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## Editorial

# Challenges for R&D and innovation in energy



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### ABSTRACT

In recent years, there has been a growing interest in the role of R&D and innovation in energy efficiency and dealing with climate change. To improve our knowledge in these matters a workshop was organized in Barcelona, Spain, in January 2014. This introduction to the special issue first presents some insights from the literature on challenges for R&D and innovation in energy. The second section summarises the articles from this workshop that make up this special issue and that provide new insights into innovation in energy. All the articles include energy policy recommendations based on the empirical analyses carried out.

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## 1. Introduction: challenges for R&D and innovation in energy

The important role that innovation has in improving energy efficiency, competitiveness and facing the challenges posed by climatic change has led to an increasing interest in knowledge about innovation and R&D activities in the energy sector and in the proper public policies to promote these activities (Alic et al., 2010; Anadon et al., 2011; OECD, 2011; Economics for Energy, 2013; Costa-Campi et al., 2014; Jamasb and Pollitt, 2015). Although there is a consensus on the economic and environmental benefits of developing new energy technologies and that innovation is a key factor in achieving energy objectives related with efficiency, environmental impact and security of supply, our knowledge on how to foster them remains insufficient.

Most empirical analyses of R&D and innovation in energy firms have focused on the effects of the liberalization process on R&D and innovation projects and activities (Markard and Truffer, 2006; Jamasb and Pollitt 2008; Sanyal and Cohen, 2009; Salies, 2010; Kim et al., 2012; Sterlacchini, 2012; Sanyal and Ghosh, 2013). More recently, some empirical analyses have examined the R&D determinants and the obstacles to innovation after liberalization (Salies, 2010; Sterlacchini, 2012; Sanyal and Ghosh, 2013; Costa-Campi et al., 2014). In addition, public policies and institutional framework characteristics have received considerable attention in the analysis of the energy innovation system (see, among others, Gallagher et al., 2012).

The energy industry, despite its importance in the economy, has traditionally shown a low level of expenditure on R&D (GEA, 2012). Moreover with the liberalization process, which began in the early 1990s, there was a decrease in R&D investments, both in the United States and in the majority of European countries, although recently a small recovery seems to have occurred (Jamasb and Pollitt, 2015). The liberalization process has brought with it

profound changes in the energy industry that have affected the R&D investment decisions of firms that, in this new competitive situation, follow criteria that are different to those of the period before reform. In this framework energy firms adopt new competitive strategies focused on the one hand on efficiency in processes to reduce costs and increase margins, and on the other on differentiation in contracts, given that energy is a homogenous product (Jamasb and Pollitt 2008).

Under competitive market conditions utilities should reduce costs and adapt to demand. The R&D projects that take a long time to mature are displaced by those with rapid implementation and returns. In addition, the low growth rate of demand for electricity in OECD countries also forces utilities to give up long-term projects (Jamasb and Pollitt 2008; Salies, 2010). In a context in which the new regulatory framework does not allow the recovery of the total cost of long-term R&D projects, firms change their objectives and reduce the volume of investment (Sterlacchini, 2012).

Technology and innovation in the energy sector present some specific characteristics in comparison to other sectors in the economy. Market failures related with R&D activities are more intense in the energy sector. Indivisibility, spillovers and uncertainty affect energy R&D in a significant way (Jamasb and Pollitt 2008). Similarly, the close relationship with the environment explains why investments in R&D in the energy sector produce greater positive externalities than other activities. The existence of spillovers creates problems of appropriability and reduces private incentives for investment (Salies, 2010; Kim et al., 2012).

In addition, innovation in the energy industry may be driven by some specific forces and face specific barriers related to the characteristics of the innovation activities in this industry. Some of the characteristics that may affect the innovative behaviour of the firms and the low level of R&D investment in this sector are the large scale of the R&D projects, the dominance of existing

technologies, preference for incremental innovations or the greater size of the firms in this sector that may allow them to overcome financial barriers more easily than firms in other sectors.

The energy industry currently presents, after the liberalization process, a set of characteristics that affect its investments in R&D. Firstly, the process of total or partial privatization has meant the practical disappearance of the old public monopolies. Second, size is a barrier to entry in deciding to invest in R&D (Salies, 2010; Kim et al., 2012; Sanyal and Cohen, 2009, Costa-Campi et al., 2014). Thirdly, a small number of analyses have also considered the barriers to R&D of cost and financing. The empirical results suggest that firms do not have financial restrictions as the availability of liquidity does not affect their R&D investment decisions (Salies, 2010; Sanyal and Cohen, 2009). More recent analyses (Costa-Campi et al., 2014) have included the study of other barriers related to access to knowledge and the market structure. Their results coincide in that financial barriers are not a determinant in explaining R&D investments, but on the other hand market domination by established firms has a significant negative influence on innovation in the sector. These results suggest that the technological mix of energy generation affects R&D and innovation, as is stated in other analyses (Markard and Truffer, 2006; Anadon and Holdren, 2009; Salies, 2010; Anadon, 2012; Sterlacchini, 2012).

