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Research Frontiers for Low-Carbon Energy Systems: some reflections on UK transition pathways

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ISAP: Towards Copenhagen…

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Outline

- Key challenges for the UK
- Past & prospective transitions in the UK
- Case studies: UKERC 2050 & EPSRC/E.ON Transition Pathways projects

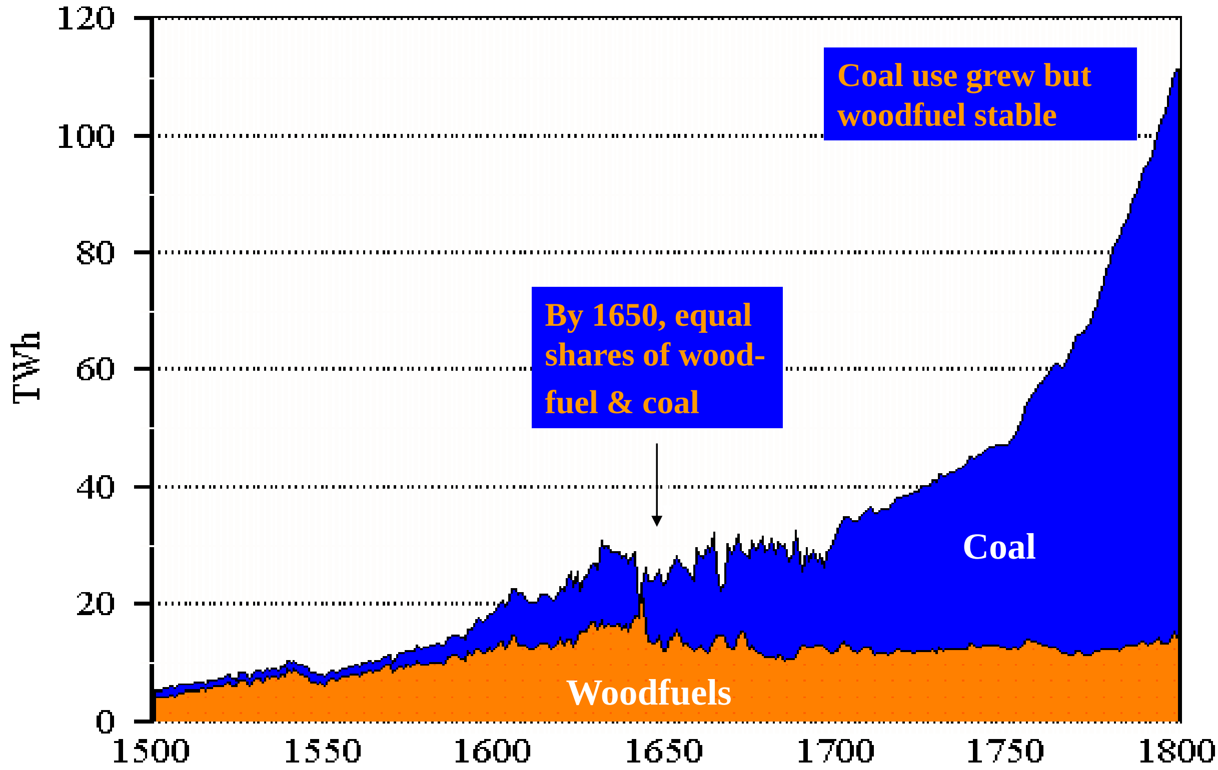
Some Key Research & Policy Challenges from a UK Perspective: can we

- Create visions, strategies & policies for an energy system that is simultaneously?
  - Low-carbon/ resilient/ just & affordable
- Build a low-carbon energy system that plays a key role in economic recovery from the Credit Crunch?
  - With tension between jobs now & investment for future
- Learn from past transitions & policies, to promote 'better' future transitions & policy learning?
- Develop & deliver better 'technologies'?
  - Ideally with properties of General Purpose Technologies
  - On both demand & supply sides
- Understand & affect the changing behaviour of key energy system 'actors'?
  - In terms of overall system governance (market/govt./people)

Energy & Britain's 1st 'Industrial Revolution': C16th-19th energy transitions

- Britain went from a traditional agricultural economy, held back by limited
  - Productivity of scarce land &
  - **Flows** of energy for food, clothing, housing & **fuel**
- To a new regime: growth & welfare transformed by
  - Using fossil fuel **stock** (coal) to get bigger energy flows
  - Along with innovations
    - including steam engine
    - & other institutional, social & political changes
- Coal & steam helped drive mechanisation, urbanisation & Britain's 'Industrial Revolution'

