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Energy Committee

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World Federation of Engineering Organizations

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Status of Sustainable Energy Engineering

2009

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WORLD FEDERATION OF ENGINEERING ORGANIZATIONS

ENERGY COMMITTEE

STATUS OF SUSTAINABLE ENERGY ENGINEERING

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FOREWORD

Energy supply has a fundamental relationship with sustainable development. The concept of sustainable energy refers to the production and use of energy resources in ways that are compatible with long term human well being and ecological balance.

WFEO set up its Standing Energy Committee to respond to the need of engineering solutions in the energy sector with the mission to provide the engineer with updated, unbiased and reliable information on the feasibility of different energy technologies based on scientific principles, engineering criteria and demonstrated technological development.

In response to such assignment, the WFEO Energy Committee set up a Task Group to develop this Report on the STATUS OF SUSTAINABLE ENERGY ENGINEERING - 2009. Members of the Task Group were appointed by WFEO Member Organizations.

This Report, being presented as a publication of the WFEO Energy Committee, gathers information on current sustainable energy proposals and the engineering views relating to the conditions of their applicability. It aims at providing the engineer and decision-making officers with updated information regarding the different proposals that are being used, or are under consideration, for the implementation of sustainable energy policies.

Barry J. Grear AO
President, World Federation of Engineering Organizations
July 2009

PREFACE

This publication gives a review of the evolution of the sustainable energy concept since the time of the publication, in 1987, of the Bruntland Report on “Our Common Future”.

In the last 22 years, the meaning of sustainable energy developed from the basic moral obligation for Humanity to use energy resources while preserving them for future generations’ needs, through the complex constraints created by climate change effects abatement requirements, to the current challenges resulting from the world economic crisis.

This publication describes the active role played by Engineering within the Scientific and Technological Community Major Group, at the Commission on Sustainable Development of the United Nations, to clarify and ascertain, among Civil Society and Countries’ representatives, the limitations imposed by the laws of nature upon sustainable energy understanding and related proposals for energy policies.

In this process, WFEO through its Standing Energy Committee was instrumental in bringing out the Engineer’s viewpoint on the sustainability of energy supply, with reliable information on the feasibility of different strategies for using clean energy technologies.

Jorge Spitalnik
Chair WFEO Energy Committee
2009

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Executive Summary

Sustainability of natural, economic and social systems is threatened by the current global financial crisis as every country works to maintain sufficient standards of living for its population even if that means a reduced emphasis on sustainability principles. Two key threats to sustainability are the high use of fossil fuels and deforestation. To bring these threats down to manageable proportions requires concerted and sustained effort internationally. Two measures together –less fossil fuels and more forests– would remove 3.1 billion tones of carbon annually. This amounts to three fourths the quantity of what is needed to stabilize the atmosphere to the point where there is no more increase of carbon. Which most likely is a pre-condition if we ever shall be able to start decreasing the greenhouse gases as was agreed at Kyoto. In particular, the role of forests in addressing climate change in their role as the “lungs of the world” is crucial; however, there exists strong political and commercial reasons to exploit forest resources leading to dramatic changes in land usage.

Sustainable Energy. The concept of sustainable energy is well defined as the energy produced and used in ways that support human development over the long term, in all its social, economic and environmental dimensions. This term does not refer simply to a continuing supply of energy, but to the production and use of energy resources in ways that promote, or at least are compatible with, long term human well being and ecological balance.

World Energy Assessment 1999. The World Energy Assessment Report (1999) described energy’s fundamental relationship to sustainable development and analysed how energy can serve as an instrument to reach that goal. The Report identified the following three important actions that significantly will contribute to sustainability: promotion of higher energy efficiency; increased use of renewables; and development and diffusion of cleaner, next generation energy technologies.

Aspects of non-sustainability of energy systems that were identified in the 1997-99 period include the following features:

- i) Modern fuels and electricity are not universally accessible.
- ii) Current energy systems are not sufficiently reliable or affordable to support widespread economic growth.
- iii) Negative local, regional and global environmental impacts of energy production and use threaten the health and well being of current and future generations.

Subsequent dealings on energy and development expectedly brought the ‘economic development’ and the ‘economic use of energy’ centre-stage. Increasing fossil energy prices added a new dimension, but the global financial crisis, and subsequent decrease in fossil energy prices has resulted in the slowing down of renewable energy source development. However, the thrust for sustainable energy remains, mainly for environmental considerations underpinned by 'energy efficiency' and 'renewable energy' as two pillars of sustainable energy supply leading to mitigation of climate change effects.

UN Commission on Sustainable Development – CSD. The Commission on Sustainable Development initiated a focus on energy as the central theme immediately after the Rio Conference. A review of development, conducted at CSD-9 in May 2001, observed that foremost in the developing countries' priorities is the eradication of poverty for the furtherance of sustainable development. Efforts need to be made to ensure that energy policies are supportive of those priorities, with financial assistance as appropriate. The environment standards should not be applied in ways that would hinder these efforts. CSD 9 identified the following overarching issues: Research and development; Capacity-building; Technology transfer; Information-sharing and dissemination; Mobilization of financial resources; Making markets work effectively for sustainable development; and Multi-stakeholder approach and public participation.

Realising the continuing importance of the energy sector, the UN Commission on Sustainable Development decided to devote its 14th and 15th meetings held in 2006 and 2007 on the thematic cluster of energy for sustainable development; industrial development; air pollution/atmosphere; and climate change. Thus, a review in 5 years of the action on energy issues became possible at the global level.

The need to accelerate access to sustainable energy services to the poor, including sustainable rural electrification programmes, in particular in rural and remote areas in developing countries, was widely recognized. Improved energy services and infrastructure, particularly for the poor, in urban, semi-urban and rural areas was considered necessary. There was a broad agreement on the development and dissemination of advanced energy technologies, including cleaner fossil fuel, energy efficiency and renewable energies, and technologies that contributed to the reduction of greenhouse gas emissions. Implementation of such actions could be pursued by means of private sector involvement, market oriented approaches and supportive public policies, and international cooperation.

Global Trends in IEA World Energy Outlook 2008. In the IEA Reference Scenario, which assumes no new government policies beyond those already adopted by mid-2008, world primary energy demand expands by 45% between 2006 and 2030 –an average rate of growth of 1.6% per year (about 0.2% below projections made in 2007). Fossil fuels would account for 80% of the world's primary energy mix in 2030– down slightly from today. Global coal demand is likely to increase at a rate of 2% per year to 2030. OPEC countries' share of global oil output is expected to rise from 44% in 2007 to 52% in 2030. The balance of production comes from non-OPEC countries. Global energy related carbon dioxide emissions are projected to rise from 28 Gt in 2006 to 41 Gt in 2030 –an increase of 45%.

Sources of Sustainable Energy. Sustainable Energy has two key components: renewable energy and energy efficiency; and a third component of nuclear energy which has to address the safety and waste disposal concerns.

Renewable Energy Technologies. IEA and the WEC have defined three generations of renewable energy technologies, reaching back more than 100 years: *"First Generation Technologies"* emerged from the industrial revolution, at the end of the 19th century, and include hydropower, biomass combustion, and geothermal power and heat. Some of these technologies are still in widespread use. *"Second Generation Technologies"* include solar heating and cooling, wind power, modern forms of bio-energy, and solar photovoltaic. These are now entering markets as a result of research, development and demonstration (RD&D) investments since the 1980s. The initial investment was prompted by energy security concerns linked to the oil crises of the 1970s but the continuing appeal of these renewables is due, at least in part, to environmental benefits. Many of the technologies reflect significant advancements in materials. *"Third Generation Technologies"* are still under development and include advanced biomass gasification, bio-refinery technologies, concentrating solar thermal power, hot dry rock geothermal energy, and ocean energy. Energy storage systems are also a key to integration of “intermittent supply” energy sources into the energy source mix and both small scale remote area power supplies and large scale central power systems. Advances in nanotechnology may also play a major role. Third generation bio fuel technologies are also included.

Energy Efficiency. Energy efficiency is one of the main technological drivers of sustainable development as dematerialization and recycling will further reduce energy intensity. Dematerialization is the new concept gaining momentum with a focus on natural capital. Worldwide the industry is now designing products that consume least natural resource. One model is to lease out product and charge for the use rather than to promote use of product sale. This ensures that the user hires the product only for the need based hours of application and the total numbers of such a product in the market is reduced. The overall impact is that lesser energy input is required for the same service to users.

Nuclear Energy. The positive side of the nuclear energy is its contribution to abatement of climate change and energy security. The nuclear industry is facing a severe challenge of adding capacities at the rate predicted, and at costs projected, by IEA. Going by the Blue Map scenario of IEA Energy Technology Perspectives Report which has projected that, to halve the GHG emissions by 2050, the installed capacity should increase four-fold, nuclear power generation will have to increase from 2,606 TWh (in 2007) to 9,857 TWh per year (in 2050).

