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The case for a new energy research, development and promotion policy for the UK☆

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ABSTRACT

This paper is a critical assessment of the current balance of efforts towards energy research and development (R&D) and the promotion of low-carbon electricity technologies in the UK. We review the UK's main technological options and their estimated cost ranges in the medium term. We contrast the energy R&D spending with the current and expected future cost of renewable promotion policies and point out the high cost of carbon saving through existing renewable promotion arrangements. We also note that liberalisation of the electricity sector has had significant implications for the landscape of energy R&D in the UK. We argue that there is a need for reappraisal of the soundness and balance of the energy R&D and renewable capacity deployment efforts towards new energy technologies. We suggest that the cost-effectiveness of UK deployment policies needs to be more closely analysed as associated costs are non-trivial and expected to rise. We also make a case for considering increasing the current low level of energy R&D expenditure. Much of energy R&D is a public good and we should consider whether the current organisation of R&D effort is fit for purpose. We argue that it is important to build and maintain the research capability in the UK in order to absorb spillovers of technological progress elsewhere in the world. Against this background, the recent signs that an energy R&D renaissance could be underway are therefore positive and welcome.

1. Introduction

This paper is a critical assessment of the current balance of efforts towards research and development (R&D) and the promotion of low-carbon electricity technologies in the UK. We review the main technological options and their estimated cost ranges in the medium term and point out the relatively high cost of carbon saving through existing renewable promotion arrangements. There is a case for revisiting the electricity technology R&D spending in relation to the current and expected future cost of renewable promotion policies. Also, we note a role for induced technical change technology learning analysis. In the light of the above factors, we argue that there is a need for a reappraisal of technology R&D and deployment policy. We suggest that there is a case for increasing R&D expenditure and scrutinising the effectiveness of current low-carbon deployment policies. In addition, there is a need for the development of new models for organising R&D activities suitable for liberalised energy sectors.

2. Context of support policies for new technologies

Deregulated electricity markets have worked well for 15 years delivering efficiency improvements and investment in new capacity in the UK. They have achieved more efficient operation of existing equipment. They have also subjected new build to market testing and ensured that 'least cost' versions of available technologies are deployed. Importantly, they have changed the public perception that electricity is special and should not be subject to a fluctuating price driven by supply and demand. Experience around the world shows that properly implemented liberalised markets can handle supply shocks. Sioshansi and Pfaffenberger (2006) note contrasting experiences of supply shocks in Norway, Chile and California. Newbery and Pollitt (1997) showed that one of the main benefits of privatisation of the Central Electricity Generating Board (CEGB) was the elimination of an overly costly nuclear new-build programme. They also showed that the society benefited from the cost reduction and environmental benefits of combined cycle gas turbine (CCGT) deployment in the UK. We believe that this experience demonstrates the need to avoid a return to strategic deployment policies based on old-style industrial policies or expensive public R&D programmes based on poor incentives. Rather, there is a need to design technology policies and organisational models that are

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commensurate with the features of a liberalised electricity sector. We note, however, that failure to innovate combined with increasing pressure from climate change policy could lead to increased government intervention in the sector.

3. Technology options and costs

The much criticised, but still influential, *linear model* of innovation promulgated by Bush (1945) posits that R&D results in technological progress, which in turn leads to diffusion of technology in the market. Clearly, to this must be added the positive feedback loops between the different development phases. Major UK official documents reviewing the energy technology options identify a range of technologies in different stages of development (ICCEPT, 2003; ICCEPT and E4tech Consulting, 2003; House of Lords, 2004; House of Commons, 2005; National Audit Office, 2005). However, in the near and medium term, the range of options is more limited. The main generation technologies with immediate potential for contribution are wind, nuclear and energy efficiency. Further ahead, there is potential in carbon capture and storage and biomass energy. Other technologies are in need of significant progress and their promise lies further in the future (Jamasb et al., 2006).

