September 10, 2001

Mr Allan Brereton
Energy Team
Performance and Innovation Unit
Cabinet Office
Admiralty Arch
The Mall
London SW1A 2WH

Dear Mr Brereton,

The Institute welcomes the Performance and Innovation Unit's Review of United Kingdom Energy Policy. The Institute of Physics is an international learned society and professional body with over 32,000 individual members. In recent years, in consultation with its membership, the Institute has grown in prominence in the field of energy and environmental policy. By way of illustration I attach copies of two recent policy submissions concerning energy and environmental policy. I trust that these will prove informative to the current PIU Review.

The Institute is acutely aware of the human challenges facing energy policy. Britain risks a substantial shortfall in the number of technically qualified young people required for diverse, secure and economic sources of energy in future. On 1 October 2001 the Institute will launch a major and wide-ranging report concerning physics higher education. The report and its associated statistical documents will provide substantial insights into national supplies of highly qualified young people. In addition, the Institute commends to the PIU the work currently underway in HM Treasury under the Chairmanship of Sir Gareth Roberts reviewing the supply of scientists and engineers in the UK. Lastly in this context, the Institute notes with interest that BNFL has recently greatly increased its direct support of UK higher education. It is in the nuclear field that the continued provision of sufficient numbers of high quality staff will be particularly important.

The Institute contributed extensively to the recent Foresight exercise and has from the beginning been a strong supporter of the Foresight concept. A publication entitled *Physics for Foresight – physics at the heart of the future* collates the Institute's full range of contributions into the recent Foresight exercise. This document is available form the Institute's website at http://physics.iop.org/IOP/Foresight/instrpts.html .

The Institute proposes that science and technology can be drivers for change and that the Foresight process and the PIU Energy Review should properly recognise this.

The Institute notes that Energy Policy is very much at the heart of current policy concerns for many organisations both public and private. In order to play the fullest role in these matters at this time, the Institute is planning to produce a document

discussing physics-based energy technologies with substantial promise for the future. In addition the Institute is discussing partnering with the Institute of Biology and the Royal Society of Chemistry to produce a series of inter-related seminars in the autumn highlighting important issues of energy and environmental concern.

Physics has much to offer future energy needs be it via the long-term goal of nuclear fusion power and the shorter-term goal of efficient, easily fabricated photovoltaics. These issues among many others shall be the subject of much discussion by the Institute in the coming months.

The Institute would be pleased to see its official submissions added to the Performance and Innovation Unit website.

The Institute will endeavour to inform the Performance and Innovation Unit of developments as its work progresses through the autumn.

Yours sincerely,

Peter Cooper
Director, Science

Enclosures:
List of Institute of Physics policy submissions dealing with Energy and Environment.
Letter of 28 September 2000 to the Energy and Natural Environment Foresight Panel.
Letter of 10 April 2001 to the International Energy Unit of the Department of Trade and Industry.

## Energy and environmental research policy responses

*http://physics.iop.org/Policy/submissions.html#energy*

1. Letter from the Chief Executive to Lord Sainsbury of Turville, regarding fusion as a source of 21st century electricity (May 2, 2001).

2. Letter from Director, Science to Mrs Loraine Dawson (Head, International Energy Unit) at the DTI regarding the EU Green Paper, Towards a European strategy for the security of energy supply (April 10, 2001).

3. Letters from the Chief Executive to Mr Philippe Busquin (European Research Commissioner), Professor Elly Plooij-van Gorsel MEP, Lord Sainsbury of Turville (Parliamentary Secretary, Science), and Ms Helen Liddell (Minister for Energy and Competitiveness in Europe) concerning Fusion – European Leadership for 21st Century Electricity Supply (January 12, 2001).

4. Renewables Obligation - response to the DTI's preliminary consultation document (4 December 2000).

5. Letter from the Department of Higher Education and Research to Sarah Wright of the Royal Society in response to the Royal Society's and the Royal Academy of Engineering's request for responses with regard to their joint study to examine the role of renewable energy policy (August 22, 2000).

6. New and renewable energy - response to the DTI departmental consultation document (1 June 1999).

7. Climate change - response to the DETR consultation on UK Climate Change Programme (15 February 1999).

8. Energy and the environment - submission to the Royal Commission on Environmental Pollution study (7 December 1998).

9. Management of Nuclear Waste - submission to the House of Lords Select Committee on Science and Technology sub-committee (4 February 1998).