Climate Change and Sustainable Energy Supply. Sustainability of energy systems is linked to climate change and in this regard the 15th meeting of the Committee of Parties to the U.N. Framework Convention on Climate Change in Copenhagen in December 2009, will be extremely important to set basic policy goals. WFEO will certainly play a leading and proactive role to evolve logical solutions and approaches to ensure a smooth mitigation and adaptation strategy. The key to future lies in not only developing engineering and technology solutions but in providing engineering support for discussions at international and national sustainable policy decision making meetings.

Opportunity for Energy Sustainability. Governments are concerned that being a first mover in establishing strong energy sustainability policy settings, inclusive of carbon emissions trading, renewable energy targets and carbon emissions reduction schemes, will reduce the competitiveness of their economies in relation to other economies that delay the introduction of similar initiatives. To introduce aggressive sustainability targets and the consequential negative impacts on economies are seen as being detrimental to political leadership futures.

WFEO Energy Committee and Thrust on Sustainable Energy. WFEO set up the Energy Committee in 2003 to respond to the need of engineering solutions in the energy sector. The Energy Committee has the following Vision: "To be the recognised engineering reference for assessing the feasibility of energy technologies", and the Mission: "To provide the engineer with updated, unbiased and reliable information on the feasibility of different energy technologies based on scientific principles, engineering criteria and demonstrated technological development".

WFEO Energy Committee has published Reports on Feasibility Conditions of Wind-Power and Nuclear Power; and has setup Task Groups to study the feasibility of Solar Energy and Bio Energy. WFEO Energy Committee has also signed a Memorandum of understanding with the World Energy Council to develop engineering inputs for solutions for energy applications.

WFEO Energy Committee organised the first International Conference on Engineering for Sustainable Energy held in Rio de Janeiro during August 15-18, 2007. Subsequently a World Engineering Congress Panel Meeting on Energy for Sustainable Development was organised on December 5, 2008 at Brasilia. Both conferences resulted in enhancing the quality of technology development and improving efficiencies of energy systems. Main conclusions of the WFEO Energy Committee's Panel on Energy for Sustainable Development stressed that energy demand, mainly in the developing world, will continue to expand and the need for clean energies will require adherence to the principles of sustainability. Climate change and energy systems will remain the driving forces towards sustainability. Investments must be focused on integrated sustainable production and efficient utilisation of energy across all sectors. The mix of energy sources in each country will require adjustments with a focus on efficiency and energy savings. In some cases, special attention will be required to provide the appropriate incentives for consumers to embrace new energy delivery technologies and to save energy.

Conclusions. The above mentioned from the IEA World Energy Outlook 2008 and presentations at WFEO Energy Conference at Brasilia clearly bring out the need to understand the role of sustainability of energy supply. The global financial crisis and climate change challenges represent an opportunity to create sustainable energy networks for sustainable development by fully using engineering solutions. The engineering profession, being the link between science, technology and society, has a key role in implementing sustainable policies and should undoubtedly perform that role.

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1. INTRODUCTION

The Brundtland Commission's report in the section "From One Earth to One World – Sustainable Development" notes that:

> "Humanity has the ability to make development sustainable to ensure that it meets the needs of the present without compromising the ability of future generations to meet their own needs. The concept of sustainable development does imply limits - not absolute limits but limitations imposed by the present state of technology and social organization on environmental resources and by the ability of the biosphere to absorb the effects of human activities.
>
> Yet in the end, sustainable development is not a fixed state of harmony, but rather a process of change in which the exploitation of resources, the direction of investments, the orientation of technological development, and institutional change are made consistent with future as well as present needs."

Sustainable development holds humans responsible for the current state of environment and challenges them to accept responsibility for initiating the changes necessary to attain sustainability. Sustainability of natural, economic and social systems is threatened by the current global financial crisis as every country works to maintain sufficient standards of living for its population even if that means a reduced emphasis on sustainability principles.

The United Nations established following 8 Millennium Development Goals aimed at globally developing the human living standards while protecting the environment under the sustainability principles:

- End Poverty and Hunger
- Universal Education
- Gender Equality
- Child Health

- Maternal Health
- Combat HIV/AIDS
- Environmental Sustainability
- Global Partnership

Eradicating extreme poverty continues to be one of the main challenges of our time, and is a major concern of the international community. The Millennium Development Goals set time bound targets, by which progress in reducing income poverty, hunger, disease, lack of adequate shelter and exclusion –while promoting gender equality, health, education and environmental sustainability– can be measured. They also embody basic human rights – the rights of each person on the planet to health, education, shelter and security. The goals are ambitious but feasible.

For that, waste has to be minimized. What is meant by 'waste' in this context? Simply stated, it represents money spent where the buyer gets no value. Example of waste, familiar to everyone, include sitting in a traffic jam on a congested freeway. Paul Hawken, author of 'Natural Capitalism – the Next Industrial Revolution' estimated, in 2001, that as much as one-half of the entire US GDP may be attributable to some form of waste. And this waste is one major cause for non-sustainability [1].

2. CHALLENGES TO THE SUSTAINABILITY AGENDA

Two key threats to sustainability are the high use of fossil fuels and deforestation. To bring these threats down to manageable proportions requires concerted and sustained effort internationally.

Mr Ola Ullsten, former Prime Minister of Sweden, and a well known environmentalist, said in 2007:

> "Ensuring that current generation capacity in India and China is up to average of OECD standard of efficiency would have greater effect than the total impact of Kyoto on the whole developing world".
>
> "If the 800 coal fired power plants that are planned for the two countries for 2012 are built it will result in a staggering 2.5 billion tonnes of carbon dioxide, from burning coal alone. This compares to the 500 million tonnes of reductions from all the Kyoto signatories for the same period of time. New technology gives us a chance, if developed." [2].

The European Union has committed its members to a 20% reduction in the use of fossil fuels by year 2020. If all countries followed this example then that would reduce 1.6 billion tonnes of carbon from the atmosphere every year. Among others, the World Bank deems it possible to reverse deforestation. A trend in that direction is already under way though at a very slow pace. Deforestation contributes to about 20% of the carbon that is being emitted to the atmosphere. That is equivalent of 1.5 billion tonnes of carbon annually.

These two measures together –less fossil fuels and more forests– would remove 3.1 billion tones of carbon annually. This amounts to three fourths the quantity of what is needed to stabilize the atmosphere to the point where there is no more increase of carbon. Which most likely is a pre-condition if we ever shall be able to start decreasing the greenhouse gases as was agreed at Kyoto.

The most basic challenge is that both developed and developing countries rely on economic growth. Developed countries do not want to give up their hard earned standard of living and developing countries do not accept any commitment that will threaten their right to achieve the standard of development of developed countries. Finding a solution to these differences possibly represents the greatest challenge to global leaders in establishing an environment and framework for sustainability.

A major hurdle to successful achievement of targets established under the Kyoto Protocol is the reliance on industry to play a dominant role in technology development and transfer from developed to developing countries. Industry has had difficulty serving this purpose and as such, the UNFCCC COP Meeting at Bali, in 2007, appropriately made governments responsible for this action.

The challenge of implementation of the Sustainable Development Agenda, as with other issues such as globalization, poverty and inequality, is that they are always dealt with in isolation and not as a part of a cohesive, integrated approach. Also there has been little effort in involving the mainstream business. Businesses have only recently begun to realise that a sustainability strategy has vast potential by opening untapped markets and serving the unarticulated customers.

Economic models that led businesses, over many decades, to focus only on the one dimensional objective of creating financial value, with scant attention to the depletion of natural resources and the increasing disparities in incomes, are now being replaced by “triple bottom line” and “social responsibility – good corporate citizenship” integrated models so there is now the opportunity for this change in focus to result in the achievement of sustainability goals; in particular, the development of affordable and sustainable energy supply mechanisms and infrastructure and to commence to address issues around global warming [3].

Market forces alone are unlikely to meet the energy needs of poor people, or to adequately protect the environment, hence sustainable development demands frameworks (including consistent policy measures and transparent regulatory regimes) to address these issues.

In particular, the role of forests in addressing climate change in their role as the “lungs of the world” is crucial; however, there exists strong political and commercial reasons to exploit forest resources leading to dramatic changes in land usage. Forests provide extensive carbon sinks and are essential to the sustainable functioning of eco systems across the world. In addition, deforestation has been identified as one of the major causes of starvation and poverty in the developing world. Sustainable forestry management will be key to arriving at a solution to the satisfaction of all participants.

3. CONCEPT OF SUSTAINABLE ENERGY

‘Energy produced and used in ways that support human development over the long term, in all its social, economic and environmental dimensions’, has been accepted as what is understood by the term ‘sustainable energy’. This term does not refer simply to a continuing supply of energy, but to the production and use of energy resources in ways that promote –or at least are compatible with– long term human well being and ecological balance [4].

