production adjustments. This idea was advocated ten years ago but has not gained the policy makers' favour.

In other words, a price, rather than a production policy, is the relevant instrument to achieve a price objective. Common sense supports such a proposition. There are difficulties, of course, in switching from one type of policy to another. These difficulties can be exaggerated however. OPEC fears that a price policy will subject it to criticisms about causing price shocks. The sobering thought is that OPEC was the object of virulent attacks by the UK prime minister, Gordon Brown, and the Australian prime minister among others for having caused prices to rise to \$100–145 per barrel when an elementary knowledge would have informed leaders that the reference prices for oil in international trade are determined in futures exchanges in which OPEC countries do not participate.

OPEC will be blamed whatever it does. This being the case, why not adopt a pricing policy that has the merit to address *directly* the price objective? The additional advantage is that OPEC will be more able to stabilise prices than futures markets where volatility is the name of the game.

Energy RD&D: a much needed clean tech stimulus

Marianne Haug

Can an industry that spends about 1 percent of net sales on Research, Development and Demonstration (RD&D) transform our energy system? Can an industry with the lowest RD&D intensity of any high tech sector tackle the clean technology investment challenges of the coming decades – 1 percent of GDP according to the Stern Review of 2006 or up to US \$540 billion per year to 2030 according to the 2008 IEA WEO estimates?

The facts are well known: industries that transformed our economies – telecommunications, information technologies, pharmaceuticals or biotechnology spent consistently 10–15 percent of net sales on RD&D. The RD&D intensity of the automobile industry that focused up to now more on incremental than radical innovations averaged about 4–5 percent per year.

The comparable figures for the energy sector are telling: oil and gas companies in OECD countries spent 0.35 percent of net sales per year on RD&D over the past five years. The fifteen top RD&D spenders among the PFC Energy fifty companies spent a mere US\$10 billion on RD&D in 2007. In absolute terms, Royal Dutch Shell spent the most – US\$1.2 billion followed by Exxon Mobil at US\$814 million, TOTAL at US\$800 million and Schlumberger at US\$728 million. RD&D intensity in the oil and gas sector is highest among the service companies: Schlumberger and Baker, Hughes averaged 3 percent per year compared to Halliburton at 2 percent. The year 2007 showed a marked increase in low carbon RD&D of oil and gas companies mainly for CCS, hydrogen/fuel cells, and biofuels, but figures vary greatly among firms. The present shake-out of clean technologies portfolios will show who among the oil and gas companies will integrate clean technologies in its core business in the medium term.

The steady decline of private RD&D spending for electric utilities is well documented for Japan, Europe and the USA. Some suggest that the liberalisation process affected the firms' willingness to invest in technology and innovation. The RD&D intensity of Japanese utilities dropped to 1 percent per year by 2002 and has hardly recovered. The RD&D intensity of the European utilities dropped to as low as 0.7 percent in 2005. The absolute RD&D spending of European utilities remained relatively constant: the top twelve European utilities invested yearly EUR 1.0–1.2 billion over the 2003–2007 period. This picture is changing as a majority of European utilities now invest proactively in clean technologies – wind, CCS, nuclear and other renewables and associated RD&D. The utilities industry relies to an important extent on the innovative capabilities and investments of its suppliers. The RD&D intensity of the European manufacturers of electrical equipment and components averages 6 percent per year and that of the non-EU manufacturers about 3 percent per year.

How do these figures fit into the overall picture? The IEA estimates in 2009 that global corporate energy RD&D is in the order of US\$40–60 billion per year. Clean energy RD&D not including nuclear expenditures may account for as much as US\$10 billion according to New Energy Finance (2009). In contrast, the public energy RD&D of IEA countries dropped by a factor of two in real terms over the past 25 years. It was a mere US\$12.1 million in 2007 or about 15–20 percent of total energy RD&D expenditures.

These trends and figures are a real cause for concern: innovation is at the heart of improving existing technologies, at replacing traditional ones and bringing about systemic or regime changes. Innovation and investments toward a clean energy transition by the private sector will not happen unless the public sector addresses the two fundamental market failures: first, energy prices need to internalise environmental and energy security externalities; and second, distortions in the incentive to innovate, the 'technology' market failure needs to be reduced or eliminated.

Much has been written and done about the first market failure. Investors value reliable price signals and a stable regulatory framework. Carbon pricing, feed-in or premium tariffs for low carbon technologies, targets, standards and public procurement are paving the way in many countries. The Kyoto Protocol, the EU-ETS, the EU Energy and Climate Package, country/state specific low carbon targets and policies and now the reengagement of the USA in the climate negotiations on the way to Copenhagen 2009 improved the enabling environment and stimulated major investments in wind, PV and biomass to name a few. We have come a long way, but the recession and strains on private capital markets have brought home the inherent risks and fragility of the system. With many low carbon technologies not yet cost competitive or still in the demonstration stage, EU allowance prices in the EUR 10–30 t/CO_2 range, and global emissions reduction targets still uncertain, incentives are insufficient to catalyse the magnitude of clean energy investments needed.