10. DTI Nuclear Review - letter and report to the Department of Trade and Industry (3 October 1994).

Mrs Loraine Dawson
Head, International Energy Unit
Department of Trade and Industry
Room 1102
1 Victoria Street
London SW1E 6SW

10 April, 2001

Dear Mrs Dawson

**Towards a European strategy for the security of energy supply**

The Institute of Physics is a leading international professional body and learned society, with over 32,000 members, which promotes the advancement and dissemination of a knowledge of, and education, in the science of physics, pure and applied.

The Institute of Physics embraces member-based professional subject groups in areas, including Environmental Physics, Combustion Physics, Nuclear Physics and Energy Management. Members are involved in many areas related to energy issues, including R&D of low emission energy technologies, understanding of the climate through climate modelling, and in environmental pollution monitoring. The Institute is well placed, therefore, to comment on technical issues pertaining to the security and supply of energy. It is not in a position to make any recommendations with regards to energy markets, which lie beyond its remit.

The Institute has been actively involved in the debate of energy and environmental issues and has submitted its views to several governmental and parliamentary consultations. A full list of the Institute's previous contributions to the energy and environment is given on the Institute's website at *http://physics.iop.org/Policy/public.html.*

The Institute welcomes the Green Paper, which it believes highlights most of the threats and opportunities the Member States of the European Union (EU) are likely to face in the short to medium future with regards to the security and supply of energy.

The Institute recognises the fundamental importance of secure energy supplies to maintain the social and economic structure in Europe. It therefore:

- supports the concept that a common policy needs to be adopted in order for the Member States to be able to supply energy from indigenous sources without being threatened by supply problems that could arise outside of the EU;

- believes that stability and security is best assured by maintaining a mixed energy economy, drawing on all energy sources as appropriate to meet energy and environmental needs;

- supports the importance of environmental and sustainability issues, as evinced by the Kyoto declaration and targets, and concludes that meeting those targets must be a prime, but difficult objective;

- urges that all energy sources be addressed for their contribution to our energy needs on an equal basis – in particular we are concerned at the political moves away from nuclear power, despite its comparative benefits in respect of climatic effects;

- believes that science and technology will be key drivers in future energy policy, and thus that increased research and development into all forms of energy generation, efficiency end use, and the science and technology underlying them, will be needed if we are to achieve these objectives; and

- believes that many of the issues relating to energy are reliant upon an ensured supply of high quality science graduates and the public's acceptance of the need for environmentally sustainable policies.

The Institute's detailed comments on points raised in the Green Paper are given in the attached annex.

I hope these points will be of help. If you need any further information on the points raised, or generally on the Institute's views on energy and environmental issues, please do not hesitate to contact me.

Yours sincerely

Peter Cooper
Director, Science

Institute *of* **Physics**

# Response to the Green Paper, Towards a European strategy for the security of energy supply

## *1. Science for energy security*

Energy supply end use, and the implications for the environment, are undoubtedly one of the most important issues facing the world.

Environmental issues will increasingly dominate the national and international agenda – including everything from sustainability and climate change to water supply and energy policy - and science and engineering will continue to be an essential part of the solution to the problems the world faces. The UK needs policies and principles that will develop its role in putting sustainability into practice and increasing its potential for sharing clean and low emission technologies with other countries around the world or exporting them.

## *2. Technologies and novel fuels for energy security*

### i. The problems associated with the security and supply of energy

The Institute is of the view that issues relating to energy supply and demand must be addressed without delay by all governments, industries and societies. Without planning we are likely to see a loss in the diversity and security of energy supply, which may lead to an unpredictable and volatile energy market. Measures need to be taken now to complement fossil fuel based energy supply with alternative lower emission sources of energy.

If, as predicted by many, fossil fuels continue to be the main fuel source for the next 20 years at least, societies, industries and governments will have to increase investment into developments in fossil fuel use and combustion research, coupled with improvements in energy use efficiency. A robust consideration of the energy demand issues will be critical in minimising the environmental impact of energy use.

However, climate change and dwindling fossil fuel reserves will be important drivers for change and continuing reliance on fossil fuels must not remove the need for governments and societies to appreciate the relevant issues and to recognise the need to invest in R&D on low emission energy technologies.

### ii. Energy efficiency

Energy efficiency will have an important role to play in the short to medium term, by reducing demand for imported fossil fuels, and clearing the path for the gradual introduction of low emission technologies developed within the EU. In addition, energy efficiency will play a key role in lowering harmful greenhouse gas emissions into the ambient environment. The problem of waste in use of energy could be tackled with changes in the style and use of energy in the home and elsewhere.

Nonetheless, security of supply is not guaranteed by energy efficiency measures alone. Diversity of supply and "optionality" must be a key consideration in securing the future of energy supply.

