Energy Systems Integration: Economics of a New Paradigm

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Executive summary

1. Motivations underlying the research

Currently there is a debate about the future energy paradigm and its reliance on Energy Systems Integration (ESI) both in developed and developing countries. ESI is based on a holistic view in which the main energy carriers are integrated to achieve synergies and efficiencies at all levels. The main stimulus for the deployment of this concept is the idea that its development will produce some co-benefits that will help to address the objectives of the energy trilemma, i.e., energy security, energy equity, and environmental sustainability. Broadly speaking, it can be described as the process of devising a short-term and long-term management of energy systems through alternative means and at different geographic scales with the aim of delivering energy and other essential services while the energy trilemma goals are achieved.

Recently there has been an emerging literature focused on discussing technical aspects related to ESI. However, such systems require not only physical solutions but also economic, regulatory, and policy frameworks to ensure an efficient performance over time. However, to our knowledge, there is a lack of research that discusses the diverse economic features of integrated energy systems. It should be noted that there is nothing automatic about the benefits of integrated systems as opposed to non-integrated ones. The performance of the integrated systems and their design will ultimately be determined by the economic and regulatory framework and rules.

2. A short account of the research performed

While ESI presents some obvious efficiency benefits, such as reducing the transaction costs, providing flexibility to meet the demand for energy services, and horizontal and vertical economies of scope, it also presents some challenges. This paper attempts to be a primer on certain relevant economic aspects related to ESI from the point of view of industrial organisation, regulation, business, and technology. First, we discuss how the economies of scope, scale, and coordination may yield changes in the vertically-unbundled and increasingly decentralised (distributed generation, electric vehicles, storage, etc.) utilities sector.

We highlight the potential links between utility networks and discuss examples of 'partially' integrated energy systems such as smart grids or cogeneration solutions. The evolution of the utilities sector (particularly telecommunications and electricity) is examined to identify trends and similarities that have led to changes in the products and services provided by these industries while the main changes happened in the regulation of the sectors are described. We also discuss the arising of multi-utilities and new business models, and the pros and cons of multi-sector regulation, along with the essential role that Information and Communication Technology (ICT) will have in these systems.

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3. Main conclusions and policy implications of the work

An integrated energy system will bring about inevitable changes in the business models of the incumbent firms as well as emergence of new ones. Multi-utilities are likely to emerge to benefit from horizontal and vertical economies of scope, but this will pose practical economic and regulatory challenges. Regulatory framework should enable new business models to evolve in both the competitive and regulated parts of the system. Integrated infrastructure systems will also revise the issue of multi-sector regulation. It is noteworthy that a distortion even in one constituent sector of an integrated energy system may require a complete adjustment of the whole regulatory system. This derives from the general theory of the second best, which also implies that integrating an efficient sector with an inefficient one may result in a social welfare reduction.

The unbundled but vertically dependent sectors will remain highly dependent on their networks to deliver system integration. It is through networks that the system can integrate diverse generation resources and aggregate demand. In this sense, utilisation of network externalities and benefits in the integrated sectors will be a key feature of ESI. New technologies will be the main facilitator of the integrated systems. New technologies will enable physical interaction of different activities in new ways. However, ICT will be the catalyst of system integration by allowing efficient utilisation of physical systems while facilitating the role of economic mechanisms in integrated systems.

Technical data are required for planning, operation, and maintenance of energy networks. In addition, other relevant information for the system are commercial, financial, and even other external data (e.g., statistics provided by weather forecasting services). Such data are increasingly valuable to network operators and market participants as the share of renewable energy connected to transmission, distribution, and consumer premises increases. As the energy markets increasingly move towards service and value-based propositions, the importance of ICT in provision of them will also grow. This entails a higher harmonisation of systems and information standards, which are focused on the data exchanged by different entities, and communication standards, focused on the physical infrastructure.

This paper is the first attempt towards outlining the economic aspects of energy system integration. Several topics addressed deserve further examination, while other areas such as the social and behavioural aspects of system integration need to be studied. Additional analysis is needed to further develop the socioeconomic issues of energy system integration. Future lines of research include discussing the definition of ESI based on real data and measuring to what extent an integration of energy systems has already been achieved. ESI will be context-specific and hence will take different forms depending on the particular conditions of each system. However, if we assume the pillars of the energy trilemma as the main goals of ESI, it will be helpful to perform policy analyses to inform decision-making and the success in achieving the intended targets.