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1. United Nations Framework Convention on Climate Change, Paris Agreement: http://unfccc.int/paris_agreement/items/9485.php

European Commission

Science for Environment Policy

Which new low-carbon technologies can be developed and commercialised quickly? New research offers analysis

A new study provides clues as to which innovative low-carbon technologies will successfully get onto the market quickly. The historical analysis of 16 energy technologies — from steam engines to wind power — found that the average length of a product's 'formative phase' is 22 years. This important period of innovation in a technology's development is shorter for products which do not need extensive new infrastructure or changes to user behaviour. The findings could help policymakers identify new technologies that can be deployed more rapidly to meet short-term environmental targets.

Strict environmental targets, such as those set for climate change under the Paris agreement[1], often call for new technologies to be quickly developed and put onto the market. This entails speeding up innovation and commercialisation processes, but history provides many examples of premature technologies which have been pushed forward by policy pressures — and then failed. Examples include the breeder reactor (a type of nuclear reactor) and synthetic fuel (synfuel) production in the US in the early 1980s.

This new study analysed the 'formative phases' of 16 different energy technologies in order to help understand how long it takes to get to market, and what affects the duration of this phase. The formative phase is the early period of a technology's development, which sets up the conditions for widespread commercialisation. Broadly speaking, it begins when a number of firms innovate a number of products in response to a new pressure, such as regulatory change or changes in customer preference. The phase ends when the products have been refined to establish one dominant design that is typically produced by fewer companies for an expanding market.

The researchers first developed a set of indicators for marking the beginning and end of the formative phase to define and compare the length of the phase across different products. Indicators to mark the beginning were agreed as: the date of the first prototype or demonstration, the first commercial application outside the lab, and the first 'sequential commercialisation' — that is, the first commercial application which leads to a series of products (i.e. the product is not just a one-off).

Indicators to mark the end of the phase were agreed as: the date when 2.5% of potential users have adopted the technology; when the number of firms producing the technology peaks or changes; when the production cost becomes significantly lower; and when 10% of the eventual market is saturated. The researchers used data for specific markets for each technology, such as individual countries.

The researchers applied these indicators to 16 established, diverse energy-using and -producing technologies and products. These included wind farms in Denmark, cars in the US and e-bikes in China as well as older technology such as the steam engine and the bicycle.

The products' overall formative phases, from the date of the first indicator to the date of the last, were between five and 168 years, with a mean average of 75 years. However, to define a more plausible 'central' formative phase, the researchers then focused on what they considered to be the two most important indicators (based on standard literature of innovation and technology lifecycles) — the date of the first sequential commercialisation and the date when 2.5% of potential users have adopted the technology.

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Using these two indicators, the 'central' formative phases were calculated to range from four to 85 years, with a mean average of 22 years.

Products with the shortest formative phases tended to be substitutes for existing products with established infrastructure, institutions and user expectations. For example, wind power in Denmark had a short central formative phase of 15 years because it could slot into existing electricity networks and markets. In contrast, steam engines in the UK and the USA, which needed new mining and industry services, had a formative phase of 85 years.

The analysis also suggested that environmental technologies tended to have longer central formative phases (average 24 years) than non-environmental technologies (average 15 years), because they depend more on supporting regulation. Factors which did *not* appear to affect the length of the formative phase included the scale of the product, the initial cost and the length of the lifetime.

Lessons may be drawn from this study to identify which current and future low-carbon technologies can quickly reach market and become commercial successes with policy support. The researchers suggest that ready substitutes for existing technologies, such as centralised low-carbon power production and hybrid-electric vehicles, meet more of the criteria for short formative phases than carbon capture and storage, which needs new carbon-dioxide pipeline infrastructure; or than electric vehicles, which demand new driving practices.

The researchers also emphasise that promoting premature technology, while bypassing key formative processes, can result in expensive interventions or even failures, as opposed to a more stable and integrated approach.

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