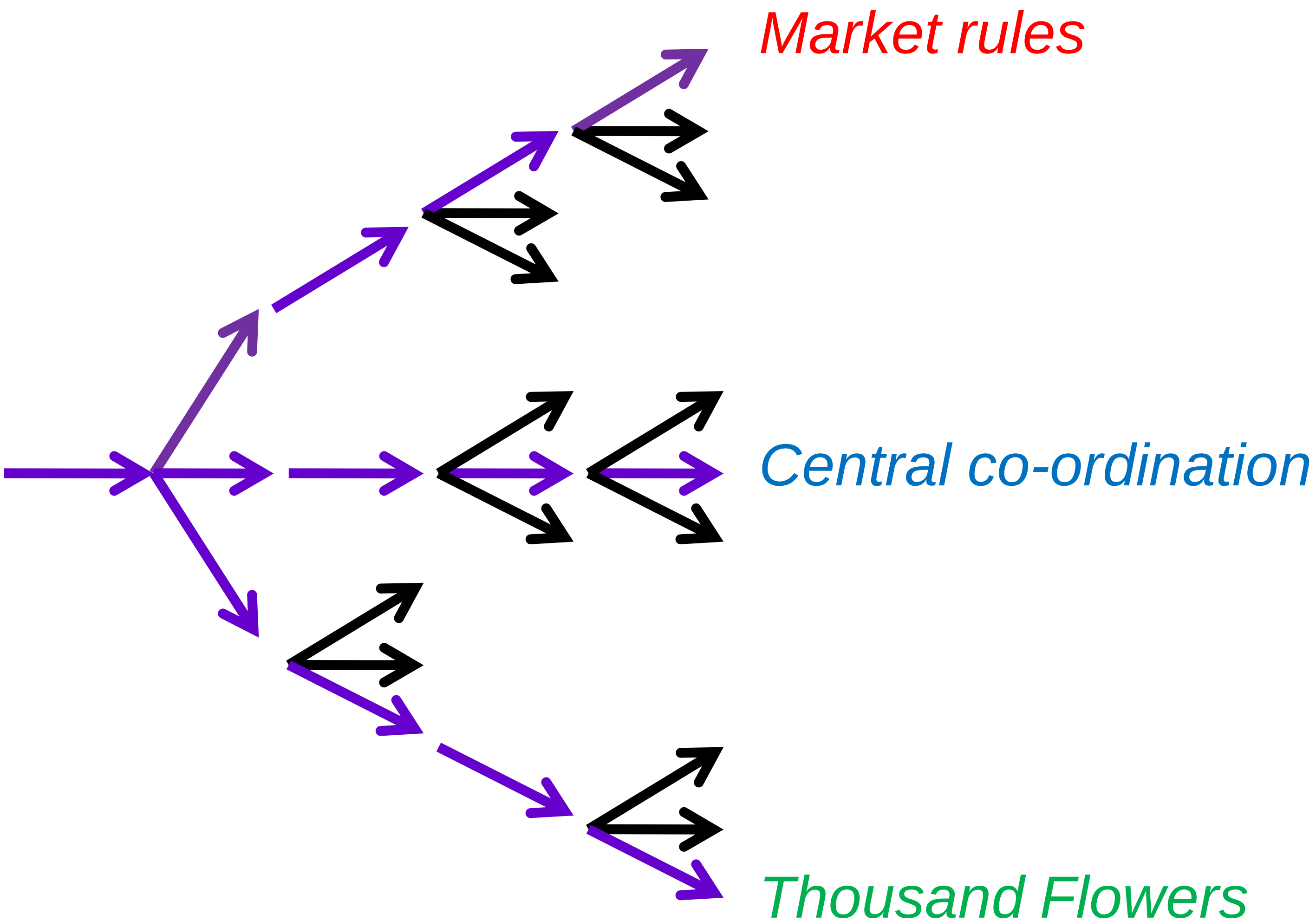
Transition Pathways: Consortium & Aims

- Interdisciplinary University Consortium
  - Bath, Cardiff, East Anglia, Imperial College, Leeds, Loughborough, Strathclyde, Surrey, UCL
  - Funded by EPSRC & E.On UK (May ‘08 - April ‘12)
- Key aims:
  - Select, develop, analyse *transition pathways* to a ‘more electric’ low carbon future
  - *Integrated ‘whole system’ assessments* of pathways’ technical, economic, social & environmental implications
  - Inform thinking & decisions on low carbon transitions & how to ‘get there from here’
- UK Context
  - Climate Change Act 2008: 80% GHG cut by 2050
  - ‘Trilemma’: low carbon, secure, affordable energy

