Energy Research & Social Science 22 (2016) 7–12

Contents lists available at ScienceDirect

Energy Research & Social Science

journal homepage: www.elsevier.com/locate/erss

Short communication

Historical energy transitions: Speed, prices and system transformation☆

Roger Fouquet

Grantham Research Institute on Climate Change and the Environment London School of Economics and Political Science (LSE), United Kingdom

ARTICLE INFO

Article history:
Received 30 June 2016
Received in revised form 13 July 2016
Accepted 22 August 2016
Available online 6 September 2016

Keyword:
Energy transitions

ABSTRACT

The relatively rare and protracted nature of energy transitions implies that it is vital to look at historical experiences for lessons about how they might unfold in the future. The fastest historical sector-specific energy transitions observed here was thirty years. However, full energy transitions, involving all sectors and services, have taken much longer. Ultimately, the price of energy services played a crucial role in creating the incentives to stimulate energy transitions, but energy price shocks may have acted as a catalyst for stimulating processes that led to certain energy transitions. An additional key factor is whether the new technology offers new characteristics of value to the consumer, which can help create a market even when the initial price is higher. A crucial factor that can delay a transition is the reaction of the incumbent and declining industries. Nevertheless, governments have, in a few instances, created the institutional setting to stimulate energy transitions to low-polluting energy sources, and this could be done again, if the political will and alternative energy sources were available. Finally, past energy transitions have had major impacts on the incumbent industries which have declined, on economic transformations and on inequality.

1. Introduction

Since the beginning of the Industrial Revolution, the global economy has extracted and used 0.5 trillion tonnes of oil equivalent of fossil fuels (see Fig. 1) and has led to 1.2 trillion tonnes of carbon dioxide emissions. The rising global emissions, along with other greenhouse gas emissions, are threatening to intensify climate change. This threat means that fossil fuels, without worldwide carbon capture and sequestration mechanism or successful geo-engineering projects, will impose a rising burden on the atmosphere. This burden highlights the potential benefits from a transition out of fossil fuels to low carbon energy sources.

Because energy transitions are seen by many scholars and analysts to be relatively rare and protracted processes, it is important to look at historical experiences for lessons about how they might unfold in the future. The literature on historical energy transitions has blossomed in the last ten years [22,25,5,39,36,1,3,59,50,43,33,28,32]. Perhaps triggered by unfolding events, and partly stimulated by the special issue in this journal, research output on using experiences from past energy transitions to inform the present and future policies has accelerated [48,52,8,2,45].

With this in mind, the purpose of this piece is to draw particularly on my own historical and long run research to offer some lessons about energy transitions. To contribute to a more refined or at least reflexive take on energy transitions, this short communication starts by reviewing the speed of past energy transitions. Afterwards, the role of prices in driving transitions is discussed. This is followed by a comment on incumbent industries that declined, with a focus on the experience of the coal industry. Then, the paper examines the impact of energy transitions on consumption patterns, economic development and inequality. Then, it explores past experiences in which environmental policy may have influenced energy transitions.

2. The speed of historical energy transitions

Since the Industrial Revolution, it has taken, on average, nearly fifty years for sector-specific energy transitions (i.e. the diffusion of energy sources and technologies) to unfold in the United Kingdom [15]. Here, the definition used for a transition was from 5% to 80% (or the peak, if it did not reach 80%) of the energy consumption for a particular service (e.g., heating, power, transportation or lighting) in a specific sector – as Sovacool [52] points-out in his conclusion,

☆ I would like to thank Benjamin Sovacool for comments related to this paper. Support for this research from the ESRC is gratefully acknowledged.

E-mail address: r.fouquet@lse.ac.uk

http://dx.doi.org/10.1016/j.erss.2016.08.014
2214-6296/

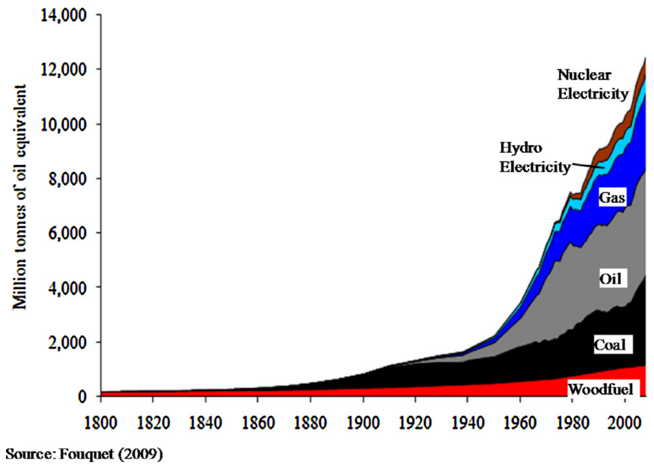

Fig. 1. Global Primary Energy Consumption, 1800–2010 [14].

the definition is critical for determining the duration of transitions. As shown in Table 1, the average duration of the innovation chain (i.e., from the invention of the key technology to 80% share of energy consumption, or to the peak) was 95 years.

