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Energy innovation timescales and technology spillovers

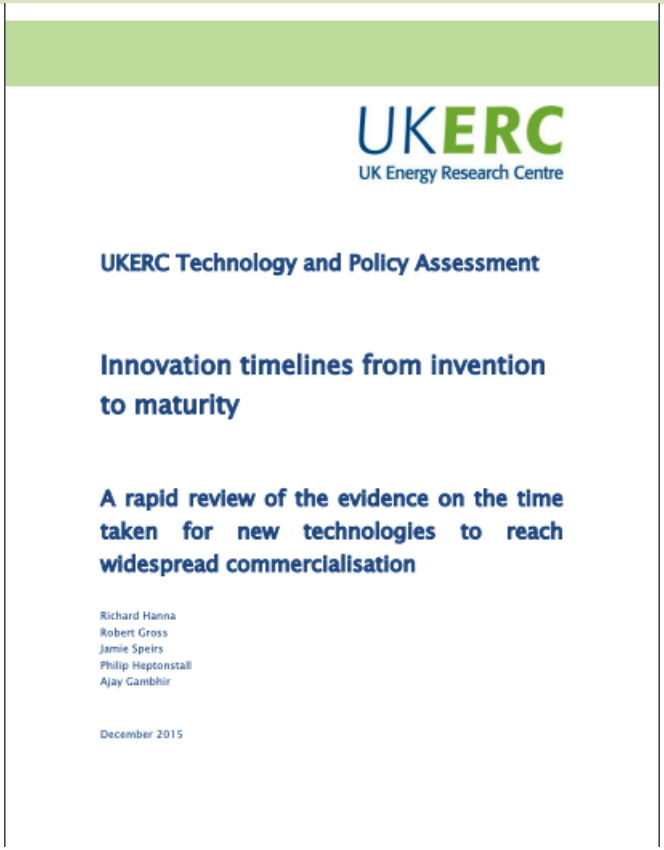
Dr Robert Gross
Dr Richard Hanna
Centre for Environmental Policy, Imperial College London

ETP-2020: Accelerating Clean Energy Technology Innovation
IEA, Paris,18 December 2019

Presentation structure

1. Background and relevant work
2. Innovation timescales: research approach and findings
3. Example evidence of technology spillovers
4. Three case studies: ATM / cash cards; CCGT; lithium ion batteries
5. Conclusions

Background and relevant work


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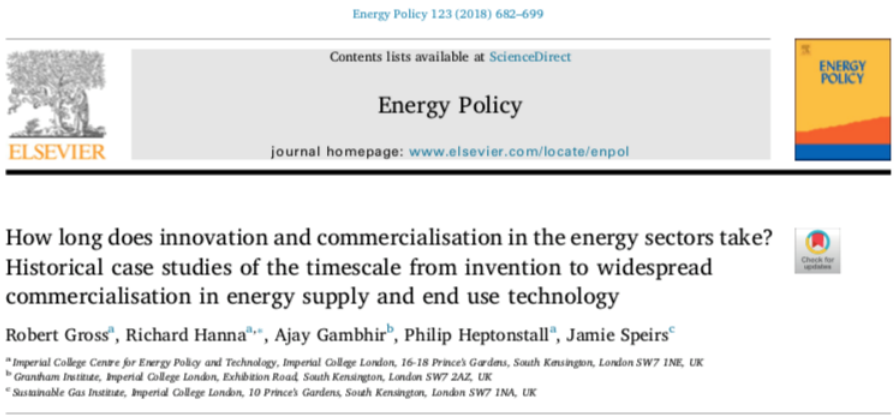
UKERC Technology and Policy Assessment

Innovation timelines from invention to maturity

A rapid review of the evidence on the time taken for new technologies to reach widespread commercialisation

Richard Hanna
Robert Gross
Jamie Speirs
Philip Heptonstall
Ajay Gambhir

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How long does innovation and commercialisation in the energy sectors take? Historical case studies of the timescale from invention to widespread commercialisation in energy supply and end use technology

Robert Gross[a], Richard Hanna[a,*], Ajay Gambhir[b], Philip Heptonstall[a], Jamie Speirs[c]

[a] Imperial College Centre for Energy Policy and Technology, Imperial College London, 16-18 Prince's Gardens, South Kensington, London SW7 1NE, UK
[b] Grantham Institute, Imperial College London, Exhibition Road, South Kensington, London SW7 2AZ, UK
[c] Sustainable Gas Institute, Imperial College London, 10 Prince's Gardens, South Kensington, London SW7 1NA, UK


Accelerating innovation towards net zero emissions

REPORT PREPARED FOR THE ALDERSGATE GROUP

:vivideconomics

Authors:
Alex Kazaglis, Aaron Tam and Dr. Jason Eis (Vivid Economics);
Prof. Jim Watson and Dr. Nicholas Hughes (UCL and UKERC);
Dr. Rob Gross and Dr. Richard Hanna (Imperial College London and UKERC).