Jamaica Sustainable Development Network has defined ‘sustainable energy’ as “Energy which is replenishable within a human lifetime and causes no long-term damage to the environment."

Agenda 21, the Action Plan of the United Nations Conference on Environment and Development, at Rio in 1992, is an endorsement of the goal of sustainable development, by the United Nations. The importance of energy as a tool for meeting this goal was acknowledged at every subsequent major United Nations Conference.

Agenda-21 (UN 1992, Chapter-9.9) observed, “Much of the world’s energy is currently produced and consumed that could not be sustained if technology were to remain constant and if overall quantities were to increase substantially” [5].

Energy is linked to global warming through greenhouse gas emission (most of which are produced by fossil fuel consumption). These emissions are addressed by the United Nations Framework Convention on Climate Change, started in 1992. In 1997, the United Nations General Assembly Special Session identified energy and transport issues as being central to achieving a sustainable future.

The energy industry endorsed the above view and recognized the need to address energy issues within a broader context. For example, the conclusions and recommendations of the 17th Congress of the World Energy Council, in 1998, discussed the need to provide commercial energy affordable to those without it, and to address energy linked environmental impacts at all levels [6].

4. SUSTAINABLE ENERGY SUPPLY

Definition of sustainable energy supply needs to be properly understood as this differs from ‘energy supply for sustainable development’, though in general discussion both the terms are used interchangeably. The UN Commission on Sustainable Development, CSD, at its annual meetings, has elaborated on differences between the thrusts of developed countries and developing countries when each deals with sustainable energy supply.

‘Sustainable energy supply’ has the basic aims of meeting ongoing global energy needs for economic and social development and ensuring energy supply security.

The requirement for sustainable development to meet the needs of the present without compromising the ability of future generations to meet their own needs contains within it two key concepts:

- the concept of 'needs', in particular the essential needs of the world's poor, to which overriding priority should be given; and
- the idea of limitations imposed by the state of technology and social organization on the environment ability to meet present and future needs.

Sustainable energy sources are most often regarded as including all renewable energy sources, such as bio fuels, solar power, wind power, wave power, geothermal power and tidal power. It usually also includes technologies that improve energy efficiency.

A narrower interpretation includes only energy sources which are not expected to be depleted in a time frame relevant to the human race. A broader interpretation may allow inclusion of fossil fuels and nuclear fission as transitional sources while technology develops, as long as new sources are developed for future generations to use. After UNCSD-15, safe and secure nuclear power is being included, as an energy source capable of meeting energy security needs while reducing CO_2 emissions.

Some experts also believe that ‘sustainable energy supply’ is targeted to attain ‘energy security’. Thus, it is an approach to reach the end-goal. Obtaining a secure and adequate supply of a traded commodity, be it food or fuel, is generally a problem prevalent amongst poor people, poor regions or poor nations, with the poor to pay the price and the rich often find willing suppliers for what they want. The World Energy Assessment Report of UNDP (1999) defines energy security as: “*the continuous availability of energy in varied forms in sufficient quantities at reasonable prices”* [7]. This definition is often referred to co-relate energy sustainability with energy security.

In India, this definition was modified in 2006 by the Expert Committee on Integrated Energy Policy of the Planning Commission, Government of India, to better reflect the country’s concerns. The Energy Security was defined as follows:

> “We are energy secure when we can supply lifeline energy to all our citizens irrespective of their ability to pay for it as well as meet their effective demand for safe and convenient energy to satisfy their various needs at competitive prices, at all times and with a prescribed confidence level considering shocks and disruptions that can be reasonably expected” [8].

This helped the committee to chart out a road map for sustainable energy supply in India. The definition adopted by the Expert Committee on Integrated Energy Policy in India may be useful for many countries in the world to address their sustainable energy supply approach.

5. WORLD ENERGY ASSESSMENT 1999

The World Energy Assessment Report (1999) provided analytical background and scientific information for decision makers at all levels. It described energy's fundamental relationship to sustainable development and analysed how energy can serve as an instrument to reach that goal. The Report discussed the whole concept under the four different sections:

i) Energy and major global issues and challenges.
ii) Energy resources and technological options.
iii) Are sustainable futures possible?
iv) Where do we go from here?

The first part gave an introduction to energy, especially to its relationship with economic development. It then considered the linkages between the present energy system and major global challenges, including poverty alleviation, health, environmental protection, energy security, and the improvement of women's lives.

The second part examined the energy resources and technological options available to meet the challenges identified in the first part. It concluded that physical resources are plentiful enough to supply the world's energy needs through the 21^{st} century and beyond, but their use may be constrained by environmental and other concerns.

The third part presented a synthesis and integration of the material presented in the earlier chapters by considering whether sustainable futures –which simultaneously address the issues raised in Part-I using the options identified in Part-II– are possible. Interesting enough the Report considered three scenarios to explore how the future might unfold from 2000 onwards using different policy approaches and technical developments. The analysis showed that a reference scenario based on the then current trends did not meet several criteria of sustainability. Two other scenarios, particularly one that is ecologically driven, are able to incorporate more characteristics of sustainable development. This part further emphasized bringing affordable energy to rural areas of developing countries and evolving approaches to widening access to liquid and gaseous fuels for cooking and heating and to electricity for meeting basic needs and stimulating income generating activities.

The fourth part presented an analysis of policy issues and options that could shift unsustainable practices in the direction of sustainable development -as called for by every major United Nations Conference of the'90s and beyond- using energy as an instrument to reach that goal. Creating energy systems that support sustainable development will require policies that take advantage of the market to promote higher energy efficiency, increased use of renewables and the development and diffusion of cleaner, next generation energy technologies. Given proper signals, the market could deliver much of what is needed. But because market forces alone are unlikely to meet the energy needs of poor people, or to adequately protect the environment, sustainable development demands frameworks, including consistent policy measures and transparent regulatory regimes, to address these issues.

The Report has significantly brought out that sustainability will be needing emphasis on three important issues:

i) Promotion of higher energy efficiency,
ii) Increased use of renewables, and
iii) The development and diffusion of cleaner, next generation energy.

This guideline was basically the theme for consideration of the way forward for sustainable energy supply since the Report was published in 1999.

6. ELEMENTS OF NON-SUSTAINABILITY

Although there seems to be no physical limits to the world's energy supply for at least the next 50 years, today's energy systems are seen as unsustainable because of the equity issues as well as the environmental, economic and geopolitical concerns that have implications far into the future. Aspects of non-sustainability of energy systems identified during 1997-99 included the following:

i) Modern fuels and electricity are not universally accessible, and lead to inequity that has moral, political, and practical dimensions in a world that is becoming increasingly interconnected;
ii) The current energy system is not sufficiently reliable or affordable to support widespread economic growth. The productivity of one-third of the world's population is compromised by lack of access to commercial energy and perhaps another one third suffers from economic hardship and insecurity due to unreliable energy supplies;
iii) Negative local, regional and global environmental impacts of energy production and use threaten the health and well being of current and future generations.

This approach to sustainability was reiterated by the World Energy Congress in 2007 at Rome [9]. Therefore, when we look at energy sustainability it is necessary to keep the above mentioned issues of non-sustainability into consideration. One should not forget that the energy issue is of such a gigantic proportion that, in spite of global efforts over the past ten years, the elements of non-sustainability have still to be fully addressed

Further dealings on energy and development expectedly brought the 'economic development' and the 'economic use of energy' centre-stage. Increasing fossil energy prices added a new dimension, but the global financial crisis, and subsequent decrease in fossil energy prices has resulted in the slowing down of renewable energy source development. However, the thrust for sustainable energy remains, mainly for environmental considerations underpinned by 'energy efficiency' and 'renewable energy' as two pillars of sustainable energy supply leading to mitigation of climate change effects.

7. UN COMMISSION ON SUSTAINABLE DEVELOPMENT - CSD

The UN Commission on Sustainable Development decided that its 9th meeting would focus on energy as an issue for development [10]. It reinforced the three basic conceptual elements as mentioned above. Subsequently, the 14th and 15th meetings of the UN Commission on Sustainable Development focused on energy, environmental and climate change issues, which again focused on these three conceptual elements [11].

7.1 CSD-9 Session Outcome

The Commission on Sustainable Development focused on energy as a central theme immediately after the Rio Conference. The magnitude and scope of energy needs facing the world today, in relation to sustainable development, can be gauged by the fact that nearly one-third of the global population of 6 billion, mostly living in developing countries, continue to lack access to adequate energy and transportation services. Wide disparities in the levels of energy consumption within and between developed and developing countries exist. By all projections the current patterns of energy production, distribution and utilization are considered unsustainable.