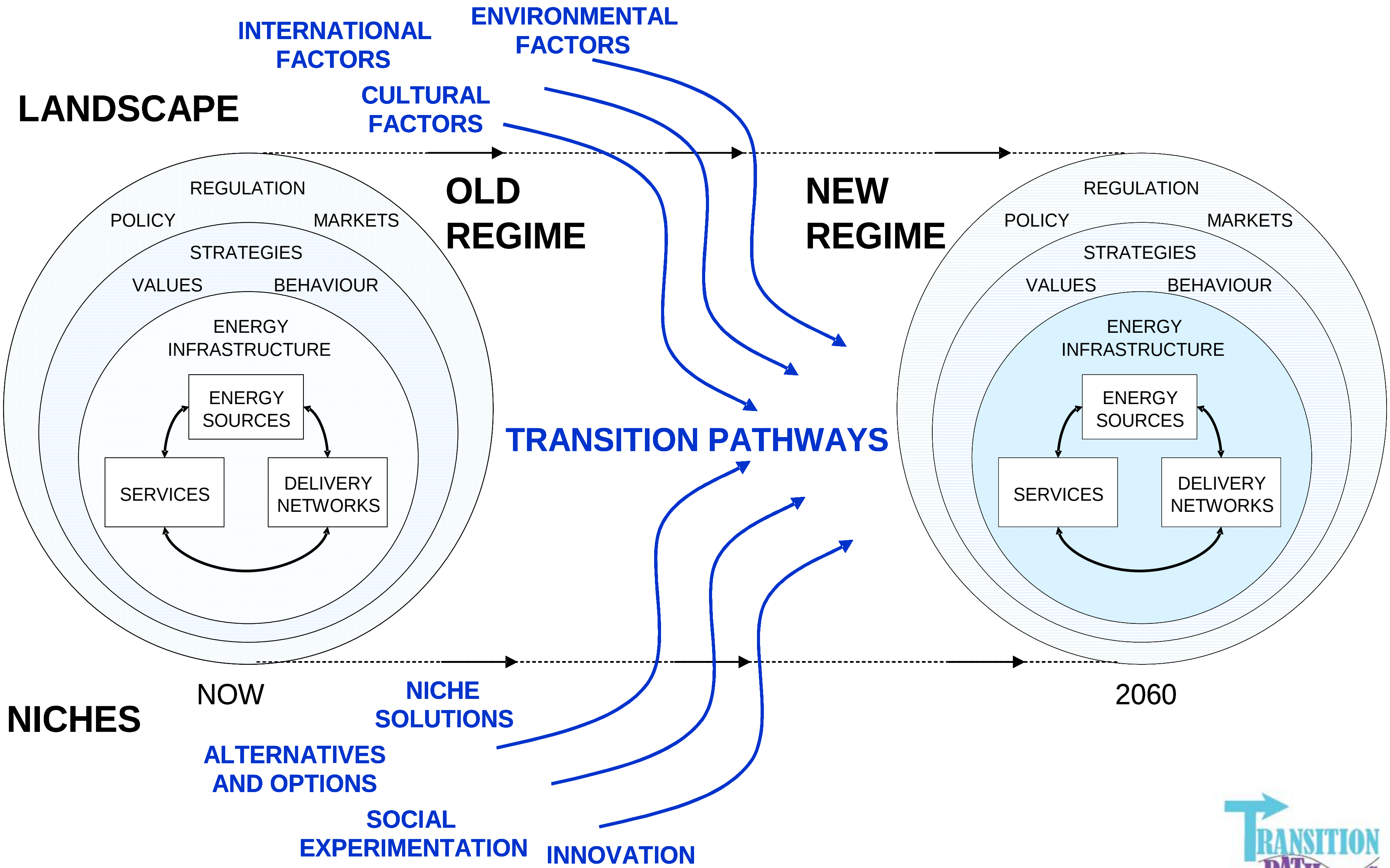
Transition Pathways approach

- Develop & analyse three transition pathways to a UK low carbon electricity system
  - Crucial influence of *market*, *government* & *civil society* actors' governance framings/'logics'
  - Pathways reflect 'co-evolution' of technologies, institutions, strategies/policies & user practices
  - Quantitative & qualitative pathway assessments
  - Exploration of pathway 'branching points'
  - Interaction with key stakeholders/advisers throughout
- Potential pathways - not predictions or roadmaps
  - Imaginative 'whole system' exploration of possibilities
  - To inform proactive & protective decisions & consensus-building towards common goals