The estimated costs of renewable sources by 2020 indicated by the Sustainable Development Commission (2005) show that the cost differences between the technological options are expected to become smaller. Moreover, the cost of each technology is, as is often the case, reported in a relatively wide range, as estimates of future costs are uncertain. For example, the cost of on-shore wind power and solar photovoltaics by 2020 is estimated at 1.5–2.5 and 10–16 p/kWh, respectively. The ranges reflect uncertainty with regard to technological progress, discount rates and quality of resources. The unit energy cost of some renewable sources such as wind and biomass can be location specific. Economic efficiency requires that policies should support the development of resources based on the 'least cost' principle. This means that the supply of low-cost or high-quality sites may be more limited than the resource base. Furthermore, many technologies are internationalised and their cost in the UK will depend on their roll-out rates elsewhere. For a typical wind turbine, for example, up to 80% of the cost is represented by the engineered turbine rather than the associated civil works (Department of Trade and Industry, 2001).

4. Policy costs—technology push vs market pull

R&D is the key factor in achieving technological progress. Margolis and Kammen (1999) show a strong relationship between total energy R&D investments and the number of patents granted in the US. They also show that the energy sector is among the least R&D intensive industries. The reasons for this are not obvious. However, this leads us to believe that there may be significant potential for stimulating technological progress by increasing R&D expenditure in the sector.

Public R&D spending on renewables and conservation in the UK has shown a marked decline during the past 15 years (Fig. 1). Much of this decline coincides with and continues in the aftermath of the liberalisation of the electricity sector. The UK energy policy agenda was dominated by the implementation of reforms (privatisation and competition) to the relative neglect of energy R&D and innovation policy. Fig. 2 shows that the UK's average annual R&D spending per capita on renewable technologies and energy efficiency between 1990 and 2005 has been lower than selected comparable countries. There are strong indications that, following liberalisation, major energy companies have reduced their R&D spending and that the new actors (e.g. independent power producers) are not involved extensively in such activities (Eurelectric, 2003). While little is known about R&D spending among the equipment manufacturers, it does not seem likely to have increased (Jamasb and Pollitt, 2008).

The decline in private R&D spending occurred at the same time as a decline in public support for energy R&D. The implicit

