



Influences on energy supply infrastructure: A comparison of different theoretical perspectives



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ABSTRACT

Changes to the energy supply infrastructure are a vital component of climate change mitigation strategies. But what exactly underlies changes to energy supply infrastructure? This paper, through exploration and critical analysis of relevant literature, explores the various underpinning influences on energy infrastructure supply using a comparison of different theoretical perspectives. These influences were explored with specific emphasis on techno-economics, social psychology, socio-technical transitions, social practices and institutional dimensions to energy supply. The aim was to have a better understanding of the (direct and indirect) role of politics and the political system in influencing energy supply infrastructure decisions through the various theoretical lenses. The study revealed that techno-economics uses financial instruments and market information as intervention tools. Its effectiveness is measured by social welfare and cost effectiveness. Social psychology uses a combination of information, incentives and innovative informative instruments as its intervention tools. Its effectiveness is measured by behavioural change. Institutions use regulatory instruments as its intervention tool. Its effectiveness is measured by regulatory compliance. Social practices look at change in broader social systems. Its effectiveness is measured by social change. Socio-technical transitions focus on determining social movements and social innovations. Its effectiveness is measured by legitimacy and social learning.

1. Introduction

Over recent decades, there has been considerable effort dedicated to better evaluating the empirical and theoretical contributions of energy supply infrastructure to economic growth and development [1–3]. Connected to this, attention has also been given to the connection between infrastructure and poverty [4]. Even though current literatures on these topics appear completely distinct a consensus has been reached [5] that, under the right conditions, energy infrastructure development can play a major role in economic development through promoting growth.

A considerable part of today's prosperity rests on stable and secure access to energy [6]. For example, as experienced in most parts of the developing world - particularly in Africa - modern production grinds to a halt without the requisite energy infrastructure. Indeed Sorrell [7] argues that infrastructure has major implications for a variety of development outcomes at three different levels: (1) the household level, through social mobility, education and health; (2) the firm level, through industrial development and productivity; and (3) the global level, through climate change issues. However, what underlies changes

in energy infrastructure provision, and to what extent would the research community (dis)agree over such changes/influences? It is in this way that *theory* needs discussion; “theory is a statement of concepts and their interrelationships that shows how and/or why a phenomenon occurs” (pg.12) [8].

Based on this context, the purpose of this paper is to critically review different understandings of the various factors, elements, processes and systems involved in the energy supply infrastructure provision. Specifically, this review analyses the theoretical reasoning of five perspectives, each of which puts forward its own rationale for explaining how new energy supply infrastructure has come to be:

1. Techno-economics
2. Social psychology
3. Theories of practice
4. Institutions
5. Socio-technical transitions

It is important to acknowledge that different perspectives exist beyond these five. Nevertheless these five perspectives span the range

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of the micro, meso and macro, in terms of conceptual and analytical foci. These perspectives also, in many ways, epitomise some of the current dominant trends in distinct social science disciplines: techno-economics reflects Neoclassical Economics and some aspects of Behavioural Economics; Social Psychology is indeed a discipline too, as well as a perspective; institutional perspective reflect traditions in Political Science that examine the organization and dynamics within the political and policymaking institutions; theories of practice is very prevalent in current Sociology research; and the socio-technical transitions perspective reflects much of the current thinking in parts of Innovation Studies and Science and Technology Studies. Relatedly, it is important to acknowledge that other perspectives exist within these disciplines too, such as how some traditional sociological perspectives may prioritise the division and distribution of labour across society [9], or indeed other social structural issues such as the class or gender. Nevertheless, selecting these five approaches serves to give the reader a taster of the different assumptions and approaches that may be utilised when researching and conceptualising change in infrastructure – ultimately, it is for the reader to reflect on their own point of departure, as part of facilitating the adoption of a considered position.

This review explores how each theoretical perspective may broadly seek to explain changes in energy supply infrastructure, in addition to simply providing an overview of some key findings from each set of literature. Moreover, the purpose of this paper is intentionally not to advocate for one particular theoretical perspective, but instead, to make clearer the salient questions and underlying assumptions for various perspectives.