Fig. 1: UK Final Energy Consumption, 1500-1800 (TWh)



Fouquet & Pearson (2003) *World Economics*, 4(3)

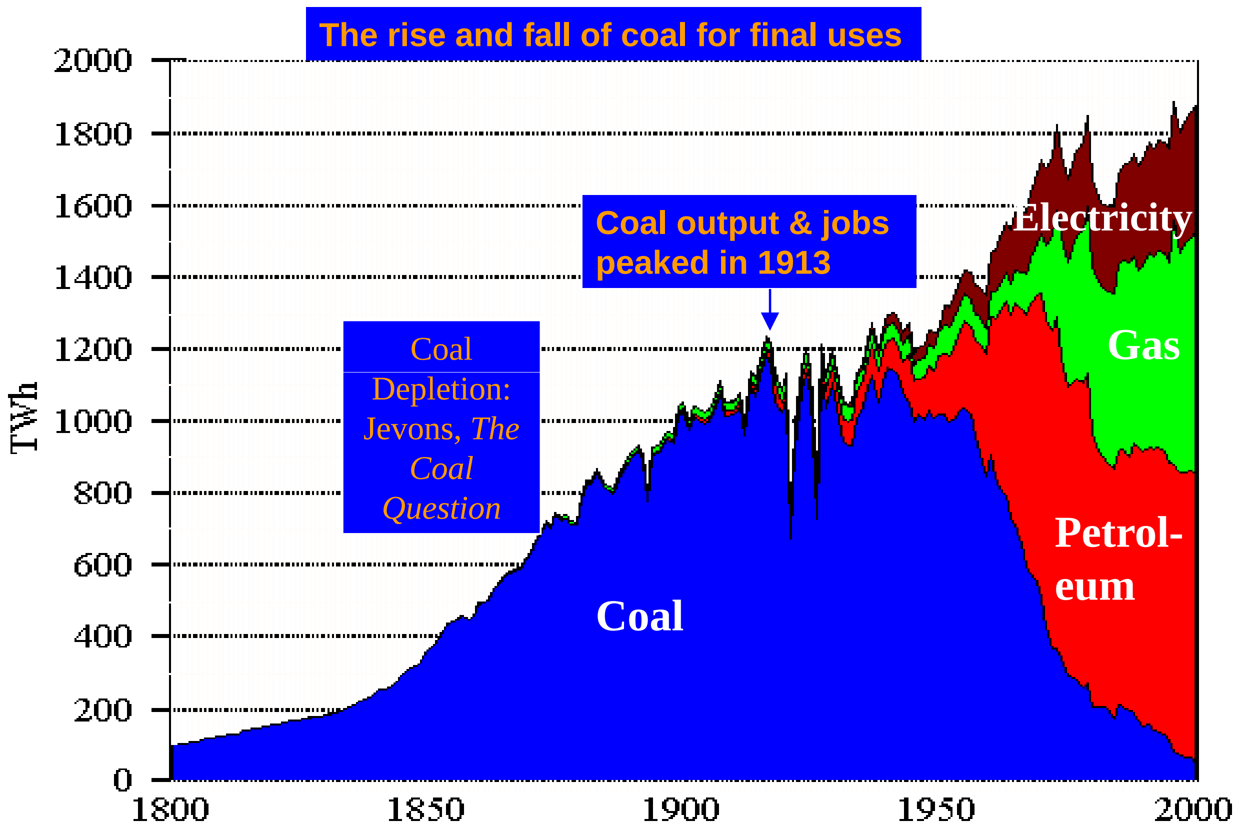
C18: coal & new steam technologies

- Beam engines pumped water from coal & copper mines
  - By 1733, 110 Newcomen 'atmospheric engines' in 7 countries
  - 1769-1800: James Watt's separate condenser patent
    - raised efficiency & profits
- Rotary steam engine – rotative power
  - Could now drive machines: Watt (1782) & others
- But by 1800, only 2200 engines in mining & manufacturing
  - High steam/water power price differential

Steam Power: UK development & diffusion

- Steam/water power price differential slowly overcome
  - By mobility advantage of steam
  - More engine efficiency, from
    - Higher pressure boilers (1840s); Corliss valves (1860s)
- Steam let production move from water & wind power sites
  - Helped develop the factory system
  - Especially textiles: Manchester - ‘Cottonopolis’
- Railways & then ships
  - Developed national & international transport & markets

Fig. 2: UK Final Energy Consumption, 1800-2000 (TWh)

