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Keynote lecture

Challenges of Implementing New Technologies for Sustainable Energy Opening address at the Sixth Grove Fuel Cell Symposium, London, 13–16 September 1999

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Abstract

To meet the commitments made in Kyoto, energy-related CO_2 emissions would have to fall to almost 30% below the level projected for a ''Business-As-Usual'' scenario. Meeting this goal will require a large-scale shift toward climate-friendly technologies such as fuel cells, which have a large long-term potential for both stationary generation and transportation. The deployment of a technology is the last major stage in the process of technological shift. Climate-friendly technologies are not being deployed at a sufficient rate or in sufficient amount to allow IEA countries to meet their targets. Hence, if technology is to play an important roll in reducing emissions within the Kyoto time frame (2008–2012) and beyond, immediate and sustained action to accelerate technology deployment will be required. Obstacles in the way of the deployment of technologies that are ready or near-ready for normal use have come to be referred to as market barriers. The simplest yet most significant form of market barrier to a new technology is the out-of-pocket cost to the user relative to the cost of technologies currently in use. Some market barriers also involve market failure, where the market fails to take account of all the costs and benefits involved, such as omitting external environmental costs, and therefore retard the deployment of more environmentally sustainable technologies. Other barriers include poor information dissemination, excessive and costly regulations, slow capital turnover rates, and inadequate financing. Efforts by governments to alleviate market barriers play an important role to complement private-sector activities, and there are many policies and measures each government could take. In addition, international technology collaboration can help promote the best use of available R&D resources and can contribute to more effective deployment of the result of research and development by sharing costs, pooling information and avoiding duplication of efforts.

Keywords: CO_2 emissions; Fuel cells; Climate-friendly technologies; Market barriers

Nobody could be more aware than we that energy is an indispensable factor for economic development and social welfare. Yet, as we also know, its production, transport and use carry the inherent handicap of negative environmental effects. The big challenge is to limit those effects to levels and forms with which we and future generations can live. We are very conscious of the difficulties in this challenge. And that is one of the reasons why fuel cells have attracted lively attention in recent years. They are among the promising technologies for reducing energy consumption, greenhouse gas emissions, and other air pollutants. At the same time they offer opportunities for economic growth and development.

But the process of easing new technologies out of the laboratory and into to the real world is complex, uncertain and usually slow. For the manufacturing enterprises, the challenge is to establish technically and commercially viable methods of manufacturing and marketing such products. For governments, the challenge is to provide a framework enabling markets to evolve along a path that favours environmentally sustainable products and transactions. In short, the challenges faced by companies and governments alike in the area of new energy technologies are closely inter-linked.

I should like to discuss with you some typical obstacles to technology deployment. We shall then look at policies or measures available — more particularly those available

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to governments — that can overcome some of these obstacles and foster the creation of markets where these technologies can be sure to flourish and bring us closer to a sustainable future.

1. An introduction to the International Energy Agency (IEA)

First, though, a few words about the IEA for those not familiar with the Agency. The IEA was created in 1974, in response to the first oil crisis, to ensure its Members' collective energy security. Since then, the Agency's scope has expanded. It is now the forum in which industrialised countries come together to co-operate on the whole range of energy policy options. Its objectives have taken on three dimensions, which we refer to as the ''3Es'': Energy Security, Economic Growth, and Environmental Sustainability.

All three objectives play a parallel role in shaping the IEA's activities and programmes. At present, much of our work is focused on environmental sustainability, since environmental concerns — more particularly those associated with greenhouse gas emissions — constitute the key challenge facing developments in the energy sector.

The Agency is currently working in a number of crucial areas involving development of technology strategies for cost-effective reduction of greenhouse gas emissions. I should like to highlight just a few of them.

The IEA's Committee on Energy Research and Technology has been considering the central issue of how science and technology can be mobilised to help IEA Member countries meet the Kyoto commitments. To this end, they submitted to IEA Energy Ministers at their Paris meeting in May 1999 a declaration under the heading ''The Technology Response to Climate Change — A Call for Action''. The dominant message was that ''immediate and sustained action will be required if technology is to play an important role in reducing emissions by 2012 and beyond''.

A number of important underlying messages flow from the IEA Committee's analysis and were conveyed to Ministers at their Paris meeting. They were told that these should be considered ''as a matter of urgency''.