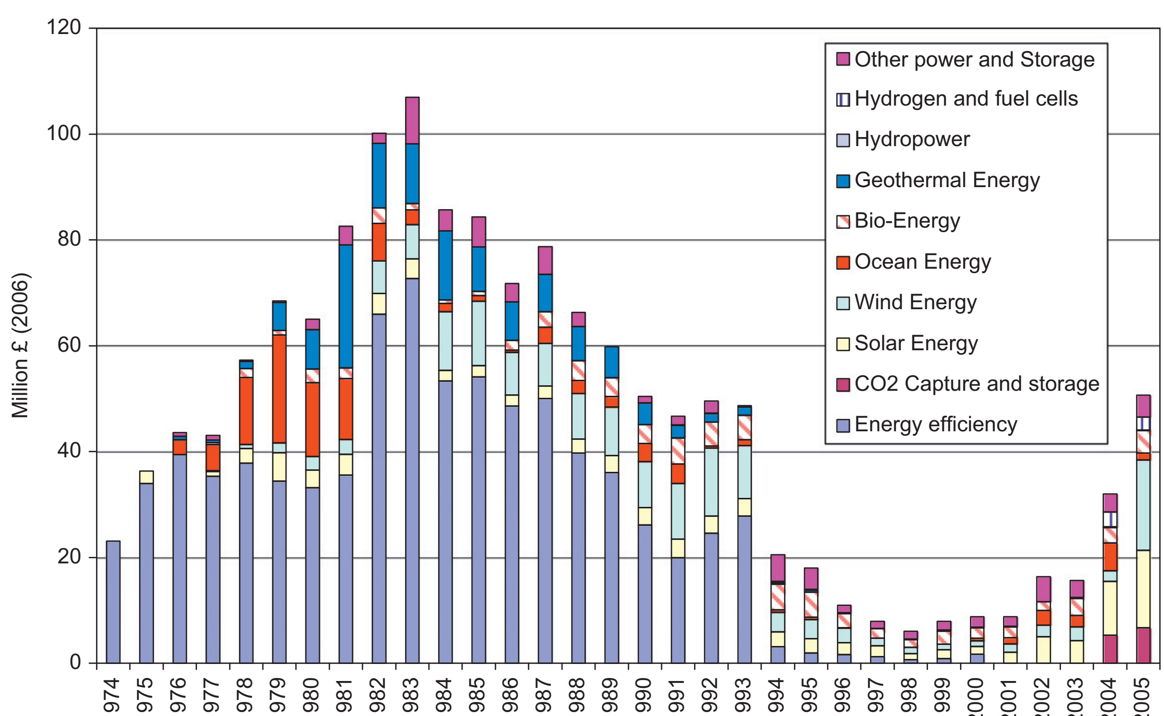

Fig. 1. Public renewable energy R&D spending in the UK (International Energy Agency energy R&D database).

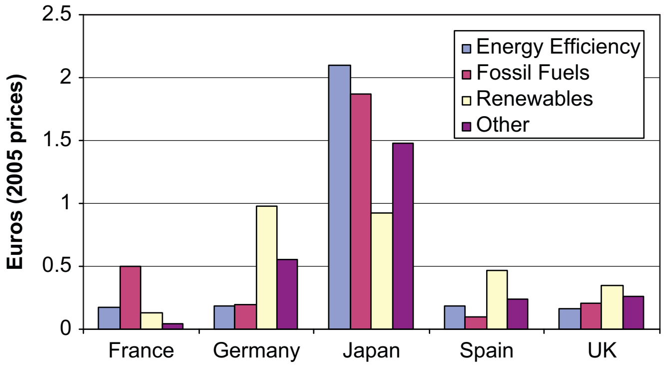

Fig. 2. Average annual per capita public R&D spending 1990–2005 (International Energy Agency energy R&D database).

assumption was that energy research is a *commodity* to be sponsored by private users. Such an assumption is, at best, inconclusive, and many technology policy specialists devote their endeavours to better understanding of whether research is indeed a commodity or a *public good* (Dooley and Runci, 2000). The decline in R&D efforts in the aftermath of liberalisation is in line with the widely held view of the occurrence of market failure. The failure of the private sector to support energy R&D in recent years would seem to confirm the hypothesis that much of this research is indeed a public good. This observation aligns with the third recommendation of the Chief Scientific Adviser's Energy Research Review Group (Department of Trade and Industry, 2002).

A more balanced approach has been promoted at the EU level. The European Commission (2005a) report, *Assessing the Impact of Energy Research*, stresses the importance and difficulty of evaluating the impact of European energy R&D. When examining the UK situation, the following is observed: "… the evaluation work does not impact much on overall resource allocation" (p. 25), including in particular that: "It is also difficult to assess institutional impacts, including those achieved from collaboration, and to disentangle the impacts of a range of factors" (p. 25). Our own work now allows for a somewhat better appreciation of the relative merits of R&D and deployment policies (e.g. Jamasb, 2007; Jamasb and Pollitt, 2008). We concede, however, that many issues remain and there are questions still to be answered.

Turning to the market pull policies and arrangements in the UK to support the uptake and diffusion of renewable technologies, we find that, between 2003 and 2006, their costs amounted to about £700 million per annum (Table 1). Moreover, by 2010, these are expected to reach £1 billion per annum. A further total of £1.6 billion is required to improve the transmission and distribution networks between 2003 and 2010. By 2015, the costs are expected to increase further to £1.5 billion per annum. Meanwhile, the cost of CO_2 reductions through the Renewable Obligation Certificate (ROC) scheme has been estimated at £210–380 per tonne (House of Lords, 2004).

