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UKERC Technology and Policy Assessment

Innovation timelines from invention to maturity: A review of the evidence on the time taken for new technologies to reach widespread commercialisation

Project scoping note

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The Technology and Policy Assessment (TPA) Theme of UKERC

The Technology and Policy Assessment (TPA) theme was set up to inform decision-making processes and address key controversies in the energy field. It aims to provide authoritative and accessible reports that set very high standards for rigour and transparency. Subjects are chosen after extensive consultation with energy sector stakeholders and discussions with the UKERC Research Committee.

The primary objective of the TPA is to provide a thorough review of the current state of knowledge. New research, such as modelling or primary data gathering may be carried out when essential. It also aims to explain its findings in a way that is accessible to non-technical readers and is useful to policymakers.

In Phase III of UKERC the TPA team will be developing a new methodology for rapid evidence reviews and future work from the TPA will have more emphasis than previously on support for and integration with the UKERC research programme. There will be support for and integration with other UKERC research themes, the wider energy research community and external organisations.

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1 Introduction and background

The role and importance of technological innovation in reducing greenhouse gas emissions is well established in national and international policies and is already a key element in the Committee on Climate Change (CCC) advice to the UK government on carbon budgets (DECC 2012, CCC 2013, IPCC 2015). In addition, a substantial number of analyses emphasise the importance of government policies in promoting innovation directly – in part through support for research and development, but also through the creation of markets for emerging technologies (Anderson *et al.* 2001, Stern 2007, DECC 2012, Gross *et al.* 2012, CCC 2013, IPCC 2015). A central tenet of this analysis is that market creation facilitates cost reduction through allowing 'learning by doing' and by providing opportunities for market participants to realise economies of scale (Gross *et al.* 2013).

The creation of markets often relies upon targeted, technologically specific policies, for example feed in tariffs for renewable energy, where tariff rates are differentiated by technology (IEA 2008, Gross *et al.* 2012). This gives rise to debate about the affordability of large scale deployment subsidies and the role of governments in deciding which technologies to support (Helm 2010, Gross *et al.* 2012, Less 2012). A related argument is associated with how governments should determine the balance between support for deployment and incremental improvement in existing technologies and support for 'blue skies' R&D which seeks to develop new technologies (Helm 2012, House of Lords 2015).

Some protagonists argue that large scale support for deployment should be substantially reduced and support for R&D scaled up on the basis that "none of the current renewables are capable of bridging the gap toward decarbonisation" (Helm 2012). There is a substantial literature on 'innovation systems', much of which suggests that the notion that it is possible to promote innovation in the absence of targeted

measures to create market opportunities for early stage technologies is likely to be misguided (IEA 2000, Anderson *et al.* 2001, Foxon *et al.* 2005, Gross *et al.* 2012, REN 21 2012).

However a key consideration that has received less attention in the literature is the amount of *time* required for a new technology to emerge from fundamental research, go through demonstration and early stage deployment and diffuse into the market place, and it these timescales that are the focus of this TPA project.

If any new low carbon technologies are to play a substantial role in reducing carbon emissions then it will be necessary for them to be proven, available and *deployed at a scale that is sufficient for them to make a material impact.* In the case of many end-use technologies that reduce demand for energy or move away from fossil fuels (such as efficient products, insulation, electric cars) then in order to make a material impact on carbon emissions they will need to be deployed in very large numbers, usually of the order of tens of millions of units in the UK alone.

In the case of some new energy supply technologies such as new nuclear power stations, carbon capture plants, or offshore wind farms the number of units that need to be deployed may be quite small. However each individual unit usually represents a large, complex construction/infrastructure project that will take many years to build and cost many billions of pounds. In many cases supporting infrastructures also need to be built, adapted or upgraded – examples are new offshore power lines, CO_2 transport and storage systems, distribution networks or district heating systems.

2. The research question for this project

Since it is possible that many years, possibly decades, will elapse before any entirely new carbon abatement innovation can make a material impact on emissions, this project therefore asks:

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

The project will seek to compare and contrast technologies with different characteristics and scales of deployment, from household scale consumer devices to large power stations. The work will consider how rapidly consumer innovations from outside the energy arena took to diffuse into the market as well as assessing cases more often cited in the literature associated with carbon abatement and energy.