Three Core Pathways & Governance Modes

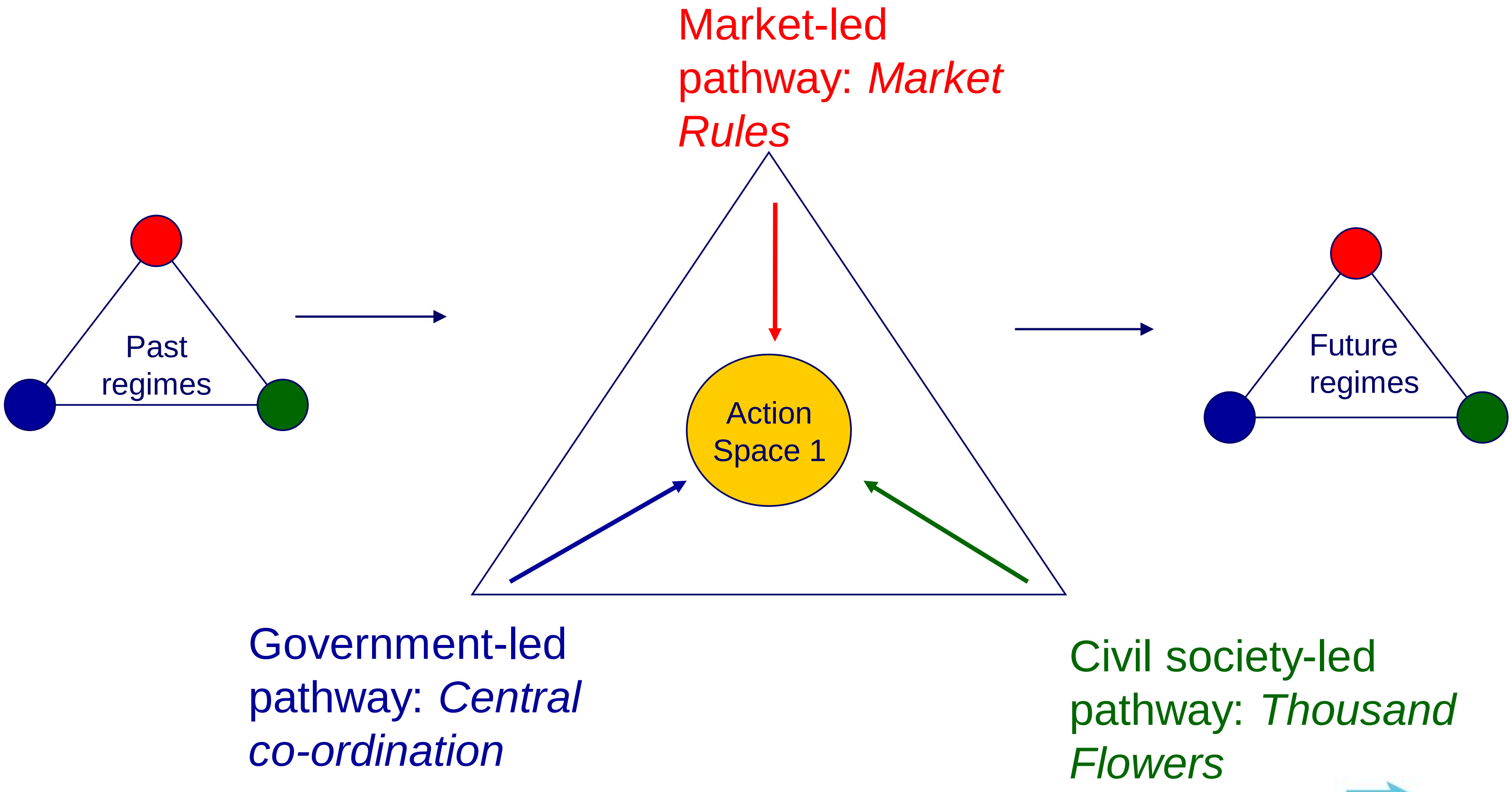


Multi-level Perspective on Transition Pathways



Source: Transition Pathways Team

The Action Space for Transition Pathways



Three Transition Pathways

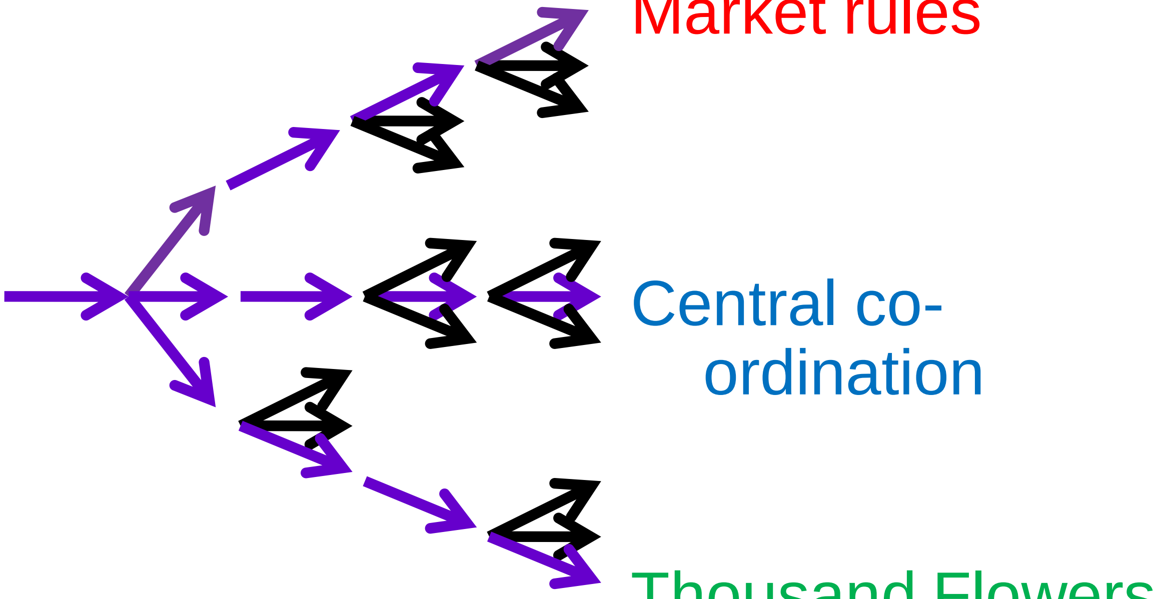
1) *Market Rules*
   - Limited interference in market arrangements; high carbon price
   - Large companies dominate; big technologies in 'highly electric' future – inc. CCS-ready coal/gas, nuclear power, offshore wind
   - 80% generation linked to high-voltage in 2050: grid reinforcement
2) *Central Co-ordination*
   - Central government & Strategic Energy Agency commission tranches of low-carbon generation from big companies
   - Via large-scale centralised technologies
   - Cooperation & tensions between key actors
3) *Thousand Flowers*:
   - More local, bottom-up diverse solutions led by ESCOs (big & small), local communities & NGOs: closer engagement of end-users
   - Local leadership in decentralized options (50% share)
   - Key technologies: onshore & offshore wind, renewable CHP & solar PV; 'smart grid' technologies to handle power flows

Challenges and risks to realising pathways

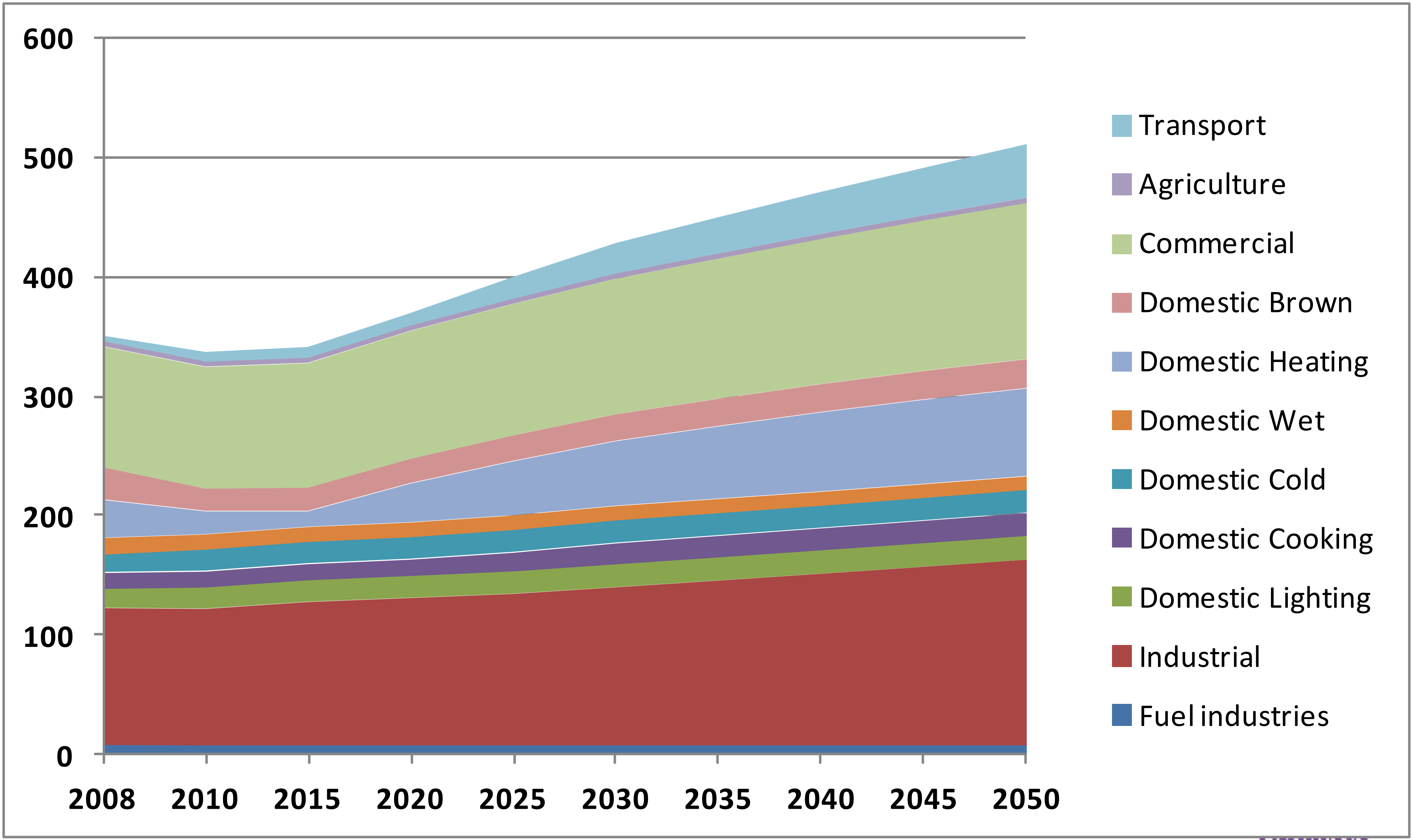
- Balancing low-carbon, security & affordability objectives, in face of multi-faceted risks & uncertainties
  - *Central Co-ordination* pathway would give direct influence but require much political leadership
  - Main risks in *Market Rules:* technical/economic feasibility & social acceptability of delivering large-scale low-carbon generation options
  - Main risks in *Thousand Flowers:* technical/economic feasibility of distributed generation; realising behavioural & technological changes to reach & sustain big demand reductions
- Key to any successful low-carbon transition
  - Trust in policymakers to stick to & deliver credible policies/incentives
  - Willingness of market & civil society actors to engage constructively