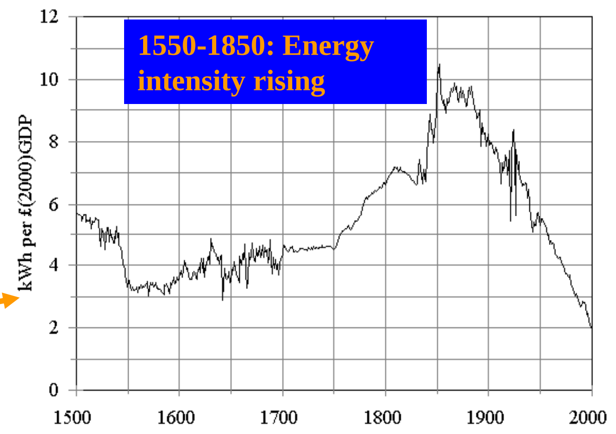


Fouquet & Pearson (2003) *World Economics*, 4(3)

Fig. 3: prices matter

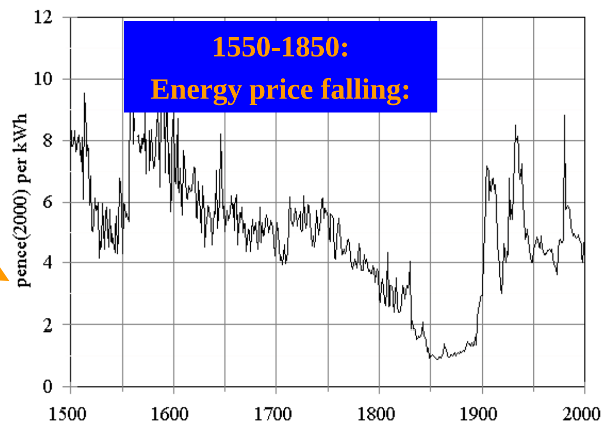
Inverse relationship between:

Energy intensity (E/GDP)



and

Real energy prices (p/kWh)



Fouquet & Pearson (2003) *World Economics*, 4(3)

A Long-Run Perspective

- New technology diffusion **took time**
  - Major productivity fx. of steam engines, locomotives & ships only observable after 1850
  - Only a few steam-intensive industries
    - Mining, textiles & metal manufactures
    - Accounted for >1/2 of industrial steam power, 1800-1900
- Not just steam: electric light slow to dominate gas (40 years: 1880-1920)
- Modern transitions can be **much faster** – but still takes time
  - To build new infrastructure
  - Overcome ‘lock-in’, turn over old capital stock

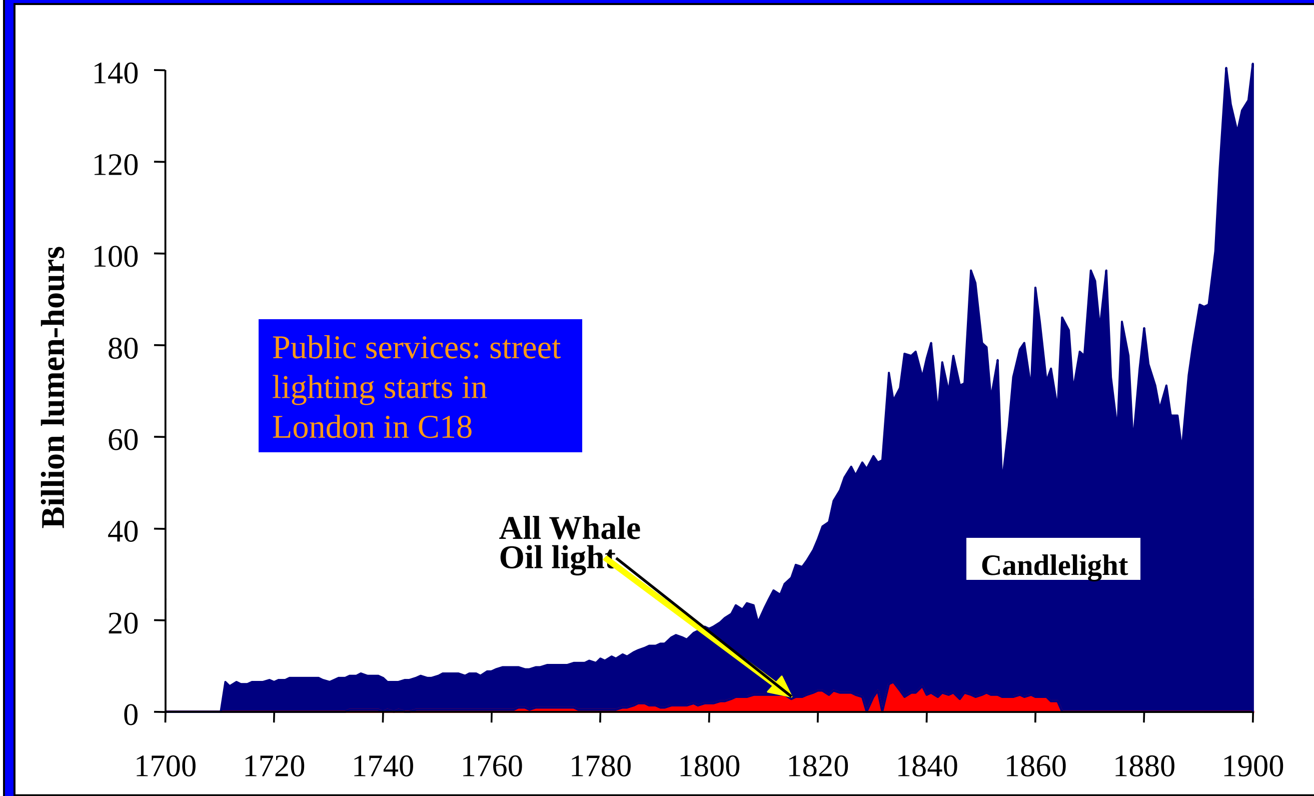
Costs of Energy transitions: pollution & climate in the UK