A review of development was conducted by the United Nations at the 9th Meeting of the Commission for Sustainable Development in May 2001. The general consideration for the participants specified "the challenge ahead will require adequate, predictable, new and additional financial resources, in accordance with Chapter 33 of Agenda 21 of the Rio Conference, and paragraphs 76 to 87 of the programme for the further implementation of Agenda 21, Technology Transfer and, where appropriate, Political Will, as well as commitment to innovative ways of applying energy efficient, environmentally sound and cost effective technologies and systems to all sectors of the economy. Energy resources are plentiful, and environmentally sound technological options exist and should be made available and facilitated by developed countries to developing countries as well as countries with economies in transition, with a view to making energy for sustainable development a reality. Ensuring adequate and affordable access to energy for present and future generations, in an environmentally sound, socially acceptable and economically viable way will require considerable efforts and substantial investments, including from the private sector."

Main issues considered at the meeting were the following:

In order to make energy systems more supportive of sustainable development, objective contributions from all stakeholders, as well as increased investments, will be needed. Change will not be driven by resources constraints for a very long time to come. Energy for Sustainable Development can be achieved by providing universal access to a cost effective mix of energy resources, compatible with different needs and requirements of various countries and regions. This should include giving a greater share of the energy mix to renewable energy sources, improving energy efficiencies and greater reliance on advanced energy technologies, including fossil fuel technologies. Policies relating to energy for sustainable development intended to promote these objectives will address many of the issues of economic and social development as well as facilitate the responsible management of environmental resources.

In view of the different contributions to global environmental degradations, countries have common but differentiated responsibilities. The choice and implementation of policies to improve the ways to achieve energy for sustainable development basically rests with governments. However, financial resources play a key role in their implementation. For developing countries, official development assistance is a main source of external funding, and substantial new additional funding for sustainable development and the implementation of Agenda 21 will be required. This is a laudable approach and is expected to fulfil all the financial funding needs for the change. However, very little ODA (Official Development Assistance) funds were made available and have now totally vanished due to the global financial crisis. Given that energy is an area with strong interdependencies among countries, international cooperation and a participatory approach should be promoted in line with the principle of common but differentiated responsibilities. The way in which issues are addressed in a country depends on the national energy situation and needs. Therefore, ranges of options and strategies become necessary to address the diverse issues involved. The choice of any specific option would obviously depend on the particular domestic situation.

Foremost in the developing countries' priorities was the eradication of poverty for the furtherance of sustainable development. Efforts should therefore be made to ensure that energy policies are supportive of developing countries' efforts to eradicate poverty, with financial assistance as appropriate. Nevertheless, environment standards should not be applied in ways that would hinder these efforts.

CSD-9 was organized on the basis of the identified needs in preparation for meeting the Millennium Development Goals of the United Nations pronounced in the year 2000. Therefore, it had a very crucial role in defining the sustainable energy supply and systems in the new millennium. The issue and options clearly defined what the governments as well as relevant regional and international organizations and other relevant stakeholders should consider when dealing with energy, taking into account, national and regional specifics and circumstances, bearing in mind the principle of common, but differentiated responsibilities.

CSD-9 clearly identified the need for governments to be responsible for development and application of energy polices to achieve sustainable development and consider the following options:

i) Combine, as appropriate, the increased use of renewable energy sources, more efficient use of energy, greater reliance on advanced energy technologies, including advanced fossil fuel technologies and the sustainable use of traditional energy resources, which could meet the growing needs for energy services in the longer term to achieve sustainable development.

ii) Integrate energy considerations in socio-economic programmes especially in policy making of major energy consuming sectors, such as the public sector, transport, industry, agriculture, urban planning and construction.

iii) Establish an appropriate enabling environment conducive to attracting investments and supportive of the objectives of sustainable development and to ensuring public participation.

iv) Develop appropriate energy services, particularly in rural areas.

v) Support efforts to improve the functioning of energy markets with respect to both supply and demand, with the aim of achieving greater stability and predictability and to ensure consumer access to energy services.

vi) Establish domestic programmes for energy efficiency.

vii) Support increased use of renewable energies; both in grid connected and decentralized systems.

viii) Optimize the efficient use of fossil fuels through the increased development and use of advanced fossil fuel technologies.

ix) Enhance international cooperation in order to assist countries in their efforts to achieve energy for sustainable development.

x) Strive to promote sustainable consumption patterns, guaranteeing the provision of the basic needs of the poor.

xi) Strengthen existing national and local institutions that develop, implement and operate national programmes on energy for sustainable development.

xii) Support research development and demonstration.

The Conference identified the following key issues and challenges to be tackled in priority*:*

i) Accessibility of energy where the challenge is that the access to energy is crucial to economic and social development and the eradication of poverty. Improving accessibility to energy implies finding ways and means by which energy services can be delivered reliably, affordably and in an economically viable, socially acceptable and environmentally sound manner.

ii) Energy efficiency can be a win-win solution both for developed and developing countries, but currently it has not reached its potential. Barriers to optimizing the energy efficiency potential involve lack of access to technology, capacity building and financial resources, as well as market related and institutional issues.

iii) Renewable energy challenges include the main issue of development, utilization and dissemination of renewable energy technologies on a scale wide enough to significantly contribute to energy for sustainable development.

iv) Advanced fuel technologies will continue to play a dominant role in the energy mix in the decades to come. The challenge is deployment and use of advanced and cleaner fossil fuel technologies to be increased. More efforts should go into supporting and further development and dissemination of these technologies.

v) Nuclear energy technologies will focus on the challenge of safety and security of nuclear fuel. Nuclear power is a sustainable energy source with both economic and environmental advantages.
vi) Rural energy challenge include the implementation of the goal accepted by the international community to halve the proportion of people living on less than 1 US$/day by 2015. In this case access to affordable energy services is a pre-requisite. Efforts at finding the most appropriate solution to the energy problems of rural areas are hampered by the enormity of the problem, the limited availability of resources and lack of appropriate technologies, as well as the high investment costs and connection fees, and insufficient attention to rural development in general.
vii) Energy and transport have a relationship where the major challenge of the transport part is to be the major energy consuming sector and the sector for which energy consumption is projected to grow at the highest rate. The challenge is to promote integrated approach to developing integrated transport systems for sustainable development.

Additionally, the following overarching issues were identified:

i) Research and development.
ii) Capacity-building.
iii) Technology transfer.
iv) Information-sharing and dissemination.
v) Mobilization of financial resources.
vi) Making markets work effectively for sustainable development.
vii) Multi-stakeholder approach and public participation.

7.2 CSD-14 and CSD-15 Sessions Outcome

Realising the continuing importance of the energy sector, the UN Commission on Sustainable Development decided to devote its 14^{th} and 15^{th} meetings held in 2006 and 2007 on the thematic cluster of energy for sustainable development; industrial development; air pollution/atmosphere; and climate change. Thus, a review in 5 years of the action on energy issues became possible at the global level.

Global leaders and participants achieved near unanimity on the industrial development and air pollution/atmosphere themes, but remained divided on key points in the energy and climate change issues. European countries rejected the decision text because agreement could not be reached on time-bound targets for renewable energy, the integration of energy policies into national planning by 2010, a formal review arrangement for energy issues in the United Nations and an international agreement on energy efficiency.

The Commission took special note of the World Summit on Sustainable Development, at Johannesburg, in 2002, and other international considerations. Attention was called by many countries to the continuing need for integrating economic development, social development and environmental protection as interdependent and mutually reinforcing pillars of sustainable development and to poverty eradication, changing unsustainable patterns of production and consumption and protecting and managing the natural resource base of economic and social development as the overarching objectives of, and essential requirements for sustainable development.

The Commission recognized that energy was crucial for sustainable development, poverty eradication and achievement of the internationally agreed development goals, and that the achievement of the Millennium Development Goals and implementation of the Johannesburg Plan of Implementation must be urgently and substantially accelerated. There was general acceptance of the need to further diversify energy supply by developing advanced, cleaner, more efficient, affordable and cost effective energy technologies (including advanced and cleaner fossil fuel technologies and renewable energy technologies). Whereas the general consensus was that the fossil fuels will have their dominant role in the energy supply for decades to come it was necessary to pay greater attention to rapidly increasing the share of renewable energy in the mix. There was a thrust on increasing the global share of renewable energy sources in a time bound targeted manner. The need for development of carbon capture and storage and enhanced oil recovery technologies was considered necessary.

The need to accelerate access to sustainable energy services to the poor, including sustainable rural electrification programmes, in particular in rural and remote areas in developing countries, was widely recognized. Improved energy services and infrastructure, particularly for the poor, in urban, semi-urban and rural areas was considered necessary.

Promoting and strengthening energy efficiency in ‘building codes’ and encouraging financial and technical support for improving insulation, lighting and natural ventilation in public, residential and commercial buildings, including the integration of energy efficiency into public procurement policies and procedures, as well as increasing efficiency in the industrial sector, including oil and gas extraction, processing, storage, loading, dispensing and transport, and reducing gas flaring and venting were stressed.