The more efficient use of energy would have an overall improvement on living standards for all, with better housing conditions, better air quality and a more tranquil environment with less pollution from traffic. This could be achieved with the implementation of a co-ordinated and integrated national and international energy policy, which must recommend and promote efficiency in the use of energy in the home and office, and the adoption of a low energy lifestyle by all. Reducing energy demand by increasing energy efficiency may in the short-term appear to be a more viable option than the implementation of non-polluting energy sources. The Institute believes that there is a need for a step change in the manner in which we create and use energy and materials, in order to limit further catastrophic effects on the environment.

Combined heat and power (CHP) could play a major role in terms of increasing domestic and industrial energy efficiency, as CHP systems allow the on-site generation of energy, by converting low cost fuel (i.e. natural gas) into electricity, which is an efficient method of electricity generation. In addition, sophisticated heat recovery systems within the CHP collect the heat generated, which can be also used on the site. CHP to date has been deployed in hospitals, high rise flats, hotels, sports centres etc., but further R&D is required to further improve efficiency, and the creation of an infrastructure necessary for distributing low-grade heat needs to be considered.

It has been suggested that that a reduction in the use, and particularly wastage of energy could be brought about by the implementation of a general carbon tax. The carbon tax, would be based on the quantity of carbon dioxide emitted per unit of energy supplied, and would be levied at source as a direct charge on the amount of carbon emitted per unit of energy supplied. This would result in higher prices to the consumer, but would stimulate efficiency improvements and reduce consumption. The revenue from the carbon tax would be used to fund R&D into low emission energy sources and into measures for mitigating the effects of climate change. The Institute is of the view that if a carbon tax was to be introduced in the foreseeable future, it must be well formulated and based on good scientific grounds.

One point that needs to be taken into consideration when discussing energy efficiency is the difficulty of storing electrical energy. On the large scale we have pumped storage schemes, such as those in North Wales; on the small scale we have batteries, which are heavy and expensive. The issue of storage is relevant in two areas, first transport, for example electric motor cars, and

second renewable sources, such as wind generation and solar power. Societies will expect electricity to be available at all times, irrespective of the weather. In fact a major breakthrough in energy storage, with greater R&D in battery related technology, would help alleviate the problems associated with the storage of electrical energy. To that effect, Innogy, part of National Power in the UK, are in the process of developing a new type of regenerative fuel cell, which could revolutionise the energy industry. In addition, R&D into superconductors capable of storing of electricity is also currently being undertaken.

It has been recently suggested that the UK and other EU nations will move increasingly to importing its natural gas supplies. The reliance on natural gas as the main energy source leaves the UK and other EU nations vulnerable to severe disruption of supply in case of adverse political or economic decisions elsewhere. While at present the UK is in a position to supply 98% of its natural gas from its own sources, this position is not sustainable in the long term. The Institute is strongly of the view that security of supply demands a balanced mix of fuel sources, including nuclear power, for base-load supply of electricity.

The next 20 years will see increased world competition for fossil fuels as Russia, other USSR nations, China, India, Africa and South America increasingly move to giving their populations western levels of transport, industrial production and living standard. These include air conditioning in hot countries and significant domestic heating in cold countries. This will provide significant challenges and opportunities to the UK and other developed countries equipped to export clean technologies and know-how.

In addition, the US President's announcement that the US does not intend to achieve emissions reduction specified in the Kyoto protocol, makes it more important that the UK continues to work with its European partners for carbon dioxide mitigation and remains engaged with the US in discussion on this vitally important scientific, technical and political issue.

### iii. Low emission and alternative sources of energy

*- Nuclear power generation*

The Institute is concerned to note that the Green Paper states that most Member States would be in favour relinquishing the nuclear sector of supply energy. The Green Paper also highlights that at present 15% of energy demand is covered by nuclear, and this could be as little as little as 6% by 2030. The energy mix for the future, under all scenarios, will inevitably have to include nuclear power generation. The decommissioning of existing nuclear power plants, unless countered by the development of new reactors, will result in nuclear power electricity generation declining over the next decade as highlighted in the Green Paper. This may lead to a greater dependence on fossil fuels to supply energy, as it is at present difficult to envisage renewables meeting the increased demands for energy, due to difficulties in supplying energy in all weather scenarios and the problems associated with storing electrical energy. In addition, it is debatable whether renewables will be able to meet

the base-load supply of energy within the time-scales highlighted and in the requisite quantities.

Electrical generation based on nuclear fission is an established 'carbon-free' electrical generation technology currently providing about a quarter of the UK's electricity and a fifth of the EU's. Importantly, recent reduction in carbon dioxide emissions, particularly in the UK, has been assisted by significant increases in nuclear power generation. New investment in nuclear generation represents the only option to maintain this trend in the foreseeable future – conversely, a reduction in nuclear generation will put an even greater strain on reaching the Kyoto targets.