- Growing C19th concerns about air, land, water pollution – but slow to act until C20
  - Alexis de Tocqueville - Manchester (1835):
    ‘A sort of black smoke covers the city. Under this half daylight 300,000 human beings are ceaselessly at work…’
  - London’s long air pollution history
    - 1952 ‘Great London Smog’: est. 3500-4000 early deaths
    - 1956 Clean Air Act – zoning, ‘smokeless’ fuel
- Then concern with small particles & acid deposition
- Now climate change & GHGs, including CO2
  - New Govt. Dept for Energy & Climate Change
  - Legally binding GHG targets

Benefits of Energy System Transitions: UK lighting example

- What’s the energy for? Energy services:
  - *illumination*, transportation, nice temperatures
- Evidence: innovation’s extraordinary potential to
  - Lower costs, raise service quality & welfare
- UK lighting services innovation
  - Mostly after 1800
    - In fuels, technologies, infrastructures & supply
  - Brought lower lighting costs & rising incomes
  - Meant ‘revolutions’ in light use & quality

Fig. 4. UK Consumption of Lighting from Tallow Candles & Whale Oil Lamps (billion lumen-hours, 1711-1900)



Fouquet & Pearson (2006) *Energy Journal*, Vol. 27(1)

Fig. 5. UK Consumption of Gas, Kerosene & Candle Light (billion lumen-hours)