Ministers were warned that it is vital that we not underestimate the scale of the effort that will be needed to meet the Kyoto commitment. In the absence of any additional action, greenhouse gas emissions will rise more than 20% above 1990 levels. Since we are now 10% above 1990 levels the ''real'' gap to be bridged in 2008–2012 is in the order of 30% if we are to meet the Kyoto target. There is no doubt that this calls for an effort of quite unprecedented magnitude, and it will most likely require major structural adjustments. Only today's commercial and near-commercial technologies will contribute to reducing emissions in this time-frame. While these technologies make it possible to meet the Kyoto targets, under ''business-as-usual'' conditions they will not be deployed on a sufficient scale for the targets to be met. Current trends in technology adoption are insufficient to meet the Kyoto targets. Policies and measures to accelerate technology deployment will therefore be required.

2010 may seem a long way off, but it will take time to implement new policies and measures. Also, due to the time required for technology introduction and capital stock turnover, many promising technologies will not significantly reduce emissions before 2012.

In most IEA countries, government-funded energy R&D has been declining, sometimes steeply, for at least a decade. The long-term R&D that will provide tomorrow's advanced technologies is losing priority. Governments should increase investment in long-term R&D and provide a good environment for private-sector R&D.

On this crucial funding issue, I would point out that domestic critics in IEA Member countries can deliver some blistering attacks on government performance. For example, one major IEA Member country's efforts in co-operative international energy research, development, demonstration and deployment were recently described as ''not commensurate with either the needs or the opportunities''. Significantly, the attack came from a specialised panel of the head of state's committee of advisors on science and technology. This distinguished panel stated that the most recent scientific evidence on climate change justified ''a larger effort in energy-technology innovation . . . than would be required to address the other environmental, economic, and international security challenges looming in the world's energy future''. The critics identified ''major deficiencies'' in the capacity of existing government institutions to manage the sort of programme required. A lack of an effective and cohesive ''strategic vision'' of energy-related issues and solutions was pinpointed, as well as inadequate coordination among agencies, poor review and evaluation, and a lack of long-term commitment.

Declaring that ''there is no time to wait,'' the chairman of the panel stressed the urgent need to implement his group's recommendations since ''the energy choices made in the next 10 to 20 years will substantially shape the character of the global energy system for much of the next century''. He stated that the ''potential leverage of modest investments . . . in this arena in the years immediately ahead is immense''. But he warned that ''timidity and delay will lock in adverse outcomes that will be far costlier to reverse — if they can be reversed at all — than it would have been to prevent them''.

But let us return to the May 1999 messages to Ministers from the IEA's Committee on Energy Research and Technology. Another important point made was that there is no single technology solution; every country will need to make a choice based on its own unique circumstances and conditions. Government support for these technologies, allowing for national circumstances, should be included in plans to reduce carbon emissions.

Of particular interest to us today, IEA Ministers were told: ‘‘Fuel cells provide a longer-term option for stationary generation. In the transport sector, more efficient conventional vehicles can provide significant near-term savings while electric, hybrid and fuel cell vehicles have much larger long-term potential’’.

Climate-friendly technologies are not being deployed at a sufficient rate or in sufficient amounts to allow IEA countries to meet their targets. The main reason for this is that these are generally more expensive than conventional technologies. The low price of energy exacerbates the problem. This price disadvantage is often increased by subsidies that artificially lower the price of fossil fuels. In addition, there is an absence of policies to internalise the social cost of carbon emissions. These price distortions are barriers to the deployment of climate-friendly technologies. Technology deployment policies can help overcome price barriers since they encourage ‘‘technology learning.’’ These ‘‘learning investments’’ will be repaid with more competitive low-carbon technologies and new cost-effective solutions to our climate problem.

A great deal is said about the important role to be played by renewable energy technologies. It is certainly true that there have been rapid advances in these technologies and their use, and further growth is expected over the next decade. But, even with rapid growth, they will remain a relatively small fraction of overall power generation by 2012. Their contribution will be much more significant after 2012.

Societal and behavioural factors can also constrain progress, especially when the benefits of technology are taken in ways that do not reduce energy use. For example, while there have been major advances in the engine efficiency of cars, the consumer preference for larger, heavier vehicles has completely negated these, and emissions from the transport sector have risen considerably.

Preparing messages for Ministerial Meetings is, of course, only a part of the ongoing work programme at the International Energy Agency.