In this review, the concept of energy supply infrastructure is first introduced for background context purposes (Section 2), the materials and methods utilised are presented (Section 3), and subsequently the various influences are presented, as per the various theoretical perspectives (Section 4). The exploration of the various perspectives starts with those that are linked more with individual cognition (techno-economics and social psychology), before moving to discuss those perspectives that are based more on social context (socio-technical transitions). It also considers two perspectives that situated in the middle ground between these individualistic and social structural perspectives. These two middle ground perspectives are focussed on social practices and institutional dimensions. The paper then finishes by identifying and discussing how these perspectives try to address the changes in energy infrastructure (Section 5).

2. Background: what is energy supply infrastructure?

There is currently no universally accepted definition as to what energy supply infrastructure is. However, many authors have provided explanations to various subsets of energy infrastructure, with examples including electricity infrastructure [10]; petroleum infrastructure [11]; natural gas infrastructure [12]; renewable energy infrastructure [13,14]. Based upon this fragmented set of literatures, we hereby define energy infrastructure as representing the (small- and large-scale) enablers that help, directly or indirectly, with the extraction, production, transportation, and management of energy from producer to consumer. In line with this definition, also included are traditional utilities associated with energy management and transport, such as: coal fired trains [15], electricity transmission lines [16], electricity generation plants [17], and oil and gas pipelines [11]. It also includes large-scale energy management technologies such as: smart grids [18,19], smart building technologies [20], modern power plants control systems, and advanced electricity distribution and metering systems [21,22].

We argue that energy supply, in its strictest sense, is *not created* out of nothing but is inevitably *influenced* in an active and often iterative way. It is exactly this discussion that this review will contribute to. Indeed, there are many ways in which ‘influences’ can be said to arise and be said to shape the physical outcomes of and likely directions for

energy supply infrastructure. Consequently, different perspectives will give agency to different sources, actors, evidence bases, and also inherently disagree with regard to its treatment of context (e.g. in ontological and epistemological terms) and scale.

3. Material and methods

This paper critically considers existing published literatures in order to understand the various influences underpinning energy supply infrastructure decisions, within and outside of the political sphere. Some of the literatures include the International Energy Agency (IEA) world energy investment outlook report 2014, the IEA world energy outlook special report 2015, published literatures from different sources in the fields of theories of practice, socio-technical transitions, social psychology, techno-economics and institutional theory in order to understand the contribution of these fields to the understanding of energy supply infrastructure decisions and provisions. A snowballing strategy was employed as part of identifying the relevant literature for consideration and, inevitably, not all the papers that were considered are actually included within this review paper.

In investigating the (deemed) influences on energy supply infrastructure, different strands of literature have been explored. In Table 1, the various perspectives are presented, while highlighting the level with which they tend to operate in practical terms. The units of analyses for the techno-economics and social psychology perspectives exist at the *micro* (individual-scale) level, where the focus is more on the individual. Contrastingly, the units of analyses for the socio-technical transitions perspective exist at the *macro* (societal-scale) level, whereby there is a shift in focus from the ‘individual’ to social structures and contexts. However, theories of practices and institutional perspectives operate more at the *meso* (middle) level, which provides a middle ground between the individualistic perspectives and the structural perspectives. Table 1 briefly highlights selected papers that implicitly/explicitly represent each of the five perspectives, and as such embody much of the discussion in the following section.

The positioning of these different perspectives will inevitably shape the empirical contributions from each of these respective points of departure. For instance, Table 2 illustratively presents an alternative example of how mobility (transportation) links to the various perspectives and how addressing different points of foci lead to an eventual need for the supply of certain infrastructure.

Ultimately, the use of theory as a tool for research investigation helps in three major ways: first, it constitutes that which underpins a research design; secondly, it constitutes that which informs our understanding of the phenomenon under investigation; and finally, it constitutes that which emerges from our study [23].

4. Comparing perspectives: influences on energy supply infrastructure provision

In this section, the five theoretical perspectives are explored in order to understand the influences on energy supply infrastructure, particularly relating to the provision of new (and the changing of the old) infrastructure. Throughout the section, a prominent thread of the indirect role of politics in influencing increased energy supply infrastructure is also considered. By ‘indirect role’, we are referring to the various routes by which politics, and individuals within politics, impact energy supply infrastructure above and beyond direct legislation or public investment.

Before going in depth into current research within each perspective (sub-sections 4.1–4.5), Table 3 summarises the overarching foci of each perspective in relation to the issue of energy supply infrastructure provision. It shows the movement in focus of the various theoretical perspectives from individual cognition towards social context/structures. This Table 3 therefore provides a zoom-out contextual overview of this section as a whole.

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