In the light of the current spending and expected future increase in the cost of capacity deployment policies, it is important that the policy instruments used ensure efficient use of resources. A recent analysis by the European Commission indicates that the UK's funding to support deployment of some major renewable sources is less cost-efficient than in most EU countries (European Commission, 2005b).

5. Lessons from liberalisation

Although R&D spending was much higher prior to liberalisation, its allocation was not according to economic value.

Table 1
Annual cost of supporting renewables between 2003 and 2006 (National Audit Office, 2005)

Income source	Average annual cost (£ million)
ROC income	470
Climate change levy exemption certificate income	30
Government grants and other public support[a]	180
European Union research funding	20
Total	700

[a] Includes some R&D spending by Research Councils and other public bodies.

Instead, it was influenced by industrial policy where nuclear and clean coal programmes absorbed most of the budgets. Renewables were neglected and an earlier tidal research programme was abandoned. Significant parts of the CEGB's deployment strategy were clearly unsuccessful. Henderson (1977) and Green (1995) reviewed the AGR and Magnox programmes, respectively, and concluded that they were wasteful, with—in particular—poor levels of learning, especially in the AGR case. The British decision to stick with gas-cooled technology for the second wave of UK nuclear power stations was arguably a major error. Many lessons have been learned from the nuclear programme mistakes, and today Britain faces a choice of safer, lower-cost, internationally developed, nuclear new-build options. The CEGB experience, however, militates against picking winners in deployment and cautions against public interference in the deployment process, particularly on the basis of claimed learning by doing. As we shall argue later, basic and flexible technological capacity and receptivity to foreign innovation are far more important.

The driving forces and objectives of liberalisation were primarily oriented towards economic efficiency and had little to do with promoting new technology research and diffusion. The objective was to improve the operational and investment efficiency of the sector through restructuring, competition, regulatory reform and privatisation. In fact, liberalisation has increased the dependence of the sector on public R&D and other support policies. We have previously shown that most liberalisation steps have likely had a negative effect on R&D (Jamasb and Pollitt, 2008). A sustained decline in R&D spending is likely to have negative consequences for the competence base and research capacity in the UK and long-term technological progress of the sector. A recent Mott Macdonald BPI (2004) report identified £60 million of investments, with a present value of £360 million of benefits in the area of electricity distribution technologies alone.

At the same time, CCGT and, to a lesser extent, wind, are examples of technologies that the private sector has successfully rolled out. An important issue is how much support is necessary for established technologies. German wind illustrates the cost of high support tariffs, which encourage inefficient generation in low-wind areas, in contrast to the UK problem of slow planning and consent procedures for new wind (Butler and Neuhoff, 2004). Wind technology is global and domestic support for deployment to achieve learning economies, which are also global, may now be misplaced (though they may have been justifiable earlier in the development cycle). It is also increasingly under the ownership of large companies, so mechanisms designed to overcome financing issues of small developers are outdated. The increasing ownership concentration in European generation seems likely to lead to private incentives to support diverse generation sources (Roques et al., 2006). However, it is unclear whether the market can provide diversity of generation sources. It is, however, interesting to note that the UK now has a more diversified mix of generation than 15 years ago.

6. Current support policies and how they should develop

It is important to ask whether there is a clear economic rationale, innovation theory and empirical evidence supporting the absolute spending levels and relative allocation of resources to technology push and market pull measures to support new technologies. The existing arrangements imply that technical progress due to market pull should be considerably stronger than that of technology push. Ideally, the decisions about the balance between these should be based on empirical analysis and evidence. We are not aware of such analytical justification. On the contrary, some results indicate that R&D can be at least as important for technology learning as is capacity deployment (Jamasb, 2007). The current support policy for renewable energy technologies in the UK may contain a significant mismatch between the technology push and market pull arrangements. Furthermore, we note that financial incentives for technology promotion are not an effective remedy by which to overcome slow and burdensome planning obstacles (as the UK experience with ROCs demonstrates).