At present, one major pioneering area of IEA research focuses on analysing the domestic policies and measures needed to reduce energy-related greenhouse gas emissions. The precise title of the project is ‘‘Domestic Policies and Measures for Meeting the Kyoto Targets and Beyond’’. Our team is examining the costs, strategies, key elements and timing of policies of change required to reduce emissions from each major energy end-use, and the role specific technologies can play in meeting the Kyoto targets. Barriers to the adoption of low CO_2 technologies are also considered.

Specifically, the project is:

- identifying policies that have been most effective in promoting improved energy efficiency;
- identifying policies needed to encourage investment in low-carbon energy supply technologies;
- developing a country-specific analysis of the challenge faced to meet the Kyoto commitments;
- estimating realistic time paths of reduced carbon emissions (accounting for time to introduce low-carbon technologies and capital stock turnover);
- looking beyond Kyoto to see what can be achieved to stabilise atmospheric concentrations of greenhouse gases.

Preliminary results have been developed for the US, Germany and Denmark in several energy sectors. Results include detailed reference cases, Kyoto-challenge cases and low-carbon technology cases. These cases help identify the policies and measures that are necessary to meet the Kyoto commitments and promote long-term stabilisation of greenhouse gases. Phase I of this project was completed at the end of 1999.

Next is the IEA’s programme of collaborative energy technology R&D. The Agency operates a programme of international collaboration on energy technology in which 33 countries, including 11 non-IEA Member countries and the European Commission, work together on developing improved technologies in a wide range of energy-producing and energy-consuming domains. There are currently 40 active research projects — or Implementing Agreements as we call them — in the areas of fossil fuel technologies, renewable energy technologies, efficient energy end-use technologies, nuclear fusion science and technology, and energy technology information dissemination. An Implementing Agreement on fuel cells has existed since 1990, and Dr. Joon, a member of the Steering Committee for this Symposium, has been presiding over the Executive Committee of the Agreement since the start of the programme. These Implementing Agreements collectively link about 400 government and private research institutes world-wide, which mobilise over US$120 million annually to develop, and disseminate information on, numerous advanced and more efficient energy technologies.

2. The ‘‘Business-As-Usual’’ world

Now, let us me return to the crucial issues of barriers to the deployment of new, environment-friendly technologies, and what sort of options are available to overcome them.

In order to understand the importance of these issues, we need to take a look at how the energy world will look if we do not introduce any particular measures and if we stick to roughly similar conditions and policies; this is what we call the ‘‘Business-As-Usual’’ case. What does the picture show?

Not surprisingly, even in 2020 (Fig. 1), there will continue to be heavy reliance on fossil fuels. Oil will remain dominant, gas will overtake coal by 2020 and nuclear power is likely to remain static. The use of renew-

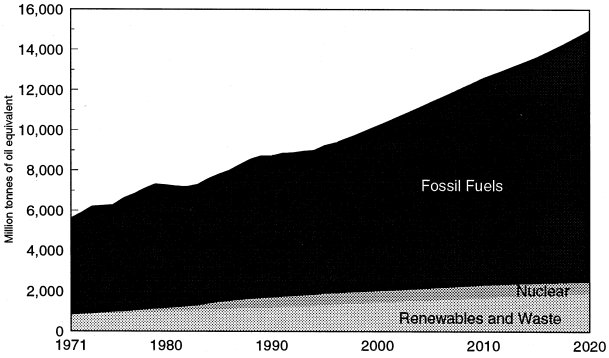

Fig. 1. World primary energy supply by fuel type (1971–2020). Source: IEA *World Energy Outlook*, 1998 edition.

able energy sources will grow, but still represent only a very small portion of the energy mix.

Under this scenario, the major industrialised countries will not succeed in reducing CO_2 emissions to the extent needed to meet the commitments made at Kyoto. Growth in the developing world will further compound the climate change problems. Large increases in CO_2 emissions are expected — particularly in Asia — as demand for energy services expands in pace with improved living standards (Fig. 2). Led by the substantial demand growth in China and India, the developing world's CO_2 emissions will surpass those of the OECD countries as early as 2010.

The IEA *World Energy Outlook* suggests that, to meet the commitments made in Kyoto, OECD energy-related CO_2 emissions would have to fall, as we have said, to almost 30% below the level projected for the ''Business-As-Usual'' scenario. Meeting this goal will require a large-scale shift, in the very near term, toward efficient and cleaner energy-producing and energy-consuming technologies.