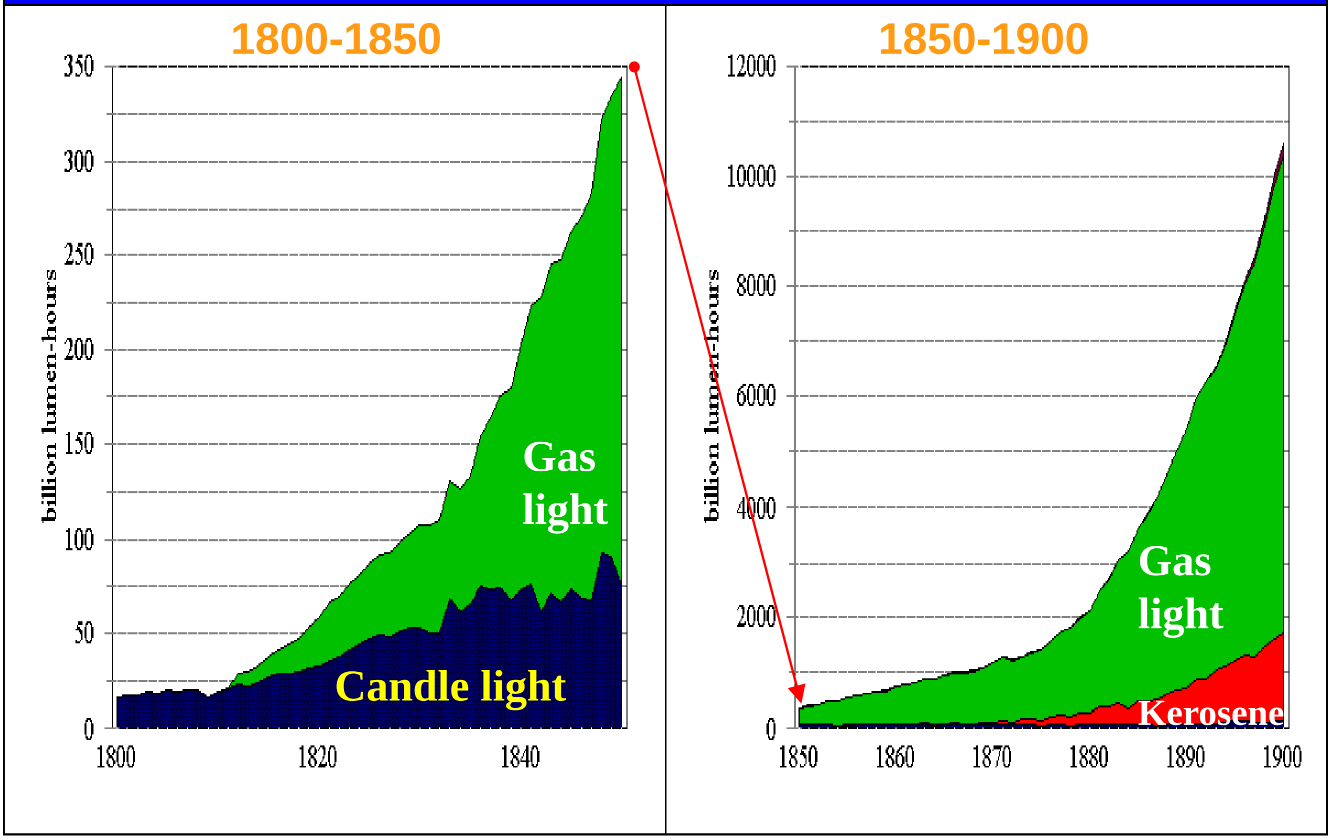


Fig. 6. UK Consumption of Kerosene, Gas & Electric Light, 1900-2000 (billion lumen-hours)