Explore, interrogate & revise pathways

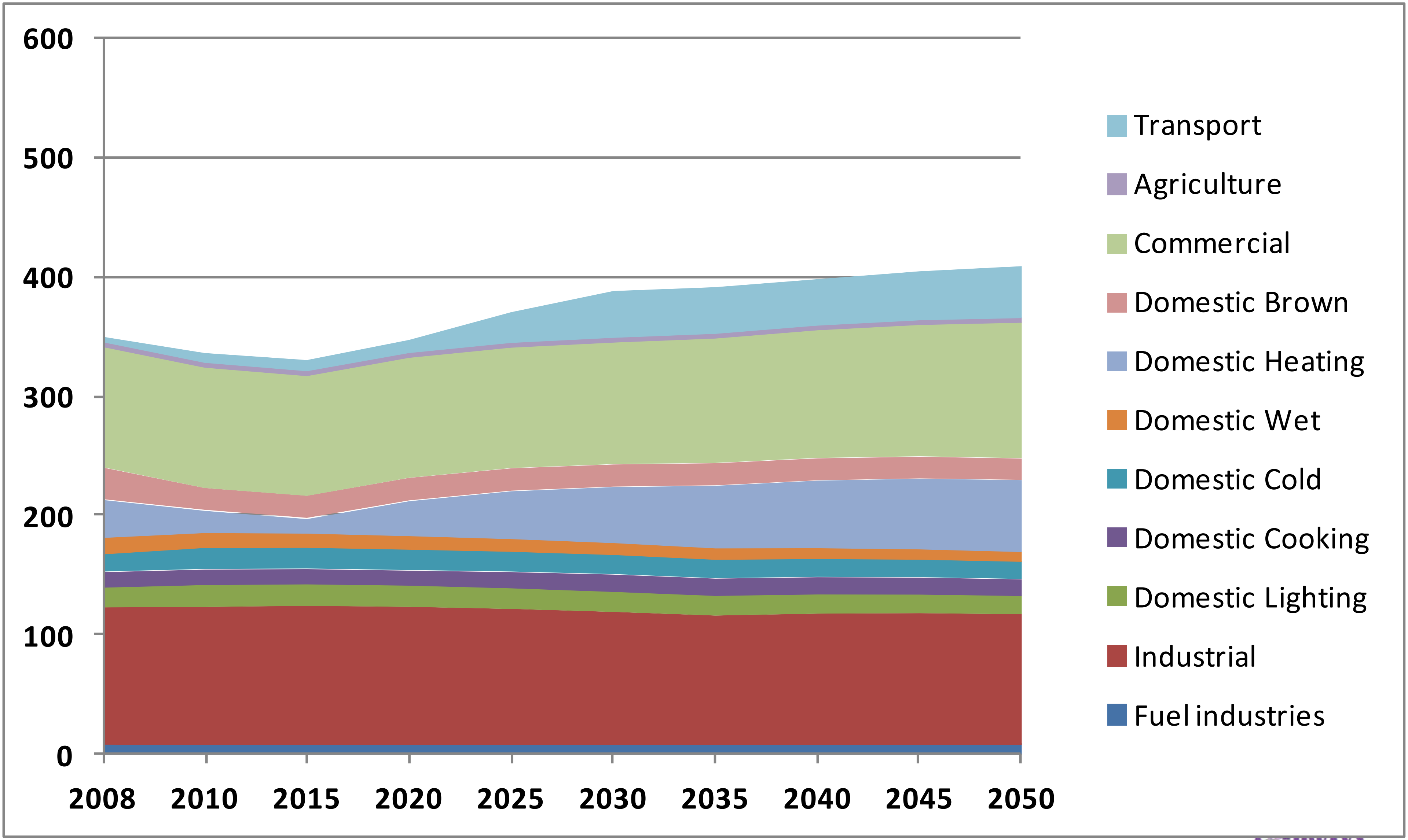
- Explore and interrogate pathways (2 iterations)
  - Technical feasibility, e.g. electricity grid enhancements
  - Social acceptability, e.g. visual energy display trials
  - Whole systems appraisal, e.g. life cycle carbon emissions
- Branching point analysis
  - Test pathway sensitivity & robustness
  - Informed by historical case studies