However, under ''Business-As-Usual'' conditions, these technologies will not be deployed at a sufficient rate or on a sufficiently widespread scale to meet the Kyoto targets. If technology is to play an important role in reducing emissions by 2012 and beyond, immediate and sustained action is essential.

3. Obstacles to technology deployment

From a government perspective — and indeed from a general perspective — there are two ways of looking at the problem with technology deployment, and these somewhat overlap each other.

The first one is the well known challenge of ''market barriers''. Market barriers are obstacles to the deployment of technologies that are ready or nearly ready for normal application. These are quite distinct from the second sort of obstacle, namely ''technical barriers,'' which involve unsolved problems in the technology itself.

In this context of barriers, I should point out here that the IEA is engaged in ongoing research on factors affecting energy technology deployment. For example, in 1996 the Agency published a book on this subject that provided case studies for several kinds of technology, such as wind power, photovoltaics and energy-efficient lighting. As well as discussing market barriers that stand in the way of wide deployment of new energy technologies, the study recommended policy measures and programmes that would encourage more rapid deployment of advances in these technologies. Not surprisingly, from among the well-known range of obstacles to market development, the study concluded that cost relative to conventional technologies remains the key, and it recommended that more be done to understand the processes by which the cost of new technologies is reduced. We have made that question an important part of our continuing work on the deployment issue.

The simplest form of market barrier to a new technology is of course the out-of-pocket cost to the users in comparison with the cost of technologies currently in use. While, for the most part, these market barriers reflect the normal workings of the economy, some of them also involve ''market failure''. In such cases, a barrier exists or is reinforced because in some way the market does not take account of all the costs and benefits involved. For instance, assume that the market prices of equipment using new and old technologies are similar, but less pollution is associated with the new equipment. A price differential would exist if the market accurately accounted for the cost to society of the pollution caused by the old equipment. Here, the absence of a differential constitutes a barrier to the adoption of the new technology.

There are still other types of barrier, such as aversion to risk on the part of both buyers and sellers, or imperfect financial markets, or split incentives to investors and users of a technology, or even simply a lack of adequate information to ensure public awareness of the technology.

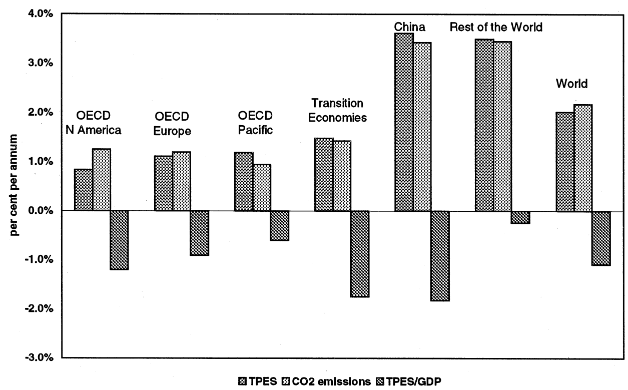

Fig. 2. Annual rates of growth (1995–2020) in total primary energy supply, CO_2 emissions and energy intensity. Source: IEA *World Energy Outlook*, 1998 edition.

The second way to look at difficulties in deployment of new technology reflects a more recent understanding of technological change and prompts us to develops the notion of barriers a bit further.

Technological progress has its own momentum, so it tends to remain oriented in certain directions, regardless of the existence or non-existence of any market barriers. It follows those ''trajectories'' established in the past where mass production and cumulative know-how have established ''beaten tracks''.

This is manifested clearly by the legions of engineers who are working on developing combined-cycle plants, turbines with higher efficiency or improved internal combustion engines; and they will continue to do so. They look for solutions based on the tried and tested technology building blocks that have been developed and have proved their worth in the past. The existing options have the volume, the markets and the infrastructure established over the years to be refined further and further. Engineers do not very often venture into radically changed systems. This is certainly very natural and safe behaviour, but it means that we are ''locked into'' the set of existing options in many areas of technology. Others, outside the established basket of options — indeed those we might need for breaking free from our carbon-based energy system — are not pursued as vigorously. This is why the progress in fuel cell technology in recent years has been so unexpected and exciting for many of us. It actually represents a very radical change away from thermal energy conversion, the engines and turbines that we are used to. But, in spite of the progress made, and in spite of the bold pledges of companies in favour of these new technologies, the overwhelming majority of development effort is still focused on the established technology options. It is therefore abundantly clear that the transition to pioneering, radically different technology is handicapped by intrinsic difficulties.

