Building on Insights from the Past

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Challenges of Low Carbon Transitions

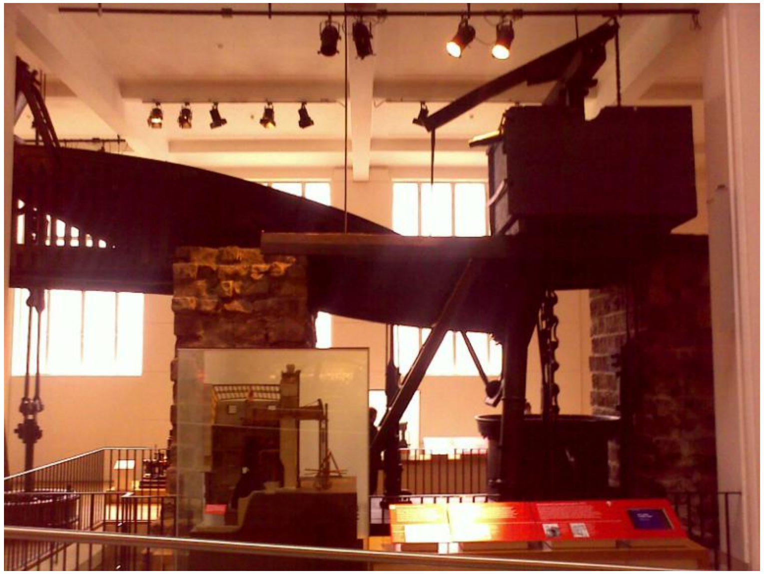
1. Low carbon technologies & practices
   - What features should they have?
   - What insights might we glean from past transitions?
2. Successful adoption of these technologies & practices
   - How do we get ‘there’ from ‘here’?
   - Interactions between new & incumbent technologies?
3. These questions lead towards
   - Macro/Micro Inventions (Allen) & General Purpose Technologies
   - The Sailing Ship Effect (SSE)/ Last Gasp Effect (LGE)
   - The issue of pre-conditions, such as those identified by Allen for the 1st industrial revolution in Britain
   - And the crucial roles of policy & institutions

A Long-Run UK Perspective

- Transitions can have profound effects on economy, people & environment
- But technology diffusion **took time** (Fig. 1)
  - Major productivity fx. of steam engines, locomotives & ships only observable after 1850 (see the work of Crafts…)
  - Few steam-intensive industries
    - 1800-1900: mining, textiles & metal manufactures accounted for >50% industrial steam power
- Not just steam: electric light slow to dominate gas (1880-1920)
- Energy system inertia
  - First mover advantage & path dependence?
  - Mining & textile industries were first with steam
  - But slow to adopt electricity in 2nd C19 Industrial Revolution
  - Relative to chemicals & engineering, shipbuilding & vehicles

Fig.1: Turning over the capital stock takes time…

- Thompson's Atmospheric Beam Engine
  - Pumped water from Derbyshire coal mines for 127 years (1791-1918)
  - Savery's patent (1698-1733); Newcomen's 'atmospheric engine' (1710-12)
  - Watt's separate condenser patent (1769-1800)
  - But this engine didn't use the new design



- Bell Crank Engine (Rotary Power)
  - This one ran 120 years (1810-1930)
  - Patented 1799 by William Murdoch
  - 75 built by Boulton & Watt, 1799-1819

Both in Science Museum, London

TRANSITION PATHWAYS

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Some Lessons from UK Transitions

- Allen identified key conditions underlying the 1st industrial revolution
- It took many decades before measurable growth effects of steam power appeared
- Modern transitions *could* be **faster** – but it still takes time
  - To build new enthusiasm, infrastructure & institutions
  - To escape the shackles of path dependence
  - Overcome ‘lock-in’ & turn over old capital stock
- Although evidence shows government **can** make a difference
- Most past transitions weren’t managed

Some Managed Transitions

- UK
  - C19 & C20: UK gas & electricity industries shaped/encouraged energy uses & habits
  - 1920s & 1930s: subsidised petrol from ethanol (Distillers Co) & coal (ICI)
  - National Grid, 1930s
  - Post WWII: nuclear plant development,
  - 1960s: CEGB & partners scaling up electric power plant
  - 1960s: transition from town gas to natural gas
- Other countries
  - France: nuclear power, 1970s – post oil shocks
  - Brazil: Proalcool ethanol programme, 1970s – post oil shocks
  - Netherlands