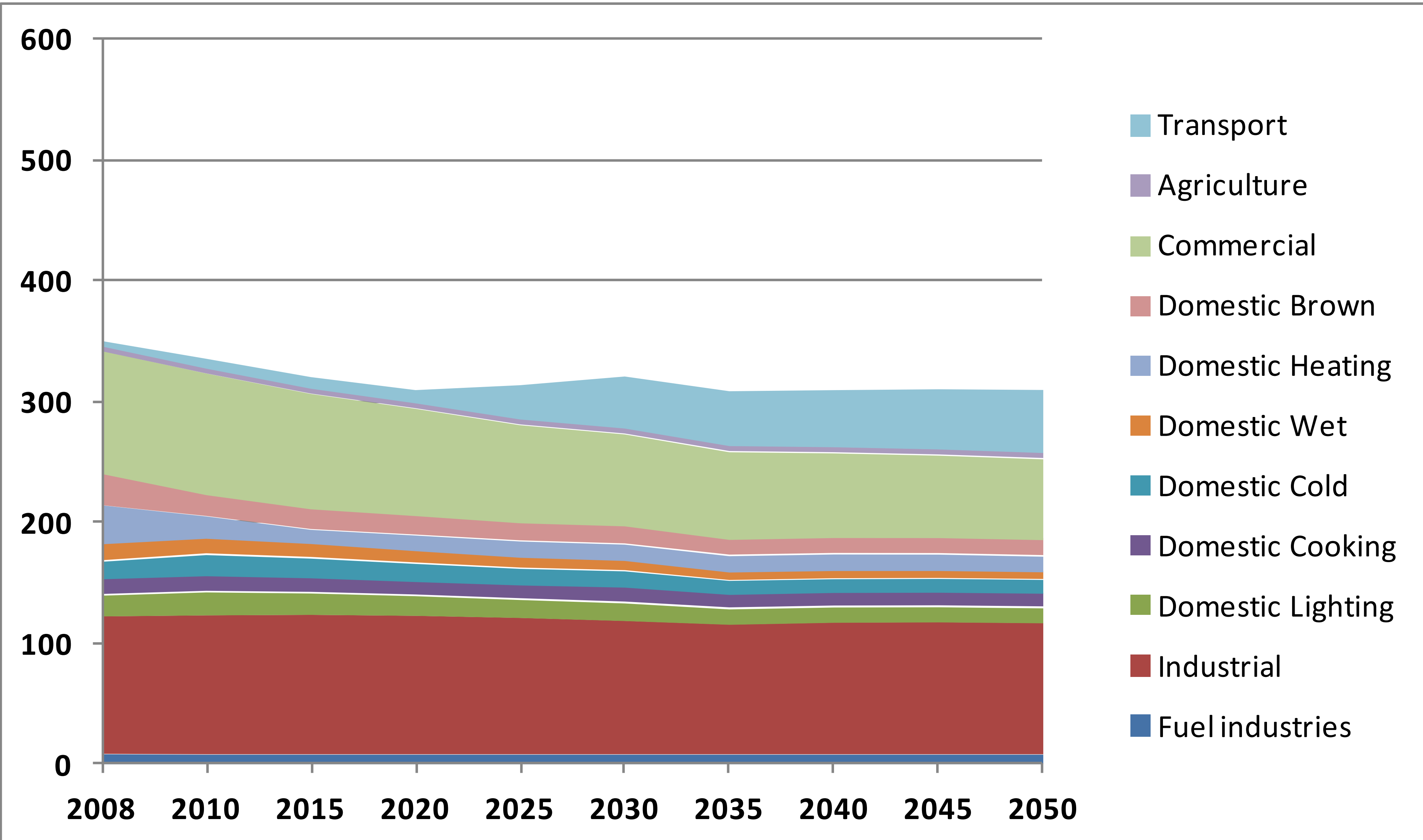
Market Rules electricity demand (TWh)



Central Coordination electricity demand (TWh)



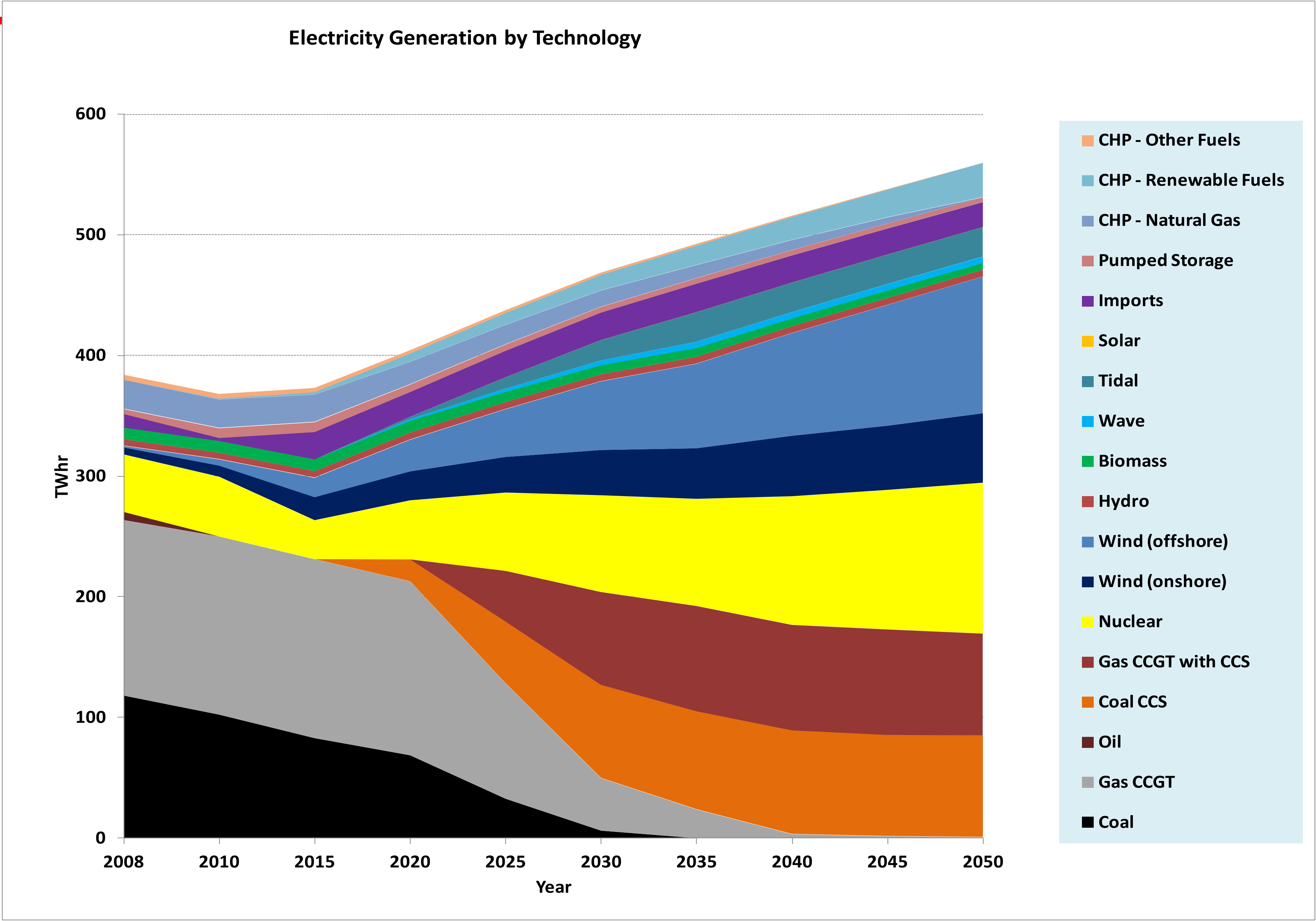
Thousand Flowers electricity demand (TWh)