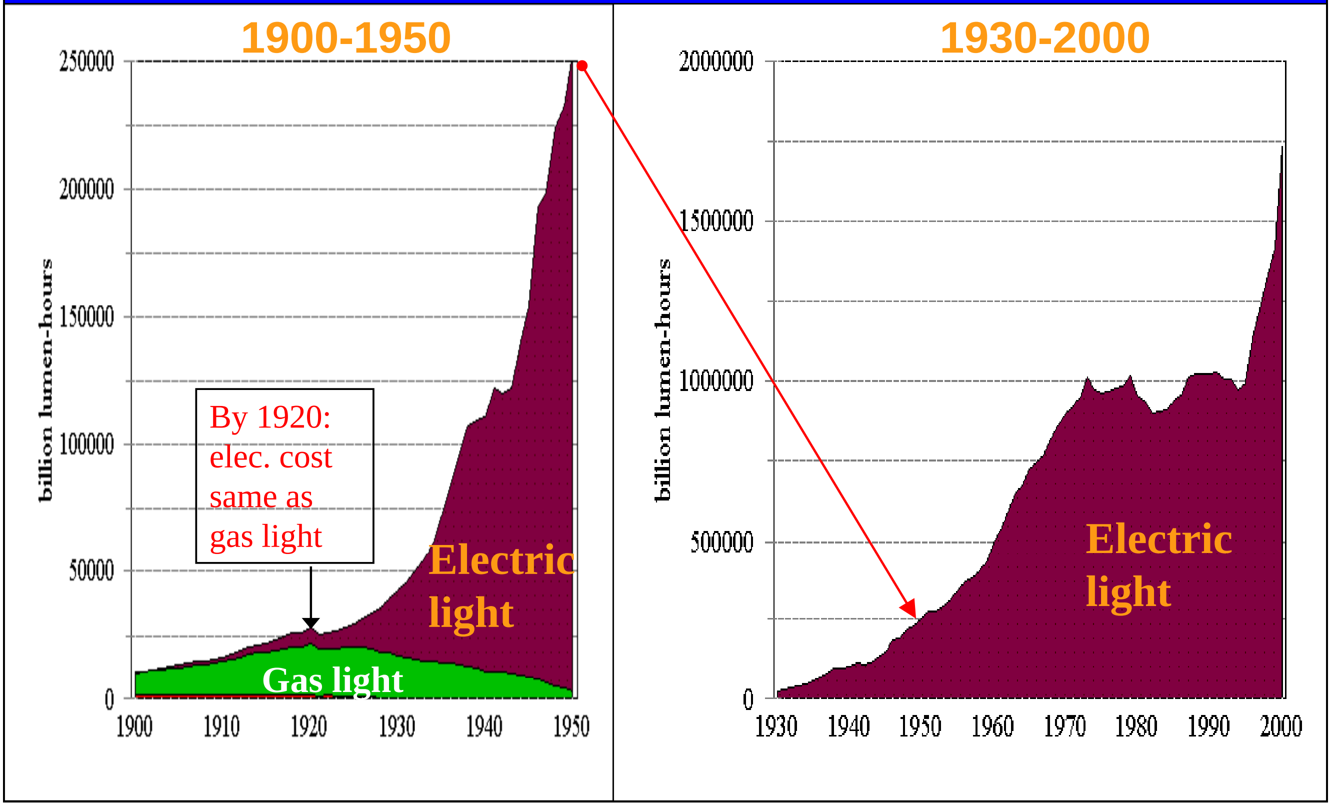
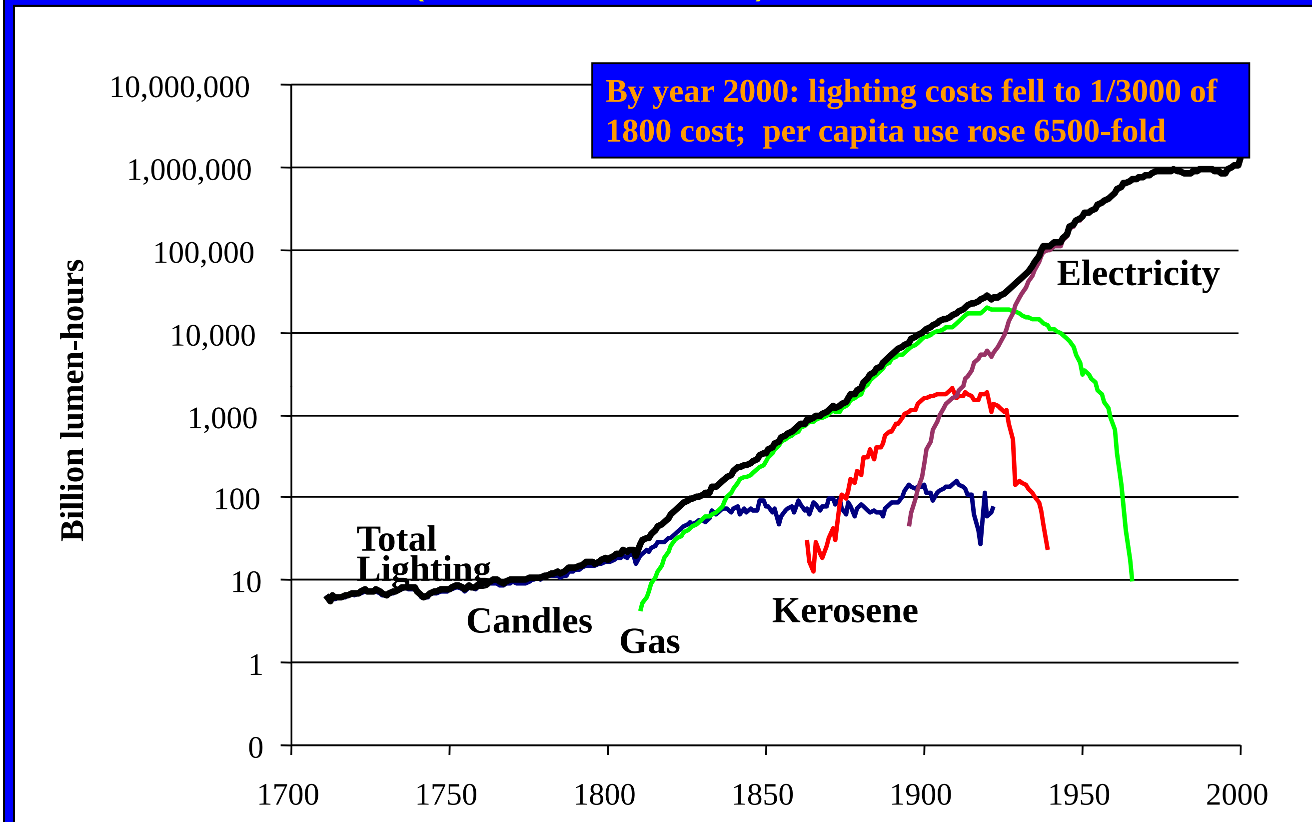