Much less has been written or done about the 'technology' failure in the energy sector. Three major, additional factors distort the incentives to innovate for private companies

First, knowledge spillovers create a gap between the societal return of an RD&D investment and the actual value captured by the innovating firm. Differences as high as 20–30 percent have been reported across some sectors. The gap is particularly pronounced for energy investments that typically have long lead and life times. Innovation decisions of private firms are based on risks and profit concern, while governments need RD&D to meet longer-term energy and climate change objectives.

Second, the lock-in effect of technology choices once made result in path-dependence for future investments. They are not only effective barriers for individual new technologies but can lock a country into an entire 'technology regime' with well-established practices, institutions, infrastructures, skills and corporate cultures. Gregory Unruh was the first to point out that our present fossil-based energy system constitutes such a 'regime lock-in' and decisively hampers the transformation towards low carbon energy. Such regime lock-in goes beyond cost competitiveness, subsidies, or maturity of technologies.

Third, private investors face considerable risks during each stage of the innovation process from the research to early commercialisation. Energy technologies are more apt to fail during the development and demonstration phase than innovations in other sectors. Investors in large-scale energy innovations confront more often the 'first mover disadvantage' than the fabled advantage. Both market risks (cost, prices and product performance) as well as regulatory risks from permitting to uncertainty about policies explain these results. The regulatory uncertainties surrounding climate change policies have escalated in particular for the energy sector.

The Stern Review of 2006 and the EU's Strategic Energy Technology (SET) Plan of 2007 recognised these 'technology' market failures and argued that technology deployment cannot wait for robust global carbon prices. Thus, a major policy shift is underway, spearheaded by the EU and the USA. Public support for energy RD&D will extend well beyond the early stages of the research and innovation cycle, and address the inherent barriers to demonstration and deployment of low-carbon energy technologies discussed above with public financing support. To give two recent examples:

Earlier this year the EU Council passed a major RD&D funding stimulus totalling EUR 2.5 billion. Of this, EUR 1.050 million is slated for seven carbon capture and storage demonstration projects, EUR 910 million for smart grid and electricity connectors to help integrate renewable energy into the grid, and EUR 565 million for offshore wind projects in the North and Baltic Seas. Further, EUR 300 million allowances under the EU Emissions Trading Scheme will be worth EUR 6–9 billion depending on when they are cashed and what the price of the allowances will be on the Commodity Exchange at that time. This will drive the construction and operation of up to twelve commercial carbon capture and storage demonstration projects. The EU Parliament is expected to approve the Council's decision in early May.

These funds are in addition to the energy R&D financing of EUR 2.35 billion under the 7th Framework Programme. A Communication on 'Financing Low Carbon Technologies' will be issued shortly with proposals for further funding and new financing mechanisms.

The US American Recovery and Reinvestment Act of 2009 allocates US$32.7 billion to the US Department of Energy to spearhead clean energy RD&D and related infrastructure, along with an additional US$6.0 billion for Innovative Technologies Loan Guarantees. This includes, inter alia, US$16.8 billion for Energy Efficiency and Renewable Energy; US$4.5 billion for Smart Grid & related programs and US$3.4 billion to fund demonstration and commercialisation of carbon capture and storage. US$400 million is provided to establish ARPA-E, the new Advanced Research Projects Agency – Energy, which is modelled after the successful Pentagon research agency, DARPA.

Will this public funding stimulus for clean energy technology RD&D make a difference? Will it be matched by increased private sector RD&D and clean energy scale-up at a time of economic uncertainty and capital shortage? Will new actors enter and transform the sector? No one can foretell the eventual multiplier, but the signaling effect cannot be overlooked.

Substantial new public funding for clean energy RD&D is only part of the story. The RD&D funding is a fraction of the much larger economic stimulus packages governments have adopted to fuel employment, innovation, and growth, some with a special focus on 'green investments'. Edendorfer and Stern classify as much as 15.2 percent or nearly US$400 billion of the US$2,610 billion stimulus packages adopted by the G-20 countries as 'green' funding. China leads the Edendorfer/Stern list of green fiscal measures among the G-20, with US$201 billion followed by the USA with US$112 billion, US$31 billion in South Korea, US$23 billion by the EU, US$14 billion in Germany and US$12 billion in Japan. The mere size of the earmarked investments are staggering. The competitive landscape for clean energy will not be the same again.