Thus, the Institute is of the view that if there are major concerns with regards to the security of supply of conventional fossil fuel sources of energy such as oil and gas, then nuclear power generation, under the appropriate provisos must not be overlooked as a long-term source of indigenous energy by EU Member States.

However, the Institute acknowledges that if nuclear power is to have a significant role in a future energy mix, then progress needs to be made on the issue of the safe disposal of nuclear waste. Within current time-scales nuclear waste has been managed satisfactorily but a decision on a repository is necessary as part of the solution. Progress is being made in other countries and the lack of progress, particularly in the UK needs to be addressed. The development of reactor designs with greater intrinsic safety properties should be encouraged. Nuclear power needs increasingly to be perceived by policy makers and societies as an economic and sustainable form of energy, but this depends upon the implementation of the right policy legislation, management and education. Recently in the UK the nuclear waste issue has received renewed consideration by parliament, government and third parties, which the Institute welcomes.

With a 10 year minimum lead time for the development of a nuclear plant from initial concept to power on the grid, a decision will need to be made in the next few years whether the EU needs to progress with the development of new reactors. It is well understood that nuclear power plants take a long time to construct and significant capital outlay is required. However, once complete, nuclear generators provide large amounts of dependable base-load electricity capacity and operate efficiently for several decades. There are arguments in favour of new construction of modern nuclear fission power plants on the sites of existing nuclear power stations. Many of these existing reactors will be decommissioned in the coming years. Replacements will be required in order to maintain or improve the EU's current diversity, security and environmental balance of electricity supply.

In addition, the Institute is of the view that nuclear fusion has an important role to play in low emission energy technology in the long-term future. Despite the fact that commercial electricity generation from nuclear fusion is not likely before 2040, its benefits as an energy source for the long-term future are very large.

- *Renewable energy technologies*

The Institute fully supports R&D into new renewable energy technologies, which may eventually reduce the requirement for fossil fuel consumption by EU nations, and the

rest of the world. Renewable energy technologies are an essential part of the future energy mix, but need an increase in research and innovation in the relevant R&D sectors, in order for the UK and the EU to be in a position to respond to the challenges of the medium to long-term future.

Renewable energy technologies currently suffer from various barriers to exploitation, which demand greater R&D. These include – the power density required by some EU Member States, particularly the UK, making the use of renewable sources problematic; disadvantages of renewables with respect to base-load capacity and the inflexibility of their supply; high economic costs in comparison to fossil fuel technologies; and they can have environmental impacts (i.e. noise pollution, visual intrusion etc.) which may be reduced only through substantially greater capital investment.

In addition, renewable energy technologies will need to be assessed comprehensively and objectively for their full environmental impacts. They must be considered against the backdrop of competitive energy markets and the need to ensure a socially beneficial energy policy. This may be perceived as a barrier to innovation and technology, but it is important that as full as possible an environmental impact assessment is made, including issues such as noise pollution, visual intrusion, environmental damage from underpinning infrastructure, and the whole life cycle of the technology from construction through to decommissioning. Environmental considerations and comparisons should not be restricted to an evaluation of emissions. Objective and consistent considerations should be applied equally to all technologies, as a balanced and stable energy policy will require a clear understanding of each technology. Energy markets and regulatory frameworks should reflect such considerations in future.

Physics and physicists are playing an essential role in the understanding of physical principles relating to energy and environmental technologies, and in R&D into renewable energy technology. Notable examples include onshore and offshore wind turbines, tidal power, wave power, photovoltaic solar power, hydrogen fuel cells and battery powered electric vehicle technologies. As already mentioned, Innogy, are in the process of developing a new type of regenerative fuel cell, which could revolutionise the energy industry. Such developments require a strong physics community with long-term research capability, closely linked to other sciences and engineering. Further information on the role that physicists are playing in the R&D of renewable energy technologies can be found in *Physics World*, August 1998 (*http://physicsweb.org/toc*). Further information on the work being conducted by Innogy, can be found in *Physics World*, October 2000.

- *Photovoltaics*

One of the most promising renewable energy technologies being developed is solar power. So far, only a small fraction of the energy currently used is generated from solar cells. The problem is the power density (the power generated per unit), and it is

questionable whether solar power will be in a position to supply energy for increasing base-load demand within the next decade.

On going research into thermophotovoltaic (TPV) cells has shown that they could have the potential to yield a power density greater than 300 times that of a standard solar cell. But in order for the true potential of solar power to be realised, greater funds for R&D are needed.