Some countries proposed initiating a process that would lead to an international agreement on energy efficiency that could cover issues such as sharing information, research, regulatory cooperation, education, training and finance. Such an agreement was considered advantageous but as the owners of technology and knowledge are mainly in the private sector a final decision remains pending.

A number of countries favoured including nuclear energy as energy source capable of meeting energy needs while reducing carbon dioxide emissions. A general consensus was not achieved. In spite of differences of opinion, the nuclear industry was recognized to be on the path of revival.

Realising the significance of energy to sustainable development the Conference recommended specific discussions on this issue at its meetings in 2010 and 2014, i.e., at an interval of four years. These two meetings will come at a crucial time as the CSD in

2010 will be able to discuss the outcome of Copenhagen Meeting and the CSD in 2014 will be able to discuss actions Post-2012 Regime.

Climate change was recognized as a global sustainable development challenge with strong social, economic and environmental dimensions. Recent findings of the inter-governmental panel on climate change regarding the impacts of climate change on sustainable development were seen as a cause of concern.

There was a broad agreement on the development and dissemination of advanced energy technologies, including cleaner fossil fuel, energy efficiency and renewable energies and other new and renewable energy sources, and technologies that contributed to the reduction of greenhouse gas emissions, including through private sector involvement, market oriented approaches and supportive public policies and international cooperation.

7.3 Contribution of the Scientific and Technological Community Major Group

WFEO and ICSU delegates, constituting the Scientific and Technological Community Major Group, made a joint statement at CSD-15 that underlined the engineering components and criteria that need to be complied with when setting up sustainable energy policies. It stated:

> Meeting the world's growing energy demands is such a massive challenge that essentially all energy sources must be on the table for consideration. This not only includes technologies for energy efficiency and conservation, and advanced renewables, but also for cleaner, less carbon-intensive fossil fuel energy techniques, as well as safe and secure nuclear energy systems. Decisions regarding the use of a given technology require a thorough analysis of its technological, economical, and environmental feasibility. This is the role that the Scientific and Technological (S&T) Community is committed to play both nationally and internationally, with all relevant stakeholders, towards implementing scientifically sound and thoroughly engineered solutions.
>
> There is no simple or uniform solution to this challenge. The optimal energy mix for any particular country will depend upon the available natural resources base, population distribution, growth in energy demand, and the status of its technical and economic capacity.
>
> Specifically tailored, economically feasible solutions are required for instance, in widely dispersed rural and island populations, or in countries with a large annual growth rate of energy demand. Failure to appreciate such differences has resulted in inadequate or limited outcomes, when implementing sustainable energy solutions in developing countries based on the experience of developed ones.
>
> In the transportation sector, actions for promoting cleaner fuels and vehicles must be complemented by policies to reduce the overall demand for personal vehicle use, by promoting a public transport that meets people’s everyday needs. In some countries, modifying unsustainable transportation energy consumption patterns will certainly require difficult cultural adjustments.

There is a need for strong support to research and development, in many areas, for instance in lowering the costs of solar photo-voltaic devices, in producing bio-fuels from cellulose materials, in achieving efficient carbon sequestration schemes for fossil-fuel based generation, and in finding feasible mechanisms for hydrogen production, storage and distribution. To help guide effective and coherent R&D investment strategies, the Scientific and Technological Community had set up in 2006 an International Science Panel on Renewable Energies.

Industrial development is an important means of creating wealth and improving quality of life. However, industrial production is often a major source of air and water pollution, greenhouse gas emissions, and other environmental problems. Consequently, a technological transformation towards more sustainable industrial production systems is essential. Ensuring industrial competitiveness requires building the required infrastructure in terms of energy supply, transport availability, trained manpower and environmental regulatory systems. But the costs for complying with sustainable restrictions are, in some cases, prohibitively high for developing countries. Thus, industrial development in developing countries must be assisted through strong affordable programs of capacity building and transfer of the cleanest available technologies.

Climate change is a fact, as confirmed by the latest reports from the IPCC. The S&T Community considers that strong measures need to be taken on two fronts. Firstly, in order to mitigate the impacts of global warming, massive reduction of greenhouse gas emissions must be urgently implemented. Secondly, strategies to adapt to the consequences of climate change need to be designed and implemented, both in relation to environmental impacts and socioeconomic consequences. Climate change is exposing the world's infrastructure to conditions it was not designed to withstand. Designing, building and maintaining resilient infrastructure that can adapt to the impacts of a changing climate becomes therefore an urgent undertaking. In addition, more research on understanding regional impacts of climate change, as well as strengthening global observation systems, are of prime importance. Science, engineering, and technology will be essential to act on such fronts, and there will be a need for a significant strengthening of relevant S&T worldwide.

Air pollutants and greenhouse gases have many common sources. It thus makes sense for all nations to explore strategies to simultaneously meet air quality control and climate change mitigation targets. There must be proactive efforts to disseminate advanced integrated atmospheric modeling tools, technologies for air quality monitoring and pollution prevention, and knowledge of best practices in air quality management.

The Scientific and Technological Community considered this CSD cycle to provide a unique opportunity to establish a global frame for addressing these extremely pressing interrelated sustainable development challenges.

At CSD-16, in May 2009, WFEO and ICSU prepared a Discussion Paper on behalf of the Scientific and Technological Community to provide an overview of the key science and technology issues related to the themes of the 16th and17th sessions of CSD: agriculture, rural development, improved management of land resources and combating drought and desertification. Throughout the paper special attention was paid to Africa, the regional focus for this CSD biennial cycle.

Realising that the debate of food versus fuel has hampered growth of bio fuels during 2007 and 2008, WFEO considered it appropriate to focus on agricultural knowledge and technology to suggest appropriate solutions. These focused on bio fuels. CSD-16 discussed first generation bio-fuels as well as the second generation bio-fuels.

The joint WFEO-ICSU discussion paper presented at CSD-16 showed that Agricultural Knowledge, Science and Technology (AKST) contributed to some major developmental achievements, including reducing hunger in many parts of the world and ensuring food security on a scale not seen before in history. The science that made the Green Revolution of the 1960s and 1970s possible has increased the income of many small farmers, particularly in Asia, and preserved millions of hectares of forest and grasslands - conserving biodiversity and reducing the amount of carbon released into the atmosphere.

Advances in AKST have enabled substantial gains in agricultural production in industrialized and developing countries alike. Over the past 30 years food production has tripled in developing countries, outstripping population growth. Over the same period, the proportion of undernourished people in developing countries dropped from 35 to 17 per cent and poverty decreased. However, the poorest and most marginalized rural and urban people continue to miss out on the benefits provided by advances in AKST.

Future increases in food and other agricultural production will have to come from sustainably intensified agriculture and more efficient use of the natural resource base, particularly water.

Regarding agriculture and the growing demand of bio-fuels, bio-energy is being developed in many countries to increase energy security, reduce greenhouse gas (GHG) emissions and stimulate rural development. However, economic, social and environmental issues limit the extent to which these goals can be met with current bio-fuel technologies. There is great concern expressed in many developing countries about the future of bio-fuels and their effect on food prices and food policies. Nevertheless, numerous countries already have promising programmes for producing bio-ethanol and bio-diesel from different crops -cassava, castor beans, cotton seeds, jatropha, palm-oil, soybean, sunflower, and sweet-potato.

First generation bio-fuels such as bio-ethanol and bio-diesel are economically competitive with fossil fuels only in the most efficient feedstock production markets and under favourable market conditions of high oil and low feedstock prices -in most countries they depend on direct and indirect subsidies. While non-market benefits such as energy security and reduced GHG emissions may justify these subsidies the net benefits remain uncertain. The intensity of land and water use in the production of first generation bio-fuels can lead to serious threats to the environment and reduce food security in developing countries.

Millions of people in developing countries, particularly in sub-Saharan Africa, South Asia and parts of Latin America, still depend on traditional bio-energy, such as wood fuels, for their basic cooking and heating needs. This can hold back development by posing considerable environmental, economic and social challenges. Efforts are needed to improve traditional bio-energy and to accelerate the transition to modern forms of energy.

In some areas, bio-energy options such as bio-gas and power generators operating with locally available biomass -including vegetable oils, manure and agricultural and forestry by-products- can become the most economical and reliable providers of energy for the poor. Liquid bio-fuels may become an interesting option for rural areas where biomass is available locally. In remote rural areas and on islands, where fossil fuel prices are usually high due to transport costs, bio-energy systems may prove to be the most economic option. In countries where large numbers of farmers subsist on very low incomes, local processing of bio-energy through community cooperatives could provide extra income and social inclusion for poor families.

A shift towards cellulose based second generation bio-fuels using wood and grassy crops would offer greater reductions in carbon dioxide emissions and less land used per unit of energy. However, technical breakthroughs would be required to achieve this. The potential for second-generation bio-fuels to be economically, environmentally and socially sustainable needs to be further explored.