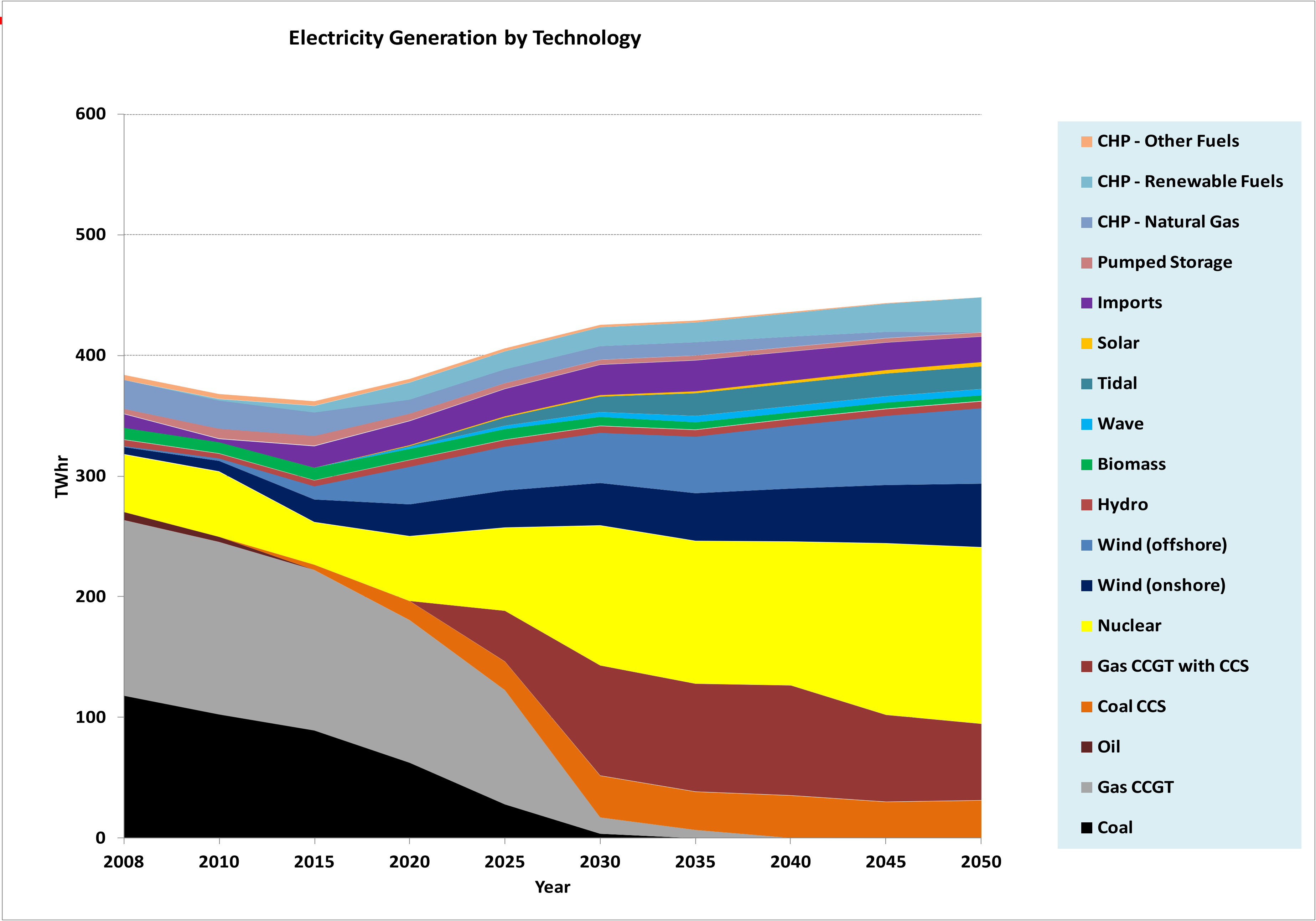
Demand, Energy Use and Behaviour

- Greater energy efficiency & use of non-electric heating sources (mostly CHP) in Thousand Flowers cuts peak demand to 38GW.
- But with significant 'excess' generation locally at times of low electricity demand.
- Load shifting through greater use of DSM, with widespread acceptance of automatic appliance control &/or deep behaviour changes, could address this,
- But our longitudinal study of responses to visual energy displays showed how quickly households returned to pre-existing use levels.
- Most early adopters used displays to picture the household's 'normal' energy use pattern - & tended to resist external appeals to change.
- The closer engagement of end users with energy system governance in Thousand Flowers suggests one way to overcome these barriers.