Thus, it was pleasing to note that the Minister for Energy, declared the government's support for photovoltaics by announcing funds for photovoltaic research, including a grant programme to support the installation of solar panel photovoltaic arrays on some 70,000 properties, in addition to support for other renewable technologies, including offshore wind and energy crops.

### iv. Hydrogen economy and transport

The EU's long-term dependence on oil as a transport fuel source could be reduced with the continued development of hydrogen fuel cells and the emergence of a "hydrogen economy". The internal combustion engine has dominated the transport industry and small-scale energy generation for over a century. But concerns over the environmental impact of exhaust emissions, has led to the development of fuel cells, which provide both ultra-low emissions and high efficiencies.

Unlike batteries, fuel cells do not require charging and do not lose energy when converting between electrical and chemical energy. Indeed, energy storage in some form of fuel is more effective than in any type of rechargeable battery, since it improves the power density of the system and ultimately the driving range of the vehicle.

Applications like stationary power plants and fuel cells for transportation could become a commercial reality within the next five to ten years, mainly due to technological improvements in the proton-exchange membrane (PEM) fuel cell. These advances have resulted in a series of strategic alliances between fuel-cell developers and car manufacturers. Further information on potential of hydrogen fuel cells can be found in *Physics World*, August 1998.

In addition, the re-formulation of oil and gas into hydrogen-rich fuels which can be used in on-board fuel cells powering electric motors could also be a viable option to traditional oil based motors.

### v. The combustion of fossil fuels

The combustion of fossil fuels will be a major source of the world's energy for the foreseeable future since alternatives cannot currently provide the quantities at an economic level. Furthermore there are certain sectors, such as civil aviation, for which no other realistic alternative fuel types are available. Combustion in all its diverse forms, therefore, will remain an important issue for many years. There has been a lack of funding and support for UK combustion research in recent years, and the profile of combustion research needs to be raised as a necessary requirement for sustainable

economic growth in the short to medium term. Fundamental and applied combustion research can decrease our use of fossil fuels, and hence greenhouse gases, and noxious emissions at source, rather than relying on clean-up technologies after the event. It is also necessary if biofuels are to be fully exploited, as well as alternative technologies such as the production of syngas from gasification plant for subsequent combustion in gas turbines.

The Institute would be in favour of continued electricity generation from coal powered generators if the generating efficiency could be increased, hence lowering emissions. In addition or alternatively coal based generators could limit their carbon emissions by the implementation of carbon sequestration technologies.

With the appropriate funding and support, clean coal electricity generation could be a very cost efficient method of reducing harmful emissions and pollution.

## *3. Mitigation and remediation*

A major challenge ahead for suppliers of fossil fuel energy technologies will be to mitigate the emissions. There is a need to identify and have in place cost-effective technologies, which can be applied rapidly, to coincide with any major policy changes.

The most obvious solution to the problem of greenhouse gas emissions is of reducing the volume of emissions at source. Remediation is not an ideal solution, and the land area of the UK is possibly too small for tree planting to make a significant contribution in lowering atmospheric carbon dioxide levels. However, existing forests and other carbon sinks (i.e. soils) should be conserved, in order to prevent the latter in particular, from becoming potential sources of carbon.

Carbon sequestration, under the right provisos, could play a role in mitigating the effects of carbon dioxide emissions in the short to medium term future. Captured carbon dioxide could be converted into an appropriate form and deposited in the earth's geological strata, preferably under the seabed. This would be best applied to emissions from large power stations. However, the main barriers to sequestration appear to be the associated high costs and concerns over the safe environmental storage of carbon dioxide.

## *4. People issues and public understanding*

In order to tackle the scientific and technological challenges presented by future energy scenarios, the UK will need to recruit more new graduates to energy and environmental disciplines. This will require offering better employment opportunities for graduates in the environmental sciences, which are currently poorly paid compared to other scientific disciplines. The sector is growing, but has few career role models as compared with other disciplines. The sector must recognise more fully the need for career development and must initiate attractive training programmes to attract the best graduates.

The public's understanding of the key issues, especially those related to science and technology will have to be enhanced. It is essential that education and information is provided in a co-ordinated way, starting in primary schools and continuing through to the adult population. But informing the public is only a part of the solution – the public has a voice and its views and concerns have to be taken into account.

28 September, 2000

The Secretariat
Energy and Natural Environment Foresight Panel
Room 582
Department of Trade and Industry
1 Victoria Street
London SW1H 0ET

Dear Sir/Madam

**The Foresight Energy and Natural Environment Panel**
**A Way to go**

The Institute of Physics, the professional body and learned society representing physics and physicists, is an enthusiastic contributor to the national Foresight Programme. I am pleased, therefore, to have the opportunity to comment on *A way to go*, the consultation document recently published by the Foresight Energy and Natural Environment Panel.