Family-type crop collecting and local community processing, through cooperative setups, could lead to providing extra income to poor families and at the same time ensuring their social inclusion. This type of program is being implemented in the semi-arid regions of the NE of Brazil, where non-edible crops are exploited for bio-diesel production and where large numbers of poor farmers subsist with very low income. This is a good example of reclaiming land use without competing with food-crop agriculture. Such programs require initially seed money from government or private agencies. Once implemented, the increase of income of these communities will bring about actual needs for infrastructure improvement to get a more efficient production and a self-reliant economy.

8. SPECIALIZED AGENCIES AND ORGANIZATIONS

Several specialized Agencies and Organizations related to energy supply and use have been contributing to the clarification of, and the evolution of thinking related to, the concept of sustainable energy.

8.1 Energy Productivity - An Important Tool for Energy Sustainability

It is necessary to focus on the productivity of growing global energy demand and its micro-economic perspective. ‘Energy productivity’ simply means ‘meeting the growing demand for energy, most productively’. Together with labor, resource, and capital productivity, energy productivity is critical to economic growth and well-being and should, therefore, be a much higher priority in national policy agendas. McKinsey's Global Institute (MGI) undertook a year long study and looked at each of the main end-use segments in the largest economies globally; identified the key micro-economic, behavioral and policy relationships -explaining energy demand in each sector, and aggregated its findings across countries and end-user segments to produce an integrated, dynamic perspective on global energy demand and productivity. While identifying opportunities for energy use improvement, MGI focused on changes that rely on currently existing technologies and have an internal rate of return of 10% or more, without reducing the comfort or convenience valued by consumers. This marginal focus on economically viable opportunities only means that making these investments would benefit the economy by freeing up resources either to increase consumption elsewhere or invest for faster growth [12].

MGI also found that while energy demand will continue to grow rapidly, there are sufficient economically viable opportunities for energy productivity improvements that could keep global energy demand growth at less than 1% per annum -or less than half of the 2.2% average growth to 2020, anticipated in business as usual scenario.

The report mentions that market distorting subsidies, information gaps, agency issues and other market inefficiencies all work against energy productivity. Furthermore the small share of energy costs for most businesses and consumers reduces end-use response to energy price signals. Therefore, shifting global energy demand from its current rapid growth trajectory will require the removal of existing policy distortions; improving transparency in the usage of energy; and the selective deployment of elements of energy policies, such as use protocol and standards. This should also reflect the true total cost of providing energy including externalities.

Energy productivity is a useful tool to analyze public-policy aims of demand abatement and energy-efficiency because it encapsulates both. By looking merely in terms of shrinking demand, we are in a danger of denying opportunities to consumers – particularly those in developing economies that are an increasingly dominant force in global energy-demand growth. Rather than seeking to reduce end-user demand –and thus the level of comfort, convenience, and economic welfare demanded by consumers– we should focus on using the benefits of energy most productively.

The concept of energy productivity provides an overarching framework for understanding the evolving relationship between 'energy demand' and 'economic growth'. 'Energy-productivity improvements' can come either from 'reducing the energy inputs required to produce the same level of energy services', or from 'increasing the quantity or quality of economic output'.

Within each of these, there are multiple components that can change over time. The same level of energy services can be produced with fewer inputs if use is less intensive (e.g. smaller appliances), if technical efficiency improves (e.g. higher-mileage-car engines), or if fuel-mix shifts, say, from biomass to more efficient electricity.

In turn, economic activity can grow more quickly than demand for energy services because of sectoral shifts, say, from energy-intensive industrial sectors to services, or from an increasing share of growth taken by non-energy-intensive, high value-added activities within a sector (e.g. increasing share of investment banking versus retail banking).

By being explicit about the relative importance of each, energy productivity acts as a useful tool to enable better understanding of the nature and source of change and more effectively seek to improve growth and energy outcomes. This will be an important tool in attaining sustainable energy supply that will be broadly environment friendly but meet all the energy needs of consumers in the most cost-effective and productive manner.

8.2 Meeting Energy Needs in an Interdependent World

The World Energy Council, WEC, organized 20th World Energy Congress, in November 2007, with the theme "The Energy Future in an Interdependent World". The aim was not to suggest that each country will be made energy secured but that each country should realize that the key to energy security, leading to sustainable energy supply, is networking and effective use of global governance in this interdependent world. The Congress represented a unique opportunity to open the debate on world energy issues not only from an industrial development stand point but also to extend it to the sustainable development topic and to several issues arising from the new world scenario. This has to be read in relation to the 17th World Energy Congress in 1998, at Houston, that gave important inputs to the World Energy Assessment Report titled 'Energy and the Challenge of Energy Sustainability'. During the past ten years, since the report was published, the global governance was given new concepts and approaches, and with that also defined the new challenge. This dynamic global governance and socio-economic system only makes it necessary for the energy experts to correlate the two situations and see how the energy scenario has changed. WEC provided options to chart individual future courses of action for sustainable energy supply.

Including sustainable development as a part of global governance will make each nation responsible to meeting global needs. The dialogue started in November 2007 at Rome will certainly open a new era for strategic alliances in the energy sector.

8.3 Global Trends in IEA World Energy Outlook 2008

The impact of the global financial crisis on world economic growth prospects, higher energy prices and some notable policy initiatives have left their mark on the World Energy Outlook (WEO) 2008 of the International Energy Agency (IEA). This projection is widely used by other agencies while considering scenarios for energy. WEO 2008 projects that the energy consumption will grow more slowly to year 2030 than that predicted in 2007, but overall trends are broadly unchanged: persistent dominance of fossil fuels –oil, gas and coal– in the energy mix; a rising share of emerging economies in global energy consumption; an increase in consuming country reliance on imports of oil and gas; and an inexorable rise in global carbon dioxide emissions.

In the IEA Reference Scenario, which assumes no new government policies beyond those already adopted by mid-2008, world primary energy demand expands by 45% between 2006 and 2030 –an average rate of growth of 1.6% per year (about 0.2% below projections made in 2007). Fossil fuels would account for 80% of the world's primary energy mix in 2030 –down slightly from today. Oil remains the dominant source though the share of coal rises much more than oil. The share of gas rises marginally. Modern renewable energy technologies increase sharply after 2010, to become the second largest source of electricity after coal.

Global coal demand is likely to increase at a rate of 2% per year to 2030. Around 90% of the corresponding 60% increase in global coal production from 2006 to 2030 is expected to occur in non-OECD countries, with China almost set to double its production, to help meet the average annual demand growth rate of 3%. Elsewhere, the US sees average annual demand growth of 0.6%, while Europe is projected to witness a reduction in demand on an average of 0.5% per year. This is in contrast to regions such as South Africa with projected demand growth of 3.8% per year and India with 4.1% per year.

OPEC countries' share of global oil output is expected to rise from 44% in 2007 to 52% in 2030. The balance of production comes from non-OPEC countries. Overall global demand for oil (excluding bio-fuels) is expected to rise from 44% in 2007 to 51% of total energy consumption in 2030. Overall global demand for oil is projected to increase at 1% per year, from 84 million barrels per day in 2007 to 106 million barrels per day in 2030. Despite the vast potential for unconventional oil sources, further investment and effort is required to tap conventional onshore oil reserves, particularly in OPEC countries. All the projected increase in world oil demand comes from non-OECD countries. India sees the fastest growth, averaging 3.9% per year over the projected period, followed by China at 3.5%. Other emerging Asian economies and the Middle East also see rapid growth. In stark contrast, the demand in all three OECD regions (North America, Europe and the Pacific) falls, due to declining non-transport demand. The share of OECD countries in global oil demand will drop from 47% in 2007 to 43% in 2030.

This energy consumption pattern has serious climate change implications as carbon dioxide emissions are likely to increase and correspondingly the temperatures will go up. The projected rise in the Reference Scenario emissions with no changes in government policies, predicts a doubling of the concentration of those gases in the atmosphere to about 1,000 parts per million of carbon dioxide equivalent by the end of this century. This would lead to an eventual global temperature increase of up to 6 deg centigrade.

Global energy related carbon dioxide emissions are projected to rise from 28 Gt in 2006 to 41 Gt in 2030 –an increase of 45%. Global GHG emissions, including non-energy carbon dioxide and all other gases, are projected to grow from 44 Gt carbon dioxide equivalent in 2005 to 60 Gt in 2030 –an increase of 35%. The power generation and transport sectors contribute over 70% of the projected increase in world energy related carbon dioxide emissions in 2030.

Without a change in policy, the world is on a path for a rise in global temperature of up to 6 deg C. IEA WEO 2008 assesses the implications for the energy sector of efforts to put the world onto a different trajectory, by means of a 550 Policy Scenario, in which greenhouse gas concentration is stabilized at 550 ppm carbon dioxide equivalent and temperature rises by about 3 deg C. A 450 ppm scenario results in a 2 deg C atmospheric temperature increase. The two policy scenarios have a similar emissions trajectory until 2020, but emissions fall much more sharply after 2020 in the 450 Policy Scenario.