Fig. 7. UK Lighting Transitions – Consumption, 1700-2000 (bn. lumen-hours,)



Source: authors ' own estimates – see Sections II.2 and II.3 Billion: 10^9 (i.e. one thousand million)

Fouquet & Pearson (2006) *Energy Journal*, Vol. 27(1)

Some Lessons from UK Energy Transitions

- Energy innovations have profound effects on human development & welfare
  - But takes time for new fuels, technologies, infrastructures & institutions to develop & benefits to come through
- There can be much inertia in UK systems
  - Path dependence? First mover advantage?
    - UK mining & textile industries slow to adopt electricity
    - Relative to chemicals & engineering, shipbuilding & vehicles
- UK slow to address environmental impacts
- But evidence shows government policy **can** make a difference

The Future for Low Carbon Energy Systems?

- Two previous UK Industrial Revolutions were about manufacturing
  - C18 revolution driven by textiles, iron & steam
  - end C19 2nd revolution: electricity, chemicals, petroleum & mass production
- Improved technology (energy & ICT, e.g. in smart grids) *might* help break link between energy services, fuel demands & emissions
  - *Could* enhance macro-level productivity
  - Energy & ICT as *General Purpose Technologies*
- A 3rd 'Industrial Revolution'?

Climate Change & Low Carbon Technologies

- Two key features of GPT's:
  - *Technological Dynamism:* continuous innovation in efficiency of the technology, so costs fall/quality rises over time
  - *Innovational Complementarities:* new technology users improve own technologies, find new uses
  - Steam engines, ICE, electrification & ICT raised productivity growth (but took decades, so patience needed)
- How to get there from here?
  - Means more than substituting low carbon technologies into *existing* uses and institutions
  - Low carbon technologies need capacity:
    - For continuous innovation & cost reduction
    - To change what we do with them & how
    - To be proactively sustainable

The UK Energy Research Centre's Challenge

- Directed by Prof. Jim Skea & Dr John Loughhead, UKERC's role:
  – Promote cohesion across the UK energy research effort
  – A bridge between the UK energy research community & the wider world (local, national & international)
- UKERC's research
  – Interdisciplinary, independent & 'whole-systems'
  – Drawing on engineering, economics & the physical, environmental & social sciences.
- UKERC a "virtual" centre, with HQ at Imperial College London

UKERC Energy 2050 Project

- How can UK move to a low-carbon energy system over next 40 years?
- Focus on 2 main goals & tradeoffs of UK energy policy
  – 80% cut in 1990-lvel carbon emissions by 2050
  – Ensuring that energy delivered reliably
- Broad approach
  – No forecasts or "best/preferred" futures
  – Acknowledge uncertainty
  – Combine scientific insights with integrating modelling tools & approaches

Core UKERC 2050 Scenarios

ENERGY SYSTEM ATTRIBUTES

Resilience →

Low Carbon ↓

		Resilience →
Low Carbon ↓	REF Reference ("firm and funded" policies as of EWP 2007)	R "Resilient"
	LC "Low carbon"	LCR "Low carbon resilient"

High level messages

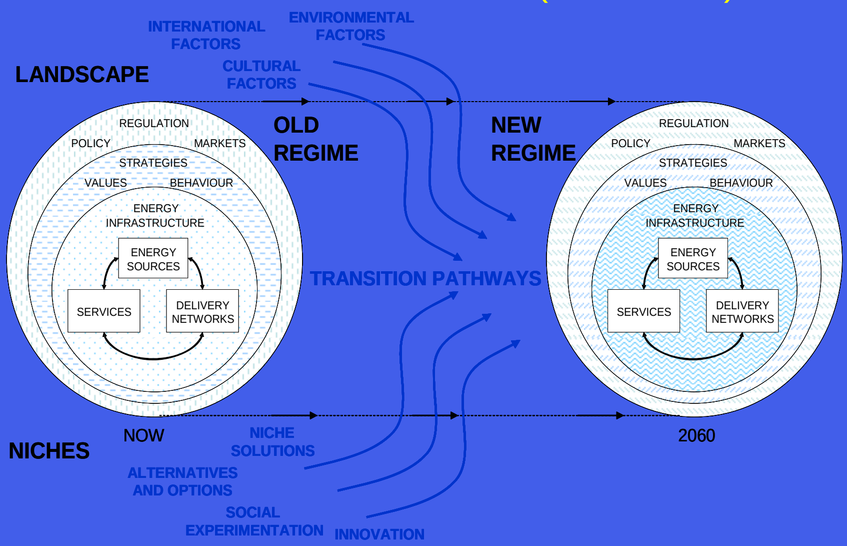
- A resilient low-carbon UK energy system is technically & economically feasible at an affordable cost
- Multiple pathways to a low-carbon economy.
  - A key trade-off: speed of reducing energy demand vs. decarbonisation of energy supply
- Cutting energy demand plays brings many benefits, ensures against:
  - Failure of key technologies to deliver
  - Social resistance to some supply side technologies
  - Price shocks & import dependence