Insights from Past Transitions:
Scoping Studies 2010

- 2010 *Transition Pathways Project* workshop: scoping studies explored aspects of UK and wider transitions
  - 1960s: CEGB rapid scaling up of electric power plant (Reynolds)
  - 1960s: the transition/conversion from town gas to natural gas (Laczay)
  - C19 & C20: UK gas & electricity industries shaped, encouraged & sought to control new energy uses & habits (Gradillas)
  - Responses of incumbent energy industries to the threat of new competition: the Sailing Ship/ Last Gasp Effect (Wallis)

See: http://www.lowcarbonpathways.org.uk/lowcarbon/news/news_0017.html

The Future for Low Carbon Energy Systems?

- First two UK Industrial Revolutions were about manufacturing
  - C18 revolution driven by textiles, iron & steam
  - end C19 2nd revolution: electricity, chemicals, petroleum & mass production
- Improved technology (e.g. energy & ICT), *might* help break link between energy services, fuel demands & CO2 emissions
  - Energy & ICT (e.g. in smart grids/controls/appliances) as *General Purpose Technologies*
- A third & low carbon 'Industrial Revolution'?
  - 'Remember, very few people enjoyed the fruits of the first Industrial Revolution until it was nearly over' (Mokyr)

General Purpose Technologies

- Three key attributes:
  - *Pervasiveness:* wide range of general applications
  - *Technological Dynamism:* continued innovation, so costs fall/ quality rises
  - *Innovational Complementarities:* GPT users improve own technologies & find new uses for the GPT
- Steam engines, ICE, electrification & ICT cited as examples
  - Raised productivity growth - but took decades
  - Since a GPT's penetration involves a long acclimatisation phase
  - While other technologies, institutions & consumption patterns adapt to it
- But the GPT model is contested theoretically & empirically
  - Doesn't allow for interdependence between technologies, etc.

General Purpose Technologies

- Three key features:
  - *Pervasiveness:* a broad range of general applications/ purposes
  - *Technological Dynamism:* continuous innovation in the technology - costs fall/quality rises
  - *Innovational Complementarities:* innovation in application sectors – users improve own technologies, find new uses
- Penetration of a GPT involves a long acclimatization phase
  - In which other technologies, forms of organization, institutions & consumption patterns adapt to it
- Steam engines, ICE, electrification & ICT cited as examples
  - raised productivity growth - but took decades

Two Reviews of GPTs

Castaldi & Nuvolari (2003): C19th steam power

- The GPT model has some limitations.
  - Doesn’t capture the “local” aspect of accumulation of technological knowledge
  - Focuses on a single technology, as opposed to “constellations of major technical innovations”
  - Doesn’t account for the interdependence among different technological trajectories

Two Reviews of GPTs

Edquist and Henrekson (2006): impact of the steam engine, electrification & ICT on productivity growth

- Major breakthroughs affect aggregate productivity growth
  - But slowly
    - Steam engine: 140 years
    - Electrification & ICT: 40-50 years
- Each breakthrough offers different lessons
- Note complex interdependence between technologies
  - Steam used as a primary source for producing electricity
  - ICT presupposed an extensive electricity network

Insights from GPTs: Technology Characteristics/Attributes

- If they are to be attractive, new (low-carbon) technologies need a bundle of desirable attributes/characteristics
- At sufficiently attractive actual or implicit prices
- Technology developers/suppliers/policy-makers need to ensure: (i) that the technology has a desirable set of attributes; (ii) and these attributes are competitively priced
- If a low-carbon attribute is a key part of the 'offer', an appropriate carbon price is necessary (although not sufficient)

The hypothesis of the *Sailing Ship Effect*

- Hypothesis: advent of a new technology may stimulate innovation in an incumbent
  - for *some* mature technologies, in *some* circumstances
  - This ‘Sailing Ship effect’ (SSE)/ ‘Last Gasp Effect’ (LGE) makes the incumbent more efficient & competitive
- Before being superseded by the successor technology
- Cited SSE/LGE examples include:
  - Late C19 sailing ships after arrival of the steam ship
  - 1880s response of gas lighting (Welsbach incandescent mantle), to incandescent lamp & earlier arc lamps
  - 1980s response of carburettors to electronic fuel ignition (Snow)
- But the story is complex and nuanced