It is difficult to determine an optimum total spending level for technology push and market pull. However, the total spending level should be with regard to expected future investments in new technologies. Moreover, as a general rule, spending on technology push and market pull should be allocated in relation to their expected relative contribution to reducing the cost of technology. We recognise the complexity of the workings of learning-by-research and learning-by-doing processes, much of which is yet to be understood (see Sagar and van der Zwaan, 2006). This is partly due to the fact that, although we have some notion of the innovation stages, we do not as yet have a coherent theory of innovation. In particular, we have a limited understanding of the development stages between basic research and market diffusion—i.e. the 'valley of death', where economic, political, social and technical barriers appear to be high. This is an area where it is important that technology push and market pull support one another.

Whether application of the above principles will have a zero-sum effect on the current total spending on technology support is a matter for policy makers. For example, an increase in total spending on energy R&D and renewable capacity deployment, if politically feasible, prevents such a zero-sum effect. We do not argue that resources must be shifted from current capacity deployment to R&D support. However, it is valid to ask whether current spending represents an efficient allocation of resources between them in terms of their relative potential for achieving technology cost reduction. Current deployment support is several times higher than current spending on R&D, implying that the former is correspondingly more effective than the latter. We are aware of the complexity inherent in this, but it is a crucial question as the stakes for the success of technology policy are high. A politically sustainable technology policy is one that is cost-effective and contributes to economic competitiveness. It is therefore essential for future research to address the important policy questions of the optimum level of total spending and allocation of innovation funds between R&D and capacity deployment.

There is a need to reappraise current support mechanisms and their expense. R&D support, competitively awarded and funded through a levy on electricity bills may be the best way forward (perhaps similar to the innovation funding incentive introduced for electricity distribution utilities). This has the advantage of overcoming market failures in R&D expenditure while making use of private incentives in the commissioning and delivery of R&D outputs. It also has benefits for the UK in building human capital and encouraging genuine innovation. Capacity subsidies suffer from a number of potential problems in the UK. First, they primarily benefit large foreign-owned utilities and overseas equipment manufacturers. Second, they encourage competition for subsidies by incumbents and picking winners by governments. Third, they may serve to take the industry and regulatory focus off the need to reform and extend the EU emissions trading system (ETS) for pricing carbon. The price of CO_2 in the EU ETS has been lower than the mean of a recent estimate of its social costs of £13 per tonne of CO_2 emitted in 2001, though comparable to the lower end of the estimate, with a 5–95% range of £2.5–36 per tonne of CO_2 (Hope, 2005; Hope and Newbery, 2008).[1] This implies that the CO_2 price represents a very significant incentive for the roll-out of low-carbon technologies in the absence of any further support programmes.

R&D support does not rely on international co-operation or roll-out policies to be effective in the same way as capacity subsidies do. It is also considerably less expensive in the near term and has the advantage of keeping roll-out options open and allowing information and attitudes to climate change to develop. The option value of waiting before implementing an expensive capacity roll-out support programme is likely to be high, given the current level of uncertainty about costs and the attitudes of other countries. Should a global technology consensus emerge, high levels of energy R&D will leave the UK well placed to respond rapidly. Earlier, we posited that a significant proportion of energy R&D is a public good. We make this observation noting that the public benefits of R&D are not measured in terms of the intellectual property generated and protected by patent or copyright. Rather, the key benefits are more ethereal and include the training of workers with portable skills,[2] a pool of tacit knowledge in key energy sectors and receptivity to international innovation. Allott (2006) highlighted the importance of human factors in public goods research in his Hughes Hall City Lecture.