Overall, the consultation document presents a fair picture of the issues and opportunities in the area of energy and the natural environment. However, the Institute considers that the role of science and technology, and especially physics and its applications, in understanding the processes and in devising means to resolve or mitigate adverse environment change has been understated.

Rather than comment in detail on the questions asked in the consultation document, the Institute would like to make the following points which relate to the issues raised in the consultation document.

1. Energy sustainability and other issues of environmental importance are a national and international priority, with the potential global environmental problems facing mankind in the next 10-50 years. Concerns regarding environmental pollution and climatic change have raised the general publics concerns regarding the environment to an all-time high.

2. The issue of stopping the growth (and preferably lowering) of atmospheric $CO_2$ levels and other greenhouse gases, is one of great importance, and possibly the one key factor in reducing the ever increasing threat of global warming and its associated threats to the earth's weather systems, ecosystems, and the overall quality of life. Realistically emissions need to be reduced by about 60% to stop growth, however, that target at present appears to be unattainable. Thus, our aspirations need to be modified as to one of minimising the rate of change.

3. Over the past decade, lifestyles have changed in response to new technological advances, social changes, increasing population numbers, all of which have led to higher energy demands. Increasing demands for transport, housing and land are having an adverse effect on the environment, and resulting in a culture and a society which performs actions without adequate thought for the consequences for the immediate and long-term future. Thus, the Institute supports the Panel's views regarding the potential environmental dangers facing us in the foreseeable future, especially water shortage, increasing energy demands, long term exposure of varying doses of hazardous pollutants, poor air quality and the associated health risks. The Institute also agrees with the Panel, that achieving sustainable development may well entail major changes in consumer behavior, in production and the manner in which society manipulates the environment.

4. The consultation document discusses several drivers for change in the energy and environment area. The Institute believes the Panel has understated the degree to which science and technology themselves are drivers for change in this area. For instance, developments in information technology, providing e-commerce and communications infrastructures, can alleviate pressures arising from the transport of people, documents and products. The invention of the jet engine transformed intercontinental travel; technological developments in clean vehicle technologies could transform the quality of life in our cities.

5. The Institute recognises the likely scale of demand of society in the future and the problems facing energy supply and demand in the 21st Century. The Institute agrees with the Panel, that there is a need for a future built on sustainability, which will aim to encourage economic growth, but in a manner that would not irreversibly damage the environment further. In view of this, the Institute supports the Royal Commission on Environmental Pollution's (RCEP) recommendation of setting up a Sustainable Energy Agency, to promote energy efficiency, lower pollution levels in all sectors and co-ordinate that with the rapid development of new energy sources and energy recovery technologies [1].

6. The more efficient use of energy should have an overall improvement on living standards for all, with better housing conditions, better air quality and a more tranquil environment with less pollution from traffic. This could be achieved with the implementation of a co-ordinated and integrated national and international energy policy, which must recommend and promote efficiency in the use of energy in the home and office, and the adoption of a low energy lifestyle by all. This could be achieved for example, with the construction of better designed buildings, having better insulated houses, more efficient refrigeration systems, energy saving lighting and by the use of low energy motors. The problem with all these examples, is that they require a large capital cost, although the returns over a lifetime are better. People tend to buy on capital rather than lifetime costs, thus, the Government needs to promote a change in thinking, and not just changes in technology. In addition, the role of information technology needs to be developed further in energy efficiency, as it has an important role to play as a control method for the better use of

energy. It must be noted, that measures towards reducing energy demand and promoting efficiency must recognise the particular needs of vulnerable citizens, such as, the poor and the elderly [2].

7. Reducing energy demand by increasing energy efficiency may in the short-term appear to be a more viable option than the implementation of non-polluting energy sources. The Institute agrees with the Panel's view that there is a need for a step change in the manner in which we create and use energy and materials, in order to limit further catastrophic effects on the environment. Thus, the Institute believes that it is worth highlighting that our increasing understanding of materials, due largely to research in physics laboratories, is likely to make a significant contribution to increased energy efficiency. One specific example is the application of optoelectronics to the development of high efficiency lighting. In terms of energy efficiency, another important area is the development of new catalysts for improving the efficiency of chemical processing and the control of pollutants therefrom, e.g. the control of pollution from motor vehicles.

8. One point that needs to be taken into consideration when discussing energy efficiency is the difficulty of storing electrical energy. On the large scale we have pumped storage schemes, such as those in North Wales; on the small scale we have batteries, which are heavy and expensive. The issue of storage is relevant in two areas, first transport, for example electric motor cars, and second renewable sources, such as wind generation and solar power. Society will expect electricity to be available at all times, irrespective of the weather.