This is why governments need to be involved in long-term R&D. But, more important, they need to be involved in the stimulating of markets to overcome these obstacles to the deployment of cleaner and more efficient energy technologies. In other words, governments should try to prevent the risk of the market ''lock-out'' of radically new, but promising options.

Regulations and incentives will remain important policy instruments to remove the traditional market barriers. But, if we are to escape from the beaten track and carve out a new path that paves the way to sustainable development, new measures should also be considered. These include the determined use of ''niche markets'' to stimulate ''learning investments,'' or exploitation of something we call ''technology procurement''.

Here are some more details about three major barriers: cost barriers, infrastructure barriers, and market organisation barriers. We shall then look at some new approaches to overcome them.

3.1. Cost Barriers

The first barrier to pinpoint is the cost barrier, to which I have already referred.

The classic approach to this problem involves the adjustment of energy prices through taxation so that the estimated costs of environmental damage are included, or ''internalised''. But this is anything but an easy task. For instance, it is not possible to account for all types of environmental damage in a universally accurate and comprehensive manner. Even if this were to become possible, the process would be very complicated and time-consuming.

Furthermore, even if market prices were suddenly modified to reflect all the externalities, not all of the climate-friendly technologies would come immediately into widespread use. Manufacturing could be more difficult and costly, materials costs could be higher, or more highly skilled and expensive labour could be required for the production tasks. On the other hand, the fact that the cost of established technologies has led to the current low, competitive price levels results from decades of gathering of experience and knowledge at all levels in the product chain — from the researcher, through the production engineer to the repair technician. In such cases, the higher cost of the new technology is a barrier to wider use, but that illustrates the normal working of the economy.

Two strategies exist to tackle this cost barrier. One is obviously through further R&D. Indeed, numerous R&D programmes on fuel cell technology focus on cost reduction because fuel cell prices will have to be reduced drastically if fuel cells are to be competitive in the markets.

The other way of reducing cost is through, what we call ''technology learning''. The term means reduction of costs of a technology through the accumulation of hands-on experience. The notion is often described as ''learning by doing,'' and it includes what we know as economies of scale. There is strong evidence across industries that experience with supplying technologies reduces prices and that there is a relatively simple, quantitative relationship between accumulated experiences and price. A well known example involves the Ford Model T, one of the first mass-produced cars. The first units, were sold at a price some 2.5 to 3 times higher than the price of *exactly the same model* 10 years later, by which time the manufacturer had accumulated the ''experience'' of producing some 10 million units. This clearly did not result from research into the Model T technology itself, which had scarcely changed. It was due to improvement and up-scaling of manufacturing techniques and the optimisation of many other factors of production. Maybe we can draw comparisons between the experience level regarding the current fuel cell for automobiles and the early Model T. One big difference of course is that, today, the fuel cell technology for automobiles has to compete with the well-established internal combustion engine technology. Current internal combustion engines are the result of more than 100 years of experience. Or more precisely, the technology is based upon more than one billion engine units that have been produced world-wide since then.

An important tool for stimulating technology learning in real life is the ''niche market''. A niche market is typically a market in which a new product can compete with established alternatives because consumers are willing to pay for specific properties of the new product. It allows industries to gain manufacturing and operational experiences enabling them to cut prices. And this eventually opens up additional niche markets that may provide enough experience to achieve cost-competitiveness in broader markets.

The costs of advanced technologies over and above the established alternatives they are designed to replace are referred to as ''learning investments''. If private-market actors purchase more expensive but cleaner technologies on their own before they are cost-competitive, then the market bears the full cost of the learning investments, and that drives down the price of the technology through the learning process. Governments may wish to assist this process by subsidising purchases, by using their own purchasing power, and by using their capacity to set market rules. An example of such a rule is the requirement that a certain fraction of power generation come from alternative sources, such as renewables or co-generation. Similarly, governments can exploit their own purchasing power in administrative areas, for example by imposing the acquisition of electrical vehicles for certain public functions.

Such measures are likely to be more effective if different national approaches are harmonised to allow international market players to act in more homogeneous markets across national frontiers.

3.2. Infrastructural barriers

Let us now look at the second key impediment to many new technologies — the lack of infrastructure.

The use of new technology may require infrastructures that are beyond the capacity of any one market actor to provide. And everybody knows that one of the key impediments to the early deployment of fuel cell cars is likely to be the lack of refuelling infrastructure. Methanol, natural gas or even a suitable gasoline blend will require substantial production and distribution facilities. This is the classic ''chicken-and-egg'' problem. Technology users will not adopt a new vehicle technology until the refuelling infrastructure exists, whereas potential fuel providers will not make the necessary investments without the assurance of a larger market of technology users.