Reducing the time taken for planning and siting consent is beneficial and delivers unambiguous cost savings (Department of Trade and Industry, 2006). Soft funding for R&D and deployment can create a dependency culture, which makes it difficult to cut programmes and discourages innovation in emerging technologies. Some of the mistakes of the past can be avoided, with no need for financial support mechanisms. These sorts of policies should be implemented before any financial mechanisms are put in place. Support policies that focus on people rather than machinery are more cost-effective, given that human capital is transferable. Many of those who were involved in R&D programmes were easily and productively absorbed in the economy following the end of the pre-liberalisation period.[3]

Firms that engage in R&D will focus on more commercially oriented research that is closer to the market and customer end of the value chain. Supporting and stimulating basic R&D will rightly

[1] Converted from original values expressed in 2001 $US using 2001 £/$ exchange rate (1.4).

[2] For example, an engineer trained and educated at university or in a national laboratory in the cutting-edge technology of open cycle gas turbines will have much to contribute to the development of high-temperature gas-cooled nuclear reactors.

[3] Repeating our view that public-sponsored skills in energy research can be usefully transferable, we note anecdotal information that the closure of the Dounreay Fast Reactor research programme in the early 1980s liberated a pool of highly qualified engineers to assist with the equally challenging tasks of off-shore oil and gas extraction. Now, reversing that flow, the UK Atomic Energy Agency is considering the possibility that Dounreay might have a useful role to play in oil and gas installation decommissioning (see http://www.ukaea.org.uk/downloads/dounreay/Dounreay%20Skills.pdf (accessed 16 May 2008)).

remain the preserve of the public sector, and increasing it will stimulate associated private R&D. Collaborative private research is, in particular, likely to be subject to market failure as it is less likely to result in competitive advantage. Another area of research policy is to engage in technology-specific international collaborations such as off-shore wind and marine energy, where the UK and a few other countries enjoy a significant resource base. In recent years, the UK has neglected public support for the public goods associated with our national energy system. Substantial effort and resources directed towards energy technology promotion, on their own, have done, and will do, little to fill that gap.

The prospect of increasing energy R&D in the UK raises questions about the institutional structures through which this expenditure is spent. During the 1990s, energy laboratories operated, or previously operated, by the CEGB and the UK Atomic Energy Authority were broken-up, redirected and closed down. As noted earlier, these actions were not the result of a considered national research policy, but were in most cases an overlooked consequence of competition policy. By contrast, government research labs outside the energy sector, such as the National Physical Laboratory or the laboratories of the former Defence Evaluation and Research Agency, have been successfully modernised during a similar timeframe via, in the latter case, part-privatisation or, as in the former case, a shift to government-owned contractor-operated (GOCO) arrangements (Wallard, 2001). We believe that the UK is well placed to have some of the most economically successful national energy laboratories in the world, if only we can build them. The recent establishment of the Energy Technologies Institute is a most welcome step and we trust that it will be implemented with the benefit of much hindsight from across UK research policy (HM Treasury, 2006).[4] It should be noted that such public support for R&D will and does stimulate related, market-tested, private sector R&D spending.

7. Conclusions

This short paper makes three substantive points about energy research and promotion policy towards low-carbon technologies in the UK. First, current levels of R&D expenditure (public and private) need to be evaluated, with a view to investigating to what extent the collapse in R&D expenditure following electricity market liberalisation has been in the public interest. Second, current capacity support mechanisms need to be critically re-evaluated given their apparent cost-ineffectiveness, likely future expansion and questions about their efficacy in an international context. Third, increased levels of public R&D and levy-supported private R&D raise issues as to the institutional capability of the UK to produce cost-effective R&D outputs. This suggests, among other things, the need to learn lessons from private finance initiatives, GOCO arrangements and other government research policy initiatives for large laboratories.

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[4] We also note that most public research laboratories operate on a fixed income of public money. Some, such as nuclear fusion research, are major users of energy in the conduct of their research. It is therefore somewhat perverse and ironic that, within the public sector budget cycle, high energy prices can curtail research opportunities rather than spur them.

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