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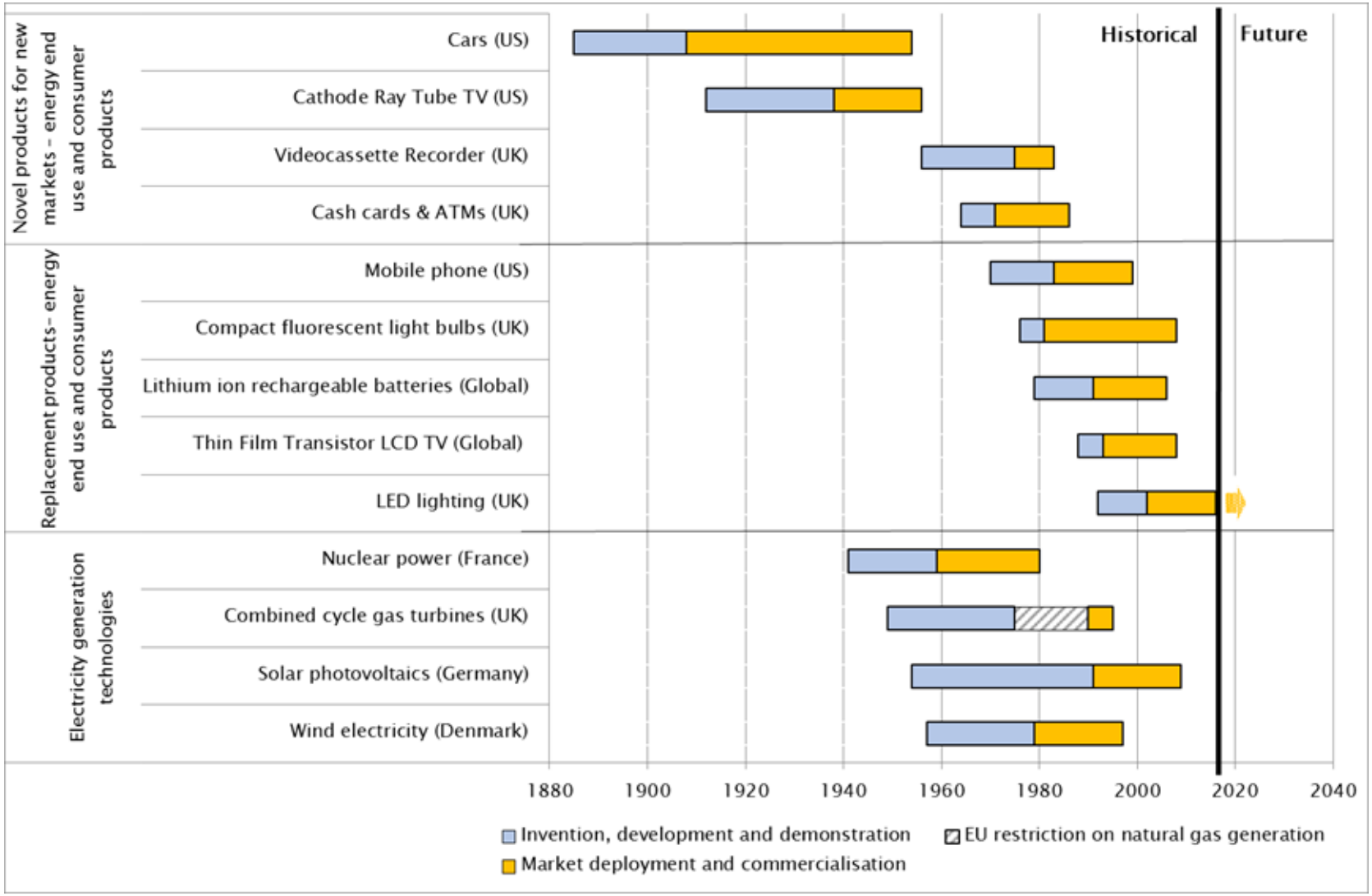
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Innovation timescales: research question and approach

"What is the evidence for the time new technological innovations take to reach commercial maturity?"