The project will answer the research question by addressing the following objectives:

- Establish the concepts around technological innovation and the time to commercialisation.
- Examine the existing literature around the time technologies take to develop to commercial maturity.
- Conduct selected case studies examining the time it takes for selected energy technologies to go from basic research to commercialisation.
- Conclude on the range of time technologies are likely to take to develop through the technological innovation system and the implications for the opportunities to improve that timescale.

3. Scope of the project

The project will compare the innovation rates of a mixture of energy sector and non-energy sector innovations, which will be selected based on a systematic literature review. The target is for around 15 innovations to be considered, which will be classified according to whether they are new or replacement products, or energy generation technologies.

The project will also undertake a smaller number (around four or five) of brief case studies of particularly relevant specific technologies such as combined cycle gas turbines (CCGT), nuclear power, solar photovoltaics (PV) and energy efficient lighting.

4. Proposed approach

The research will be conducted using a Rapid Evidence Assessment (REA), defined as "a short but systematic assessment on a constrained topic" (GSR 2013). REA's have been designed to maintain the rigour of a full systematic review, but to deliver results rapidly within constraints imposed by cost and time (Hailey *et al.* 2000, Khangura *et al.* 2012).

The proposed approach follows the procedures established in previous TPA assessments, which are directly comparable to established protocols for conducting REAs (Collins *et al.* 2014). As such the REA will involve the following steps:

- Publication of this scoping note on the UKERC website.
- Establishing a small group of experts, representing a variety of opinions and perspectives, to advise the project team; this will be carried out through a streamlined consultation process (i.e. using electronic consultations rather than meetings).
- A systematic search of a clearly defined evidence base using keywords.

- Categorisation, prioritisation and analysis of the evidence, including an appraisal of methodological quality.
- Drafting of a report.
- Expert feedback and peer review of this draft report.
- Publication and dissemination through appropriate mechanisms.

The methodological lessons that emerge from this project will also help inform the TPA team's approach to further Rapid Evidence Reviews during Phase III of the UKERC programme.

5. Identifying evidence

Given the short timescales available and the status of the study as a rapid evidence assessment, evidence will be identified through keyword searches limited to two databases: Elsevier Science Direct (http://www.sciencedirect.com) and World Cat (http://imperialcollegelondon.worldcat.org/), using Boolean combinations of relevant terms. Initially, innovation and temporal keywords will be used as the search terms (see Table 1), which will then focused by combining them with specific technologies or products identified in the literature search as being instructive to the research aims. The search terms will be revised if necessary during the course of the project.

Returned results will be filtered for relevance based on their title and abstract. If this is not sufficient to determine relevance, further inspection of the main text will be performed. The criteria for relevance is that, in relation to innovative technologies or products, the document considers some or all of the following:

- Timescales from basic research to commercialisation.

- Specific timescales of individual stages of the product or technology life cycle.
- Relevant historical information pertaining to the historical development of a given innovation.

Following the filtering of retained search results, key descriptive information of each of the results will be captured, namely:

- The innovative product or technology considered.
- The timescales for specific innovation stages presented.
- The geographic region that each result relates to (if not global).

Given that the global scale is of primary interest, regional or national scale descriptors will be used to constrain the number of studies, such that, in addition to those studies with a global scope, only studies focused on OECD or EU (including the UK) countries, the USA or Japan will be examined in detail.

Table 1: Proposed initial set of keywords selected for use in the search terms

Initial search term categories		**Subsequent search term filters**
Innovation	**Temporal**	**Innovative technology or product**
Innovation Research Mass market "Market saturation"	Time Life Cycle Rate	Cars / automobiles "Catalytic converter" "Lithium ion" AND "car batteries" "Lithium ion" AND "rechargeable batteries" Television / "Cathode Ray Tube TV" / "CRT

Commercialisation Deployment Diffusion Uptake "Innovation life cycle" "Technology life cycle" Technology "Product development"	Speed History	TV"/ "Liquid Crystal Display TV" / "LCD TV" "Automatic Teller Machine" / ATM / "cash cards" "Videocassette recorder" / VCR Photocopier / "plain paper copier" "Mobile phone" "Compact fluorescent light bulbs" / CFLs "LED light bulbs" / "LED lamps" "Combined cycle gas turbines" / CCGT "Wind electricity" "Nuclear power" "Solar photovoltaics" / "solar PV"

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