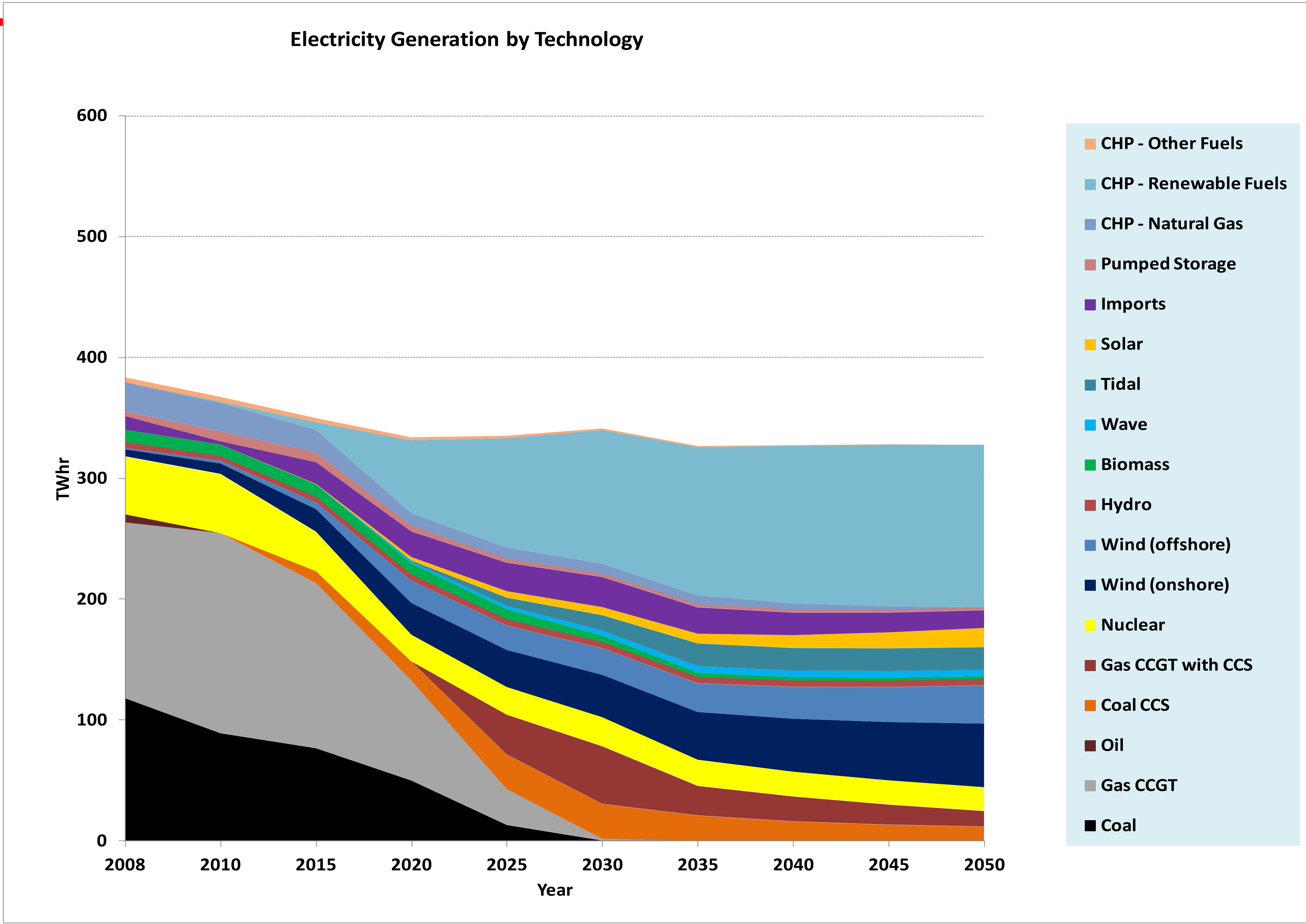
Electricity generation mix in ‘Market Rules’ pathway



Electricity generation mix in 'Central Co-ordination'



Electricity generation mix in ‘Thousand Flowers’