To put this in context, the wind turbine (which converted wind power into electricity) was introduced in the 1880s. More recently, the invention of solar photovoltaics (SPV) was in 1954. In other words, it is unlikely that either technology will meet the average duration of the innovation chain for successful energy transitions (although, SPVs may still do so, if they reach a share of 80% by 2050). However, it could be argued that because of the large number of inventions in energy technologies in the last 150 years, the strong path dependence in modern energy systems has delayed the uptake of certain technologies [19].

The shortest period between invention and uptake was ten years. This occurred in the cases of gas and kerosene lighting. The lack of technological lock-ins (as they were competing with the primitive tallow candles), the dramatically superior qualities of the energy source and the technology compared with the incumbent and the great demand for lighting in the nineteenth century implied that the innovation chain was exceptionally rapid [21]. The fastest diffusion was from horse to railways in the mid-nineteenth century and steam engines to electricity in the first-half of the twentieth century. These new technologies and energy sources provided cheaper and better quality services. As a result, despite the need for an infrastructure to use the new energy source or technology, both made the transition very quickly – in 30 years.

In other words, the speed of uptake of new technologies and energy transitions is influenced by the rise in demand for energy services. Faster growth (due to high income elasticities and rising incomes, which will be discussed below) is likely to imply a faster potential energy transitions. This also suggests that energy transitions may be more demand-led. Alternatively, when income elasticities are low, demand may be less of a driver of energy transitions. When income elasticities are low, such as at high levels of economic development, energy transitions may have to be led by supply-side transformations. Thus, the policy drivers for stimulating energy transitions in developing economies and post-industrialised economies may be very different.

Rubio and Folchi [47] present evidence on the energy transitions from coal to oil for 20 Latin American countries over the first half of the 20th century. They argue that these small energy consumers had earlier and faster transitions than leading nations. By outlining a whole series of energy transitions, they identify a number of different energy transition processes. Factors such as domestic energy resources, the size of the internal market for energy services, trade relations and policy decisions have been important in determining the nature and speed of the transitions experienced. They suggest that the lessons will be particularly relevant for understanding the way in which non-pioneering countries might adopt low carbon energy sources and technologies.

Underlying every full energy transition – from biomass to coal, coal to oil or oil to natural gas – is a disaggregation of a number of sectors and services. For every sector (including the residential, industrial and transport sectors) and for every services (e.g., heating and lighting), technological and institutional solutions needed to be developed to achieve a specific transition. The technology and institutions needed for each individual transition often differed for each sector and service. As a result, there has been a tendency towards very slow full or aggregated energy transitions (for a more detailed discussion of the complexities of transforming energy systems, see Refs. [29,51]. Whether a full transition can be accelerated, as Sovacool [52], Kern and Rogge [35] and Bromley [7] argue, depends on creating all the correct conditions for this to occur.

3. The role of prices in energy transitions

For each individual energy transition, the technology or new energy source that emerged and would eventually become dominant started as a niche product. A small group of consumers were willing to pay a premium for the energy services attached to the new technology. A successful new energy source or technology provided the same service (i.e. heating, power, transport or light) with superior or additional characteristics (e.g. easier, cleaner or more flexible to use). For instance, electric lighting in the late nineteenth century, which was more costly than gas lighting, offered a novelty factor that expensive restaurants and theatres were willing to pay for. Over time, economies of scale subsequently improved the technology and the price of the energy source, driving down the cost of generating energy services, making it competitive with the incumbent energy technology and source.

However, the price of the energy service is crucial for achieving a full energy transition. If the price of the service fell sufficiently (either because the energy efficiency improved or the price of energy declined), full transitions could occur. For instance, kerosene was used for lighting in the late 1800s largely by the poor and rural population that could not afford the investment in the infrastructure to supply gas to their homes. However, in urban areas, the price of kerosene lighting never dropped cheap enough to compete with gas lighting (once piping was installed) and, there-

Table 1
The Average Duration of Energy Transitions in the United Kingdom.

	Period	Driver	Duration of Innovation Chain	Duration of Diffusion
Shortest	700–2000	–	50 years	30 years
Average	700–2000	–	245 years	125 years
Average	1700–2000	–	95 years	49 years
Average	1700–2000	Cheaper Service	65 years	40 years
Average	1700–2000	Better Service	155 years	51 years

Source: Fouquet [15].