Once the choice of the fuel is clear, governments could provide incentives such as tax reductions, subsidies or expedited regulatory review, which would encourage the private sector to build up a refuelling network. However, the fuel choice is not yet clear and this conference will address that issue. In the meantime, some governments have started to act as a brokers. They have displayed a will to advance the communication and negotiation between the various market players, such as car producers, refineries and other energy suppliers. The aim is to get them all pulling in one coordinated direction. To use that ''chicken-and-egg'' metaphor, some governments are trying to get the chicken to sit on the egg so that it is hatched more rapidly.

3.3. Market organisation barriers

The third barrier I should like to mention today is that of market organisation.

A simple illustration of market organisation barriers can be seen in the housing and commercial building sector, where decisions affecting energy efficiency are typically made by real-estate developers and architects. Their primary concern is the initial cost of the houses or buildings, and they have no clear incentives for focusing on the life-cycle costs of energy-related choices because those costs are passed on to the owner or tenant. When, de facto, decision-makers on energy-related choices have little interest in the new technologies, and when the far-off, scattered voices of individual end-users are too distant to be heard, what incentive can the manufacturers have to focus on those new technologies? This phenomenon of ''split incentives'' in the housing and building sector also raises problems for fuel cell technology because this sector could yield a very large market for small-scale co-generation units.

An important approach to addressing these market organisation barriers is to integrate energy efficiency principles into sector policies. One example — albeit not directly related to fuel cells — is to incorporate or consolidate energy efficiency provisions in building codes and standards for existing and new buildings. In this way, improving energy efficiency and emissions performance with usual capital stock turnover will become ingrained into business practice in each sector. To bring this approach into effect, energy and environmental authorities should work closely with housing authorities to ensure that ongoing modification, renewal, and extension of existing buildings incorporates investment on improved energy efficiency.

Another successful approach to solving this split incentives problem is called ''technology procurement''.

Many people are familiar with the slightly different term ''government procurement,'' where government authorities define rules for public purchases. In the case of ''technology procurement,'' a government agency acts as a kind of a broker for other, private purchasers. It identifies and bundles potential customers for a highly efficient product that is viable but not yet available in the market. A call for tenders is launched and if the group of potential buyers is sufficiently interesting for a supplier, it will make a bid. The successful supplier thus wins a sure sales volume from this competition for its new, tailor-made product. The ‘‘technology procurement’’ process can help reduce risks to enterprising manufacturers by developing an assured first market, and thus steer them towards improved environmental performance in their products.

This procedure has been the subject of many tests, some organised by the IEA Implementing Agreement on Demand-Side Management. In the buildings equipment area, high-efficiency thermal insulation windows, heat pump laundry dryers and bureau lighting equipment have been developed and made available on the market as a result of this approach. Through this mechanism it has become abundantly clear that focused technological advances can be triggered in certain areas and, more importantly, that products can be actually introduced into the markets. There is no reason to believe that such mechanisms could not be adapted to the market for fuel cells in some market application.

4. Conclusions

Let me now conclude with a few general remarks.

First, market introduction of a new and radically changed technology is a challenge of considerable magnitude, particularly for the companies required to make the investments and develop the products. While I have focused largely on the government perspective, it is very clear that the introduction of such technology needs to be driven by the pioneer industries. It is they who must innovate to establish the new technology paths, as alternatives to the beaten track. And there is no doubt that fuel cell technology has begun to establish its new technology path.

At the same time, governments are increasingly aware that removing market barriers in order to accelerate technology deployment is very important, but also that simply going through the motions of removing barriers is not sufficient. They have recognised the need to find ways to promote technological advances in directions that offer the highest promise for sustainability. The government approach should not be misunderstood and regarded as ‘‘interventionist’’. While admittedly tentative, it is an approach aimed at stimulating market forces and orienting them towards the solutions that offer the greatest promise for securing a sustainable energy future.

Finally, we should not forget that a crucial factor for successful development and deployment is a thorough and solid understanding between industry and governments regarding their respective roles. A primary requirement is most certainly the dynamic of a properly functioning and fruitful dialogue between government and industry. In this way each player can be expected to pull his weight effectively, but above all, to pull in the same direction.