Potential Significance of the SSE Hypothesis for Lower Carbon Transitions & Policy

- Significantly increased (price/quality) competitiveness of incumbents, through SSEs & fossil fuel price shifts, could :
  - Slow newcomers' sales & travel down experience curves
  - Raise policy costs via higher subsidies needed for competitive penetration
  - Forecasts that don't allow for SSEs overestimate penetration
- So, appreciating SSEs/Last Gasps matters, where there are mature technologies & we seek radical innovation
- And suggests giving proper attention to dynamic interactions between new & incumbent technologies

A Third and Low-Carbon 'Industrial Revolution'?

- Getting there from here means more than
  - Substituting low carbon technologies into *existing* uses/ institutions
- Low carbon technologies ideally need to be like GPTs, i.e. with capacity
  - To be widely diffused & used
  - For continuous innovation & cost reduction
  - To change what we do with them & how
- But GPTs take time to develop
  - Slowed by path dependence, lock-in & Sailing Ship/Last Gasp Effects
- And they need to be low-carbon
  - Energy security may drive us in a different direction
- And not just more efficient, as the Kaya identity reminds us

$$C = (C/E)*(E/GDP)*(GDP/Pop)*Pop$$

  - Rebound & backfire can influence energy intensity
  - Growth in the developing world means that we can't rely simply on falling energy intensity

A Third and Low-Carbon 'Industrial Revolution'?

- A managed transition: can we develop the policies & institutions that stimulate
  - Penetration of more efficient *and* low carbon technologies?
  - The decline of less efficient & higher carbon incumbents?
  - Relative prices, resources and institutions: if Allen's (2009) messages about the 1st industrial revolution hold for this revolution, can we find the necessary institutional changes, relative prices, and physical, human & financial resources?
- My contention is that although circumstances have changed, appreciating insights from the successes & failures of past transitions can help us address the challenges of a low-carbon transition
  - Experiences across earlier centuries (and other countries) give us the long view
  - While experiences of particular C20 transitions offer pertinent insights that are relevant today

Transition Pathways to a Low Carbon Economy

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

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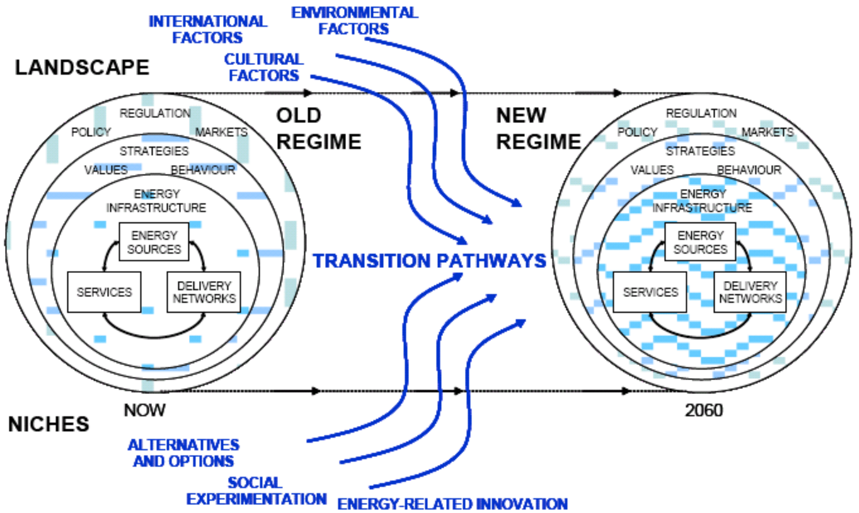

Figure 1: Possible Transition Pathways and the Factors that Influence them (Source: Transition pathways project team)

- Partners at 9 UK Universities are exploring the dynamics of transition pathways in the UK electricity system
- 80% GHG emissions cut by 2050 - how to get there from here?
- Pathways matter: analysis includes exploration of branching points, informed by historical analysis

For more, see http://www.lowcarbonpathways.org.uk

TRANSITION PATHWAYS

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Thank You!