The promise of technology

- New & improved technologies vital for long-term CO_2 goals
- Supply side technologies need
  - Bigger commitment to RD&D
  - Stronger financial incentives
  - Lower regulatory/ market barriers
- Need more energy RD&D investment, & balance between
  - Early & late stage RD&D
  - Roles of private & public sectors
- De-centralised energy generation a potentially disruptive technology
  - Take-up depends on interplay of technology, policy & consumer behaviour

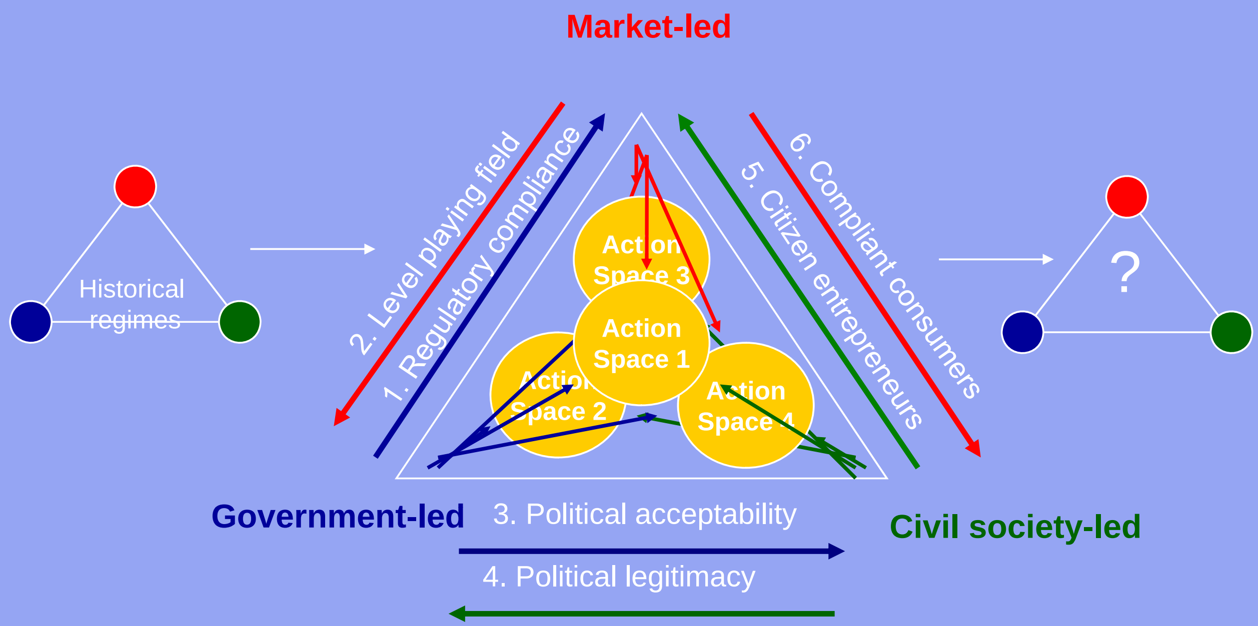
Transition Pathways to a Low Carbon Economy

EPSRC/E.ON-funded research consortium (2008-2011)



- **Partners at 8 UK Universities (Bath. Imperial, King's College London, L'boro, Strathclyde, Surrey, UeA)**
- **Explore dynamics of transition pathways in UK electricity**
- **80% cut by 2050 - how to get there from here? Pathways matter.**

Mapping the Electricity Regime -Shifting Patterns of Governance: the mix & balance of actions led by actors in government, liberalized markets & civil society



Perspective on Energy System Transitions

- Transitions mean interactions between
  - Fuels & energy converting technologies
  - Infrastructures (transport networks, pipes & wires…)
  - Institutions (markets, companies, finance…)
  - Policy regimes (institutions, regulations…)
  - Economic variables (prices, income/output…)
  - Environment
  - People…
- These are complex, *evolving* energy *systems*
  - Must focus on much more than fuels & technologies

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