9. At present, fossil fuels are the major source of energy in the world. However, the continuous use of fossil fuels will eventually result in $CO_2$ levels exceeding the recommended upper limit of 550 ppmv which, as highlighted in the recent RCEP report, is believed will lead to dangerous and destructive climate change [1]. In any case, fossil fuels are a finite source of energy, and unless measures are taken to supply energy by alternative sources, a future beckons, where the prices of coal, oil and gas will escalate, resulting in a volatile, unpredictable energy market.

10. The Institute has noted the Government's commitment to meet challenging environmental targets, such as a reduction in the emission of greenhouse gases of 12.5% by 2008-12 and of $CO_2$ by 20% by 2010 [3]. Thus, it is of concern to note that the RCEP report states that the UK is at present poorly prepared to meet these long-term targets.

11. The Institute concurs with the statement in the consultation document, that despite the fact that a 60% reduction in current levels of green house gas emissions can be achieved, this could be countered with large increases in emissions from developing countries, undergoing rapid industrialisation. The Institute has made aware to the Government, in its response to the DTI departmental consultation document, *New and Renewable Energy* [3], that the UK needs to push for international progress in reducing global warming gases, and has highlighted the fact that the consequences of global population growth and regional economic development will need particular consideration.

12. The Institute supports R&D into new renewable energy technologies, which will take the burden off the fossil fuels, which will result in lower greenhouse gas emissions. In addition, the Institute encourages raising the awareness and understanding of environmental issues not only by the influential decision makers, but equally importantly by the general public. New and renewable energies are an essential part of the future mix, but as mentioned in the consultation document, they need to be accompanied by an increase in research and innovation in the relevant R&D sectors now, in order for us to be in a position to respond to the challenges of the medium to long-term future. The UK benefits from a long history of developing cutting edge technologies for clean energy supply, but cannot be regarded as having a monopoly in these technologies. The Scandinavian countries and the Netherlands would appear to be ahead of us in technologies for combined heat and power (CHP), while Denmark is ahead in wind power technologies. One option for the UK would be to take a lead in wave power R&D, as the technology has the potential to make a significant contribution to electricity generation in the UK [2].

13. The Institute notes with concern that the recent Comprehensive Spending Review appears to have omitted support for promising renewable sources of electricity, including biomass and offshore wind power [4]. Public support and funding for energy R&D in the UK has declined dramatically over the last decade, and the Government needs to increase emphasis on R&D into new and renewable technologies, by providing the requisite funding, if the UK is to meet its declared Kyoto commitments by 2010 [5]. In addition, support for this industry has the potential to give the UK a strong position in an emerging new industry with global potential. UK business is well placed to exploit the global business opportunities of building a greener energy future. The UK has the opportunity both to reduce its contribution to pollutant emission and to gain in its share of environmental contracts worldwide.

14. Physics and physicists are playing an essential role in the understanding of physical principles relating to energy and environmental technologies, and in renewable energy technology R&D. Notable examples of energy technology research include, wind turbines (onshore as well as offshore), tidal power, wave power, photovoltaic solar power, and hydrogen fuel cells. Such developments require a strong physics community with long-term research plans, closely linked to other sciences and engineering [3]. In addition physicists are studying atmospheric physics and specifically the role of pollutants in affecting the atmosphere. Monitoring and understanding their effect is clearly a necessary preliminary to devising effective methods of control.

15. Despite advances in alternative energy sources, it is clear that the combustion of fossil fuels will be a major source of the world's energy for the foreseeable future since alternatives cannot currently provide the quantities at an economic level. The requirement for clean and efficient combustion is accentuated by the increasing energy demands of both developed and developing countries. Combustion, in all its diverse forms, will therefore remain an important issue for many years. This is the case in context of climate change, where combustion

efficiency must be increased, and emissions reduced, if sustainable economic growth is to be attained through the reduction of greenhouse gases, acid rain and photochemical smog.

16. The competitiveness of the UK energy industry, and the achievement of the Government's commitment on the stabilisation of greenhouse gas emissions, depends upon a strong research base. This must be judged against significant reduction in recent years of R&D expenditure by the UK energy industry. We are at a stage where the academic sector, working closely with industry, must play a leading role in the provision of research results and expertise in the combustion area.