Both climate-policy scenarios assume a hybrid policy approach, comprising a plausible combination of cap-and-trade system, sectoral agreements and national measures. A cap-and-trade system modelled for the power generation and industry sectors in the OECD and other EU group of countries; is expanded post 2020 in the 450 Policy Scenario only, to incorporate the Other Major Economies group, which includes China and India. International Sectoral Agreements –covering iron and steel, cement, aviation and road transport– operate across OECD, other EU and Other Major Economies Groups, while national policies are assumed to be implemented for all sectors in Other Countries, and worldwide in the buildings sector.

This modelling predicts that energy-related carbon dioxide emissions rise from 27 Gt in 2006 to 33 Gt in 2030 in the 550 Policy Scenario –19% lower than in Reference Scenario. The share of low carbon energy –hydropower, nuclear, biomass, renewables and fossil fuel power plants with carbon capture and storage (CCS)– in the world primary energy mix increases from 19% in 2006 to 25% in 2030 as a result of lower demand. OECD oil and gas imports are 15% lower than in the Reference Scenario; international oil prices are 18% lower.

The shift in the energy mix that brings about these emission reductions requires much more investment in energy-related infrastructure and equipment. Global energy investment in 2010-2030 is $ 4.1 trillion higher (or 0.25% of annual world GDP) in the 550 Policy Scenario than in the Reference Scenario. Most extra spending is on the demand side, with $17 per person per year spent worldwide on more efficient cars, appliances and buildings. Investment in power plants is $1.2 trillion higher, three quarters in OECD countries. On the other hand, improved energy efficiency delivers fuel cost savings of over $7 trillion between 2010 and 2030.

The scale of the challenge in the 450 Policy Scenario is even greater, with world energy related carbon dioxide emissions dropping sharply from 2020 onwards, reaching 25.7 Gt in 2030. The 2030 emissions level for the world as a whole is less than the level of projected emissions for non-OECD countries alone in the Reference Scenario. In other words, the OECD countries alone cannot put the world onto the path to 450 ppm trajectory, even if they were to reduce their emissions to zero. Achieving such an outcome will require much more rapid growth in the use of hydropower, biomass, wind, geothermal, solar-electric and other renewables –which together are predicted to account for 40% of global power generation by 2030. Yet-to-be-demonstrated technologies such as carbon capture and storage (CCS) also contribute significantly to lower emissions. Relative to the Reference scenario, global energy investment is $9.3 trillion higher, or 0.55% of annual world GDP. Fuel savings, at $5.8 trillion, are lower than in the 550 Policy Scenario.

9. RENEWABLES FOR SUSTAINABLE ENERGY SUPPLY

This sets "sustainable energy" apart from other renewable energy terminology such as "alternative energy" and "green energy", by focusing on the ability of an energy source mix to provide a path that ensures continued provision of energy. From an engineering viewpoint sustainable energy has to be technologically, environmentally and economically feasible and at the same time should not compromise the ability of future generations to meet their own needs. Thus, the sustainable energy definition is an overarching one, which includes alternative energy and green energy but the end advantage will be low carbon addition to atmosphere which could broadly be covered under “No or Low carbon dioxide emission to the atmosphere”. This broadly sets the framework concept to identify the sustainable energy technologies for the future. Under this broad framework the three major approaches for overcoming non-sustainability of energy supplies identified in the World Energy Assessment (1999) are still valid even in the era of global financial crisis and fossil energy price fluctuation.

As identified in earlier sections of this report, Sustainable Energy has two key components: renewable energy and energy efficiency; and a third component of nuclear energy which has to address the safety and waste disposal concerns. These are discussed below.

9.1 Renewable Energy Technologies

The International Energy Agency, IEA, has stated that:

> “Renewable energy technologies are essential contributors to sustainable energy as they generally contribute to world energy security, reducing dependence on fossil fuel resources, and providing opportunities for mitigating greenhouse gases.”

This role for renewable energy technologies to mitigate greenhouse gases was introduced possibly after the Bali Conference of UNFCCC, in December 2007. In addition renewable energy technologies have an important role not only in mitigating greenhouse gases but in adapting to greenhouses gases.

IEA and the WEC have defined three generations of renewable energy technologies, reaching back more than 100 years:

"First Generation Technologies" emerged from the industrial revolution, at the end of the 19th century, and include hydropower, biomass combustion, and geothermal power and heat. Some of these technologies are still in widespread use.

"Second Generation Technologies" include solar heating and cooling, wind power, modern forms of bio-energy, and solar photovoltaic. These are now entering markets as a result of research, development and demonstration (RD&D) investments since the 1980s. The initial investment was prompted by energy security concerns linked to the oil crises of the 1970s but the continuing appeal of these renewables is due, at least in part, to environmental benefits. Many of the technologies reflect significant advancements in materials.

"Third Generation Technologies" are still under development and include advanced biomass gasification, bio-refinery technologies, concentrating solar thermal power, hot dry rock geothermal energy, and ocean energy. Energy storage systems are also a key to integration of “intermittent supply” energy sources into the energy source mix and both small scale remote area power supplies and large scale central power systems. Advances in nanotechnology may also play a major role.

First- and second-generation technologies have entered the markets, and third-generation technologies heavily depend on long term scientific and engineering research and development commitments, where the public sector has a role to play.

A 2008 comprehensive cost-benefit analysis review of energy solutions in the context of global warming and other issues ranked wind power combined with battery electric vehicles (BEV) as the most efficient, followed by concentrated solar power, geothermal power, tidal power, photovoltaic, wave power, clean coal technology, carbon capture and storage, nuclear energy, and finally bio-fuels.

9.1.1 First Generation Renewable Energy Technologies

First-generation technologies are most competitive in locations with abundant resources. Their future use depends on the exploration of the available resource potential, particularly in developing countries, and on overcoming challenges related to the environment and social acceptance. Among sources of renewable energy, hydroelectric plants have the advantage of being long-lived -many existing plants have operated for more than 100 years. Also, hydroelectric plants are clean and have few emissions. There is a strong lobby criticising building of new large reservoir based hydroelectric power plants. This lobby operates mainly from the countries that have exhausted all potential hydro resources. Criticisms directed at large-scale hydroelectric plants include: dislocation of people living where the reservoirs are planned and release of significant amounts of carbon dioxide during construction and flooding of the reservoir. However, it has been found that high emissions are associated only with shallow reservoirs in warm tropical locales. In reservoirs where the draw out changes the level by several meters the criticism of large methane gas emissions lacks acceptable evidence. Generally speaking, hydroelectric plants produce much lower life-cycle emissions than other types of power generation. Hydroelectric power, which underwent extensive development during growth of electrification in the 19th and 20th centuries, is experiencing resurgence of development in the 21st century.

The highest hydroelectric growth is observed in China. India is also venturing into large hydro-electric schemes in the country and neighbouring countries like Nepal and Bhutan. Also, in Brazil, large hydropower projects are under way. This growth is driven despite opposition from NGOs and some interest groups.

Geothermal power plants can operate twenty four hours per day, providing base-load capacity, and the world potential capacity for geothermal power generation is estimated at 85 GW over the next 30 years. However, geothermal power is accessible only in limited areas of the world, including Australia, Central America, East Africa, Indonesia, Mexico, New Zealand, the Philippines and the United States.

9.1.2 Second Generation Renewable Energy Technologies

Markets for second-generation technologies are strong and growing, mainly in countries such as Australia, China, Germany, India, Japan, Spain, and the United States. The challenge is to broaden the market base for continued growth worldwide. Strategic deployment in one country not only reduces technology costs for users there, but also for those in other countries, contributing to overall cost reductions and performance improvement. An upsurge in 2001 resulted in growth of second generation production industries and employment in them. Though 2008 has seen a slow down it is expected that with installed capacities for manufacturing renewable energy based devices not being fully utilized, the industrialists will operate at a much lower production costs. Second generation devices will expand for commercial reasons, and the growth will be based on market instruments and policy incentives.

Solar heating systems are a well known second-generation technology and generally consist of solar thermal collectors, a fluid system to move the heat from the collector to its point of usage, and a reservoir or tank for heat storage and subsequent use. The systems may be used to heat domestic hot water, swimming pool water, or for space heating. The heat can also be used for industrial applications or as an energy input for other uses such as cooling equipment. In many climates, a solar heating system can provide a very high percentage (50 to 75%) of domestic hot water energy.

In the 1980s and early 1990s, most photovoltaic modules provided Remote Area Power Supply, but from around 1995, industry efforts have focused increasingly on developing building integrated photovoltaic and power plants for grid connected applications. Currently the largest photovoltaic power plant in North America is the Nellis Solar Power Plant of 15 MW capacity. Australia, China, Germany, Israel, Japan and USA have played important roles in increasing the production level and corresponding lowering of cost. Germany has put thrust on higher use of building integrated photovoltaic panels for electricity generation by providing higher subsidies and incentives. This effort started in 2001 and has already made its impact.