- A Rapid Evidence Assessment (REA) – a short but systematic assessment using Science Direct and World Cat
- Initial scope not constrained to energy technologies
- Examine the existing literature around innovation timescales
- Summarise the range of time technologies have taken to develop through the technological innovation system
- 13 innovations reviewed including five detailed energy-specific case studies: solar PV, CCGT, nuclear power, lithium ion batteries, CFL / LED lighting.

Innovation timescales – findings summary



Types of knowledge spillovers in energy technologies

Type of knowledge spillover	Definition
Intra-technology knowledge spillovers	Knowledge flows within the same type of energy technology
Inter-technology spillovers	Knowledge flows to or from other energy supply or end use technologies
External technology spillovers	Knowledge flows to or from technologies outside the energy sector

Table source: Adapted from Noailly & Shestalova (2017)

Knowledge flows and technology spillovers may also have an international dimension (Verdolini & Galeotti, 2011).

Patent analysis typically used to identify knowledge flows within and across technologies (e.g. Nemet, 2012; Noailly & Shestalova, 2017).

Technology spillovers: example evidence

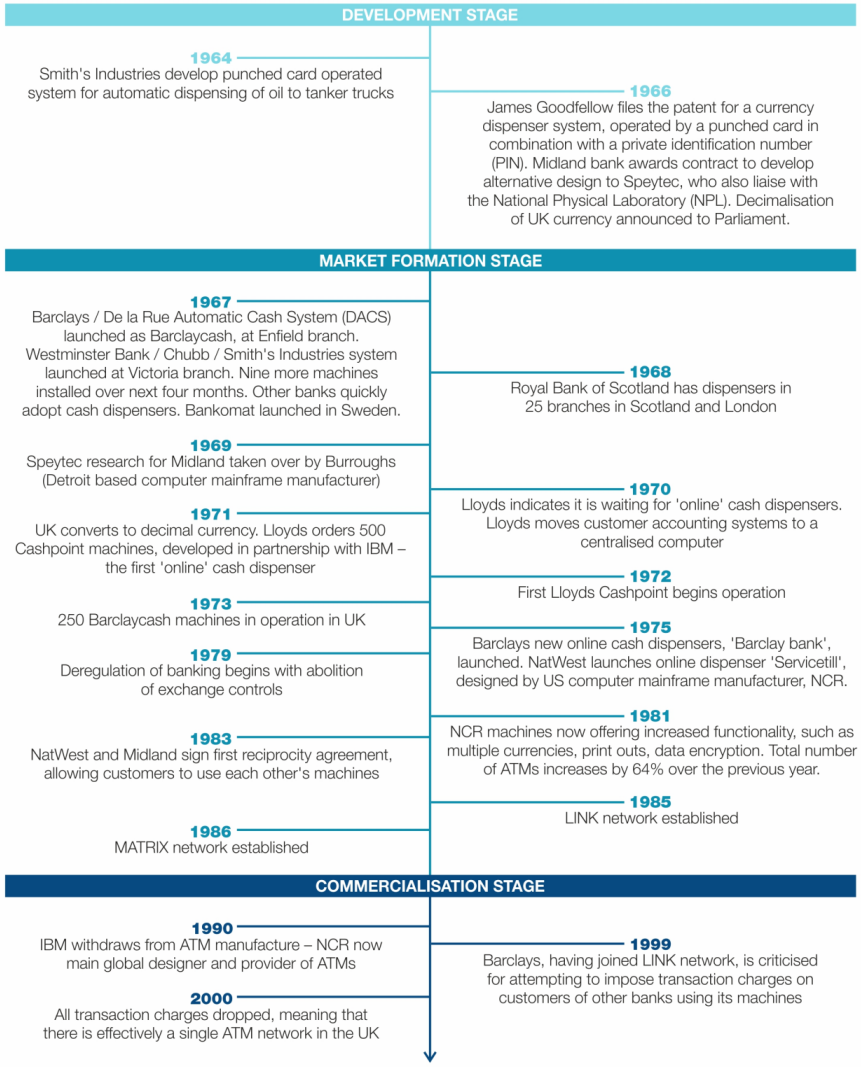
- Our detailed case studies support existing evidence in the innovation literature (e.g. Nemet, 2012) that knowledge from other (non-energy) technology sectors have been important in energy technology advances.