17. In view of the lack of funding and support for UK combustion research in recent years, the profile of combustion research needs to be raised as it is a necessary requirement for sustainable economic growth in the short to medium term. Fundamental and applied combustion research can decrease our use of fossil fuels, and hence greenhouse gases, and noxious emissions at source, rather than relying on clean-up technologies after the event. It is also necessary if bio-fuels are to be fully exploited, as well as alternative technologies such as the production of syngas from gasification plant for subsequent combustion in gas turbines.

18. It is vital for the UK to maintain a programme of basic research to inform environmental policy; especially in the understanding of environmental processes and the measurement and analysis of data. The Institute has expressed concern that research funding structures have not encouraged interdisciplinary collaboration, which is key for environmental research [3].

19. Renewable energy technologies must be assessed comprehensively and objectively for their full environmental impacts. They must be considered against the backdrop of competitive energy markets and the need to ensure a socially beneficial energy policy [3]. This may be perceived as a barrier to innovation and technology, alongside the other barriers to innovation detailed in the consultation document, but it is important that as full as possible an environmental impact assessment is made, including issues such as noise pollution, visual intrusion, environmental damage from underpinning infrastructure, and the whole life cycle of the technology from construction through to decommissioning. Environmental considerations and comparisons should not be restricted to an evaluation of emissions. Objective and consistent considerations should be applied equally to all technologies, as a balanced and stable energy policy will require a clear understanding of each technology. Energy markets and regulatory frameworks should reflect such considerations in future [3].

20. One such energy source that the Institute considers must be evaluated and considered as part of an energy mix is nuclear power. Politically and publicly, nuclear power may be out of favour, but many of the problems associated with nuclear power are more of perception than reality. With the possibility of renewables only being able to contribute around 10% of the UK's electricity by 2010, and inherent environmental considerations from fossil-based sources, there may be a need to invest more in the development of new reactors, in light of most

of the current power stations nearing the end of their useful life. Unless tackled, this could result in a shortfall of electricity supply, except through more fossil fuel combustion. Nuclear power makes a substantial contribution to UK electricity generation, in a manner suited to base-load demand and without significant generation of harmful greenhouse gases. The environmental attributes mean that nuclear power deserves the fullest consideration in the climate change debate, recognising the as yet unresolved issue of nuclear waste. A long-term plan is needed for the disposal of waste and the development of intrinsicly safe reactors. Increasingly nuclear power will be perceived by policy makers as an economic and sustainable form of energy, depending upon the implementation of the right policy legislation and management. The environmental challenges ahead require that nuclear power receives a fair assessment as part of several competing generating capabilities and energy efficiency strategies, within a mixed energy economy. It is the Institute's view that a combination of forward thinking technologies is required. Nuclear power evolution should be among these developments.

21. In addition to nuclear power (i.e. fission), the Institute firmly believes that nuclear fusion has an important role to play in clean energy technology in the next 20 years and beyond. The view expressed by the Technology Foresight Panel on Energy, in its 1995 report, *Progress Through Partnership,* that nuclear fusion and advanced nuclear reactors in the time period of the Foresight exercise would not lead to significant benefit to the UK [6], is shortsighted and risks missing real opportunities. The report also states that the Panel has dismissed nuclear fusion, owing to the UK not having sufficient R&D capability to pursue such energy technologies, and recommends, only a watching brief be maintained, unless there is a change of circumstance. The Institute believes that obtaining energy from plasmas remains a real long-term prospect, and that it should be within the Foresight Panel's remit to look beyond 2020, where R&D investment in nuclear fusion before 2020 is required in order to reap substantial benefits in the supply of clean energy. Despite the fact that electricity generation from nuclear fusion is not likely before 2020, its benefits as an energy source for the long-term future are far ranging.

22. Moreover, the science and technology involved in energy research by the UKAEA is resulting in a range of new ideas. *Fusion Business*, a publication by UKAEA Culham Division, highlights a number of technological advances based on fusion power technology, including an environmentally-friendly bus, which is electrically driven with a small diesel engine which charges the batteries [7], and the application of plasmas to develop new technology for use in wind turbines [8].

23. A key component in any policy that needs public support or attempts to influence human behaviour is the need to enhance the public's understanding of science and technology. Individuals must be able to understand in a broader sense what terms like 'global warming' mean and also comprehend the issues relating to matters such as nuclear waste. Only with such understanding are they likely to change their actions and behaviour in respect to the environment and climate, both directly and indirectly. It is essential that education and information in this area is provided in a co-ordinated way, spanning primary education through to the adult

population. It is vital to include those involved in legislation in order to ensure that decisions are based on a proper understanding of the issues [9].

The Institute of Physics has been pleased to involve its members in the Foresight process. If there are any further ways in which the Institute can assist the work of the Energy and Natural Environment Panel, then please do not hesitate to contact me.

Yours faithfully

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Director, Science

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