Some of the second-generation renewables, such as wind power, have high potential and have already realised significant reductions in production costs. At the end of 2006, it produced less than 1% of world-wide electricity use, but it accounts for approximately 20% of electricity use in wind power in Denmark, 9% in wind power in Spain, and 7% in wind power in Germany. Global wind energy markets continue to boom [13]. European wind companies grow in U.S. However, it may be difficult to site wind turbines in some areas for aesthetic or environmental reasons, and it may be difficult to integrate wind power into electricity grids in some cases. China, Denmark, Germany, India, Spain and USA have played important role in enlarging the use pattern.

Brazil has one of the largest renewable energy programs in the world, involving production of ethanol fuel from sugar cane, and ethanol now provides 18 percent of the country's automotive fuel. As a result of this, together with the exploitation of domestic deep water oil sources, Brazil, which years ago had to import a large share of the petroleum needed for domestic consumption, recently reached complete self-sufficiency in oil. Most cars on the road today in Brazil run with “flex” type engines that use indistinctly petrol, ethanol or any blend of both. In the U.S. cars run on blends of up to 10% ethanol, and motor vehicle manufacturers already produce vehicles designed to run on much higher ethanol blends. Use of bio-fuels looked promising till the first half of 2007, but, in some countries, the food versus fuel controversy that started in the second half of 2007, resulted in a big set back. This type of fuel can possibly be given a boost only in the third generation technology phase. In spite of all the opposition to bio-fuel crops due to their competition with food crops, bio-fuel plantations have increased and new agricultural bio-technologies are being identified and studied to improve land productivity.

9.1.3 Third Generation Renewable Energy Technologies

The European Union has put forth the firm resolution of increasing contribution of renewables to 20% and savings through energy efficiency measures at 20% by 2020. This has triggered a new enthusiasm of support for renewables and energy efficiency. As this decision was taken in the first half of December 2008, after the global financial crisis, EU leaders must have also considered the funding options for this 20:20 scheme by 2020.

Third-generation technologies are still under development and include advanced biomass gasification, bio-refinery technologies, solar thermal power stations, hot dry rock geothermal energy, and ocean energy. Third-generation technologies are not yet widely demonstrated or have limited commercialization. Many are on the horizon and may have potential comparable to other renewable energy technologies, but still depend on attracting sufficient attention and RD&D funding.

According to the International Energy Agency, new bio-energy (bio-fuel) technologies being developed today, notably cellulosic ethanol bio-refineries, could allow bio-fuels to play a much bigger role in the future than previously thought. Cellulosic ethanol can be made from plant matter composed primarily of non-edible cellulose fibres that form the stems and branches of most plants. Crop residues (such as corn stalk, bagasse from sugar cane industries, wheat straw and rice straw), wood waste, and municipal solid waste are potential sources of cellulosic biomass. Dedicated energy crops, such as switch grass, are also promising cellulose sources that can be sustainably produced in many regions.

Solar thermal power stations have been successfully operating in California commercially since the late 1980s, including the largest solar power plant of any kind, the 350 MW Solar Energy Generating System. Nevada Solar One is another 64 MW plant which has recently opened. Other parabolic trough power plants being proposed are two 50 MW plants in Spain, and a 100 MW plant in Israel.

In terms of Ocean energy, another third-generation technology, Portugal has the world's first commercial wave farm, the "Aguçadora Wave Park".

Solar power panels that use nanotechnology, which can create circuits out of individual silicon molecules, may cost half as much as traditional photovoltaic cells. Nanosolar has secured more than $100 million from investors to build a factory for nanotechnology thin-film solar panels. The company's plant has a planned production capacity of 430 megawatts peak power of solar cells per year.

9.2 Growth of Renewable Energy Industry

Years 2006 and 2007 have seen phenomenal growth in the renewable energy sector and the industry. Overall, US$100 billion has been put into this sector throughout the globe. This is being led by Germany and followed by China, USA and Japan in that order. These investments have boosted the industry and brought down costs and increased use. In spite of high cost their use was on the increase. Every expert is deliberating and debating if the decreasing oil price in 2008-9 will result in lowering of renewable energy device use. However, as a result of stronger support for climate security and environmental consideration the use pattern is not reversing though users would prefer avoiding the initial equipment or device cost. Equipment leasing companies are now emerging. This pattern will mean that the user will not have to invest into generation systems and will only pay for the service and supply. This phenomenon is expected to catch on leading to speedy expansion of renewable energy devices.

Renewable Energy World has analysed a number of perspectives on how the credit crisis is affecting development of renewables [14] and concluded that a number of challenges are hindering short-term growth in many areas, but the overall picture still looks good for the industry. This projection was based on the global scenario and covered USA, Germany, China, and most of the European markets. This conjuncture may become an opportunity to convert the financial crisis into an opportunity for growth of renewable energy projects.

9.3 R & D for Renewable Energy Systems

Research and Development activities are extremely important to ensure development of site specific equipment. R&D activities in respect of Solar Thermal Power Generation would cover design and development of concentrating solar thermal power systems, including parabolic troughs, central receiver systems, and dish/engine systems. The R&D effort should be directed mainly at reducing cost of production and maintenance, and include both production design and fabrication/assembly techniques. In addition, R&D should cover balance of system issues involved in hybridization with biomass combustion based system and/or molten salt thermal storage [15].

R&D activities in respect of solar photovoltaic generation, for the near and medium term would include improvement in solar cell efficiency to 15% at commercial level; improvement in PV module technology with high packing density and suitability for solar roofs, and development of light weight modules for use in solar lanterns and similar applications.

In the long term the R&D will include focus on:

- getting the same electrical, optical, chemical and physical performance from low cost materials as that delivered by expensive materials,
- developing new paradigms for solar cell design that surpass current efficiency limits,
- finding catalysts that enable inexpensive, efficient conversion of solar energy into chemical fuel,
- identifying novel methods of self-assembly of molecular components into functionally integrated systems, and
- developing new materials for solar energy conversion infrastructure, such as robust, and inexpensive, thermal management materials.

A key issue is how to integrate intermittent energy sources such as wind, wave, and solar, into modern power systems to meet the time varying demands of consumers. Research into storage and conversion systems as well as development of so called “smart” electricity transmission and distribution networks that can cater for distributed and embedded generation is required [13]. Research and infrastructure development in communications and IT will be crucial to deploy smart grids suitable to accommodate sustainable generation and meet modern consumer expectations of quality, availability, and reliability.

10. ENERGY EFFICIENCY

As mentioned before, energy efficiency is one of the main technological drivers of sustainable development as dematerialization and recycling will further reduce energy intensity. Dematerialization is the new concept gaining momentum with a focus on natural capital. Worldwide the industry is now designing products that consume the least natural resource. One model is to lease out product and charge for the use rather than to promote use of product sale. This ensures that the user hires the product only for the need based hours of application and the total numbers of such a product in the market is reduced. The overall impact is that lesser energy input is required for the same service to users.

Energy policies have traditionally underestimated the benefits of end-use efficiency for society, the environment, and employment. This is mainly due to the additional costs in terms of materials and processes associated to efficiency improvement. Achievable levels of economic efficiency depend on a country's industrialization, motorization, electrification, human capital and policies. But their realization can be jeopardized by sector and technology specific obstacles –including lack of knowledge, legal and administrative obstacles, and the market power of energy industries. Governments and companies should recognize innovations that can overcome these obstacles. The external costs of energy use can be covered by energy taxes, environmental legislation, and greenhouse gas emissions trading. As realized at CSD-15, in 2007, there is also an important role for international harmonization of regulations for the efficiency of traded products.

The economic potentials of more efficient energy use will continue to grow with new technologies and with cost reductions resulting from economies of scale and learning effects. Considerations of the 'second law of thermodynamics at all levels of energy conversion' and 'technological improvement at the level of useful energy' suggest further potential for improving efficiency by a substantial amount that may be reached during this century. IT innovations will have significant place in future energy efficiency through smart management of equipment and systems. Also, structural changes in industrialized and transition economies –moving to less energy intensive production and consumption– will likely contribute to stagnant or lower energy demand per capita in these countries.

The main goal of energy analysis in the context of sustainable development is to explore ways to reduce the amount of energy used to produce a service or a unit of economic output –and indirectly, to reduce related emissions. Relevance of the energy productivity concept put forth by MGI can be appreciated in this context. Two questions are important:

i) how tight is the link between final energy use and the energy service in a given end use? and
ii) what is the potential for technological and organizational changes to weaken that link in the next 10 to 20 years?

Because the technology used in different regions differs substantially, the potential for economic efficiency varies. Still, more efficient energy use is one of the main options for achieving global energy sustainability. Energy efficiency improvement can free productivity from