Whole systems appraisal of pathways

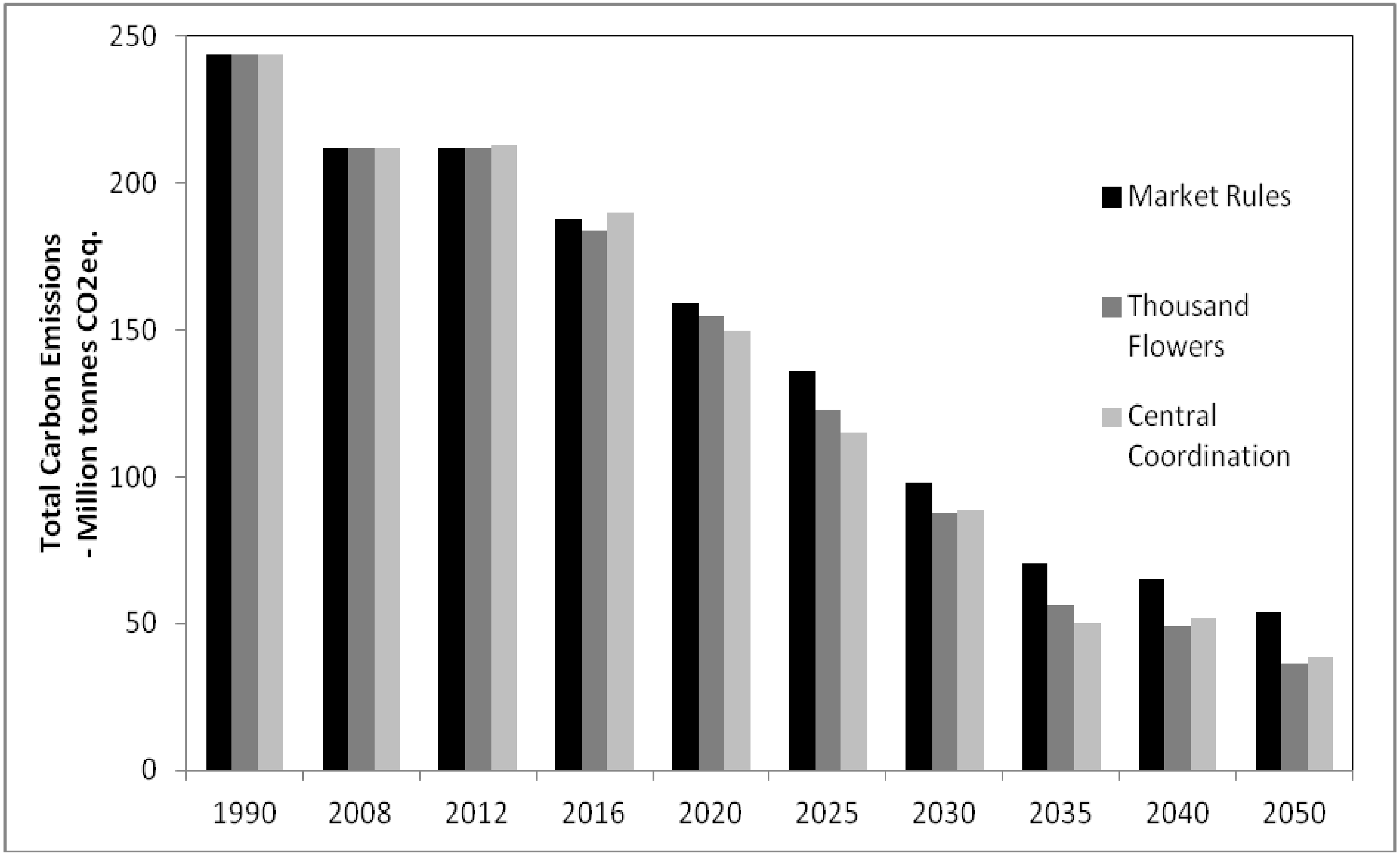
- Establish a ‘sustainability appraisal framework’, including the identification of key technical, environmental, economic & social constraints
- Identify key constraints or risks that may limit such pathways – risk assessment of the UK *Electricity Supply Industry*
- Provide quantitative & qualitative ‘whole systems’/ ‘full fuel cycle’ energy & environmental appraisal of the pathways
- Map environmental & carbon implications of the pathways using aggregate footprints

UPSTREAM EMISSIONS

- **Upstream from delivered fuel**
  - Extraction, refining, transport, …. etc.
- **Two main GHG burdens**
  1. Additional energy requirements to ‘fuel’ upstream activities
  2. Methane leakage
     - Coal mining activities – quite a significant contribution
     - Natural 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%

Total UK Carbon Emissions (MtC_e) from the Electricity Sector under the Three Transition Pathways (including upstream emissions)



Whole systems appraisal – Key Findings

- The impact of ‘upstream emissions’ distinguishes our findings from those of CCC & DECC.
  - None of the pathways yield zero GHG emissions by 2050, because of this
  - UK ESI cannot realistically be decarbonised by 2030-2040, as CCC advocated
  - Real requirement is for more dramatic ESI carbon reductions
  - CCS technologies likely to deliver only 70% reduction in carbon emissions on whole system basis (cx. normal 90% assumed)
  - Biomass co-firing with CCS may mitigate upstream emissions on full life-cycle basis: needs careful study in future
- Particulate Matter Formation (PMF) & Human Toxicity (heavy metal emissions) may need attention, especially with CCS technologies

Value of 'Transition Pathways' analysis

- Exploration of pathways & branching points informs actions needed & consensus building for common goals
- Shows pathways with different/shifting roles for government, market & civil society actors
  - And how they might lead to alternative visions & realities of a low-carbon electricity system
- Identifies challenges raised for different actors
- Shows implications of risks & uncertainties, including
  - Future progress in different energy technologies & portfolios
  - Whole system sustainability challenges for technologies & pathways
  - Role of ICTs to help facilitate change through smart grid/controls
  - Demanding role of changes in actors' habits, practices & wider social values, & how actors might interact well or badly with technologies
  - Role of policies & incentives

TRANSITION PATHWAYS

Realising Transition Pathways project (2012-16)

- The consortium is now undertaking further research, supported by the UK Research Councils Energy Programme, on ‘realising transition pathways’, by
  - Analysing actors’ choices and decisions within dynamic changes in electricity supply and demand systems
  - Undertaking detailed analysis of the social, behavioural and technical drivers and implications of demand side responses and their integration into electricity systems
  - Undertaking techno-economic systems modelling and energy and environmental assessments of the developments in electricity supply
- These elements will be drawn together to form a detailed whole systems analysis of the transition pathways:
  - quantitative modelling and analysis of electricity systems, and
  - qualitative assessment of the roles of government, market and civil society actors

Publications

- Foxon, T J, Hammond, G P and Pearson, P J (2010), 'Developing transition pathways for a low carbon electricity system in the UK', *Technological Forecasting and Social Change* **77**,1203-1213.
- Special issue of *Energy Policy* on 'Transition Pathways', including
  - Foxon, T J, 'Transition pathways to a low carbon electricity future', *Energy Policy* (in press)
- Special issue of *Energy Policy* on 'Past and prospective energy transitions', including
  - Pearson, P J and Foxon, T J, 'A Low Carbon Industrial Revolution? Insights and Challenges from Past Technological and Economic Transformations' , *Energy Policy* (in press)
- Further working papers and presentations available on project website:

  www.lowcarbonpathways.org.uk

Calculating investment costs for pathways

- Calculate investment costs of additional & replacement generating capacity for each pathway
- Based on Ofgem (2009) Project Discovery methodology
- Caveats:
  - Costs not discounted back to present values
  - Not included: demand side investment costs; learning rates for technologies; operation, maintenance & decommissioning costs
- Results:
  - Similar cumulative investment costs to 2050
  - Thousand Flowers: higher investment costs up to 2030, from more rapid transition to distributed generation
  - Market Rules: higher investment costs 2030-2050 from continuing investment in CCS, nuclear & offshore wind needed for rising demand

TRANSITION PATHWAYS

Cumulative investment costs for pathways