- *Innovation timescales review / related research examples:*
  - CCGT – Military / jet aircraft engines;
  - Solar PV – Space satellites, consumer electronics, semiconductors;
  - Lithium ion batteries for consumer electronics and electric vehicles;
  - ATMs / cash cards – Automatic oil dispensers and later use of ICT / online computerized systems.

- *Other examples from the literature:*
  - BIPV – Construction industry, carports with integrated PV and hybrid / electric vehicles, batteries and smart energy management (Gazis, 2019)
  - Wind turbines – Marine, aerospace, and power electronics industries (Nemet, 2012, Samaras, 2006)
  - Electricity, ICT and smart grids (Hiteva & Watson, 2019)

Cash dispensing systems and cash cards in the UK

- Early diffusion of ATMs and cash cards through offline machines drawing upon a spillover from automatic oil dispensers.
- ATM / cash card deployment was accelerated by harnessing ICT and online technology to offer additional benefits for consumers and businesses.
- Clear opportunity for digital technologies to increase flexibility and accelerate customer take-up of energy efficiency, low-carbon heating and clean mobility solutions.



CCGT (Europe, US, Japan)

Pre-invention period: related development (1873 – 1948)

- 1873 – Frank Stolze's first patents for designs similar to modern gas turbine technology.
- 1905 – Prototype gas turbine constructed by Armengaud and Lemale in France.
- 1925 – Combined cycle concept first developed with respect to mercury steam plants by Emmet.
- 1939 – First aircraft jet engine demonstrated b- Von Ohain's jet.
- 1941 – First jet aircraft flight in the UK by the Whittle engine.

Invention, development and demonstration (1949 – 1969)

1949 – General Electric installed a 'fully-fired combined cycle turbine' in the US.

- 1956 – Seippel and Bereuter of Brown Boveri installed a CCGT in Luxembourg.
- 1950s to mid-1960s – Limited CCGTs built, despite a range of applications (e.g. locomotive trains, ships and tanks.
- Mid-1960s – Electricity blackouts in USA and UK due to sudden peaks in demand.

Market deployment and commercialisation (1970 – 1994)

- 1970 – first 'large' CCGTs (greater than 100MW) sold by Mitsubishi and Brown Boveri in Japan and France
- 1973/4 – First oil shock – oil and gas not viable for power generation.
- Mid 1970s to mid-1980s – Complexity of CCGTs compounded by demand for larger units, leading to reliability problems.
- Late 1980s – Lower oil and gas prices allowed CCGT to out-compete coal-fired generation: rapid growth in orders for new CCGT plants.
- In 1994, CCGT plants achieve a 10% share of UK electricity generation

Key events leading to the commercialisation of CCGT

Compiled from Watson (1997a & b) and Kern (2012)

Lithium ion batteries

Invention, development and demonstration (1979-1990)

- 1973 – First non-rechargeable, lithium metal battery developed
- 1979 – Development of the lithium cobalt oxide positive electrode
- 1980 – Demonstration of the concept of the lithium ion rechargeable battery
- 1985 – First prototype cell using lithium cobalt oxide and graphite electrodes
- 1991 – First commercial, rechargeable lithium ion battery released

Market deployment and commercialisation (1991-1998)

- Mid 1990s - Introduction of lithium polymer battery format
- 1996-2004 - Development of phospho-olivine electrodes and improvement of performance through doping and nanoscale particles of iron phosphate
- 1998 – Global sales of lithium ion batteries achieve dominant market share for any rechargeable battery chemistry
- 2000 – Lithium ion batteries account for over 50% of rechargeable battery market
- 2007 – Lithium ion batteries represent 80% of rechargeable battery sales

Lithium ion batteries for electric vehicles – market growth (1995-)

- 1995 – First electric vehicle concepts to use lithium ion batteries released in Japan
- 2010 - Energy Density continues to increase above 200Wh/kg - ~5%/y
- 2012 – IEA estimates EV battery costs at US$485/kWh, $235 above $150 commercialisation target
- 2014 - EV fleet 0.8% of passenger cars and 50% growth on 2013
- 2015 – Cost of EV lithium ion batteries reducing at ~14% percent annually

Possible questions for discussion

Our research does not systematically review extent to which knowledge flows and technology spillovers may affect speed of energy innovation.

- What is the role of technology spillovers in accelerating time to market and wider deployment of low carbon technologies?
- Is rapid technological change more likely to result from knowledge spillovers which are more diversified (i.e. across sectors) vs more specialised (within sectors?)
- Which concurrent innovations, technologies and industries should be targeted by policies to maximise opportunities for spillovers to accelerate low carbon innovation?