Generally the literature maintains that business investment in R&D and innovation is approached with objectives and returns in the short term. The improvement of energy efficiency in the industry and innovation in the technology of generation and the application of digitalization to networks and metering in the energy sector are clearly objectives of this type. In recent research it can also be observed that firms are fostering innovation to reduce their environmental impact. These investment decisions allow a positive relation to be established between a smart regulation to encourage responsible environmental practices and self-regulation. The firms incorporate these environmental innovations as a new competitive strategy based on differentiation and reputation compared to competitors and with a view to attract smart investors. These investments all represent incremental innovations the effectiveness of which is measured by improved profits.

This new focus on competition allows private and public objectives and performance to be joined. Smart regulation and self-regulation explain the recovery of investments in R&D in the energy sector, but their incremental and applied nature do not allow them alone to tackle the great challenges of energy policy. The mitigation of climate change is a commitment that demands a broader approach with a longer view. A large amount of resources, and the involvement of the scientific community, of governments and private agents are necessary to achieve these objectives. The research projects are long-term and their returns are of social and economic interest for society as a whole. These investments in R&D have sunk costs and their application usually has a long pre-competitive period. These characteristics justify public–private collaboration. (Newell, 2010; Henderson and Newell, 2011).

These investments in R&D are of a systemic and disruptive nature, for which reason it is not the firms that will take on these projects. A forward-looking climate change policy demands support for R&D through subsidies to research by firms and public investment in projects with specific objectives that involve energy firms, suppliers and consumers. (Anadon and Holdren, 2009). The literature underlines the pull effect of public investment on private investment in all segments of the industrial process of utilities and suppliers (Gallagher et al., 2012), a matter of special importance in the energy sector given that a large part of the R&D and innovation takes place in the firms that supply the technology. The experiences studied in the literature are not conclusive with regard to the design of the institutional framework in which a public–

private energy policy should be developed, even though the creation of independent institutions composed of scientists and business people and supported by public capital appears to obtain favourable results in the United States, and with a different format, in the United Kingdom and China. Nevertheless, these experiences have not yet been functioning for a period long enough to provide solid information and results (Anadon, 2012).

The climate change mitigation objective is the cornerstone of European energy policy. The documents on climate and energy for the period 2020–2030 (European Commission, 2014, 2015) situate R&D as one of the five mutually-reinforcing and closely inter-related dimensions designed to bring greater energy security, sustainability and competitiveness. However, to this date there is no institutional design available for a vehicle for this new focus of the European Commission.

To sum up, recent studies of R&D and innovation in the energy sector have allowed advances to be made in knowledge about the effects of liberalization, about some characteristics of firms that influence their R&D investment decisions in a market situation and about public policies to foster innovation in energy. Nevertheless, new analyses are necessary to have more precise knowledge of R&D activities in the sector and their strategies and effects and to design suitable policies to foster R&D and innovation in the sector.

In order to advance knowledge regarding the role of R&D and energy technologies and the public policies to foster them, a workshop was organized in Barcelona in January 2014, where the papers of this special issue were presented. In this introduction, we have first examined some of the challenges to R&D and innovation in energy. In the next section, we introduce the articles that make up this special issue.

## 2. Overview of the contributions to the special issue

The papers in this special issue deal with R&D and innovation in energy. In the first paper, Jamasb and Pollit (2015) present an overview of the effects of electricity market liberalization on innovation. In particular, they revise and update their previous findings on the effects of privatization, market based reforms and incentives on R&D and patenting activities in the electricity sector in the UK. Their results show that energy R&D expenditure declined after liberalization but that it has also partially recovered. They also pointed out that profit incentives have shifted R&D resources to near market innovation; and, that R&D productivity measured by the ratio between patents and R&D expenditure has increased. From their analysis they suggest a number of implications for energy R&D policies. Firstly, they emphasize that the main role of government support should be oriented towards basic research and to encouraging collaborative research. Secondly, that a key factor in innovation policies is long-term stability and regulatory commitment. Thirdly, they stress that energy R&D needs to pay attention to “social technology”. Finally, they underline the importance of the division of the R&D roles for the different public and private actors involved in electricity technology and innovation.

The next two papers deal with the sources of knowledge for energy technologies (Rexhäuser and Löschel, 2015) and the location of green R&D activities (Noailly and Ryfisch, 2015) respectively. Rexhäuser and Löschel (2015) examine, first, the role that prior inventions in renewable energy and in energy efficiency or conservation have, as a technology push factor, on both technologies. In addition, they also study the effect of previous inventions in non-energy technologies on energy technologies. This analysis helps to improve our understanding of the different sources of knowledge for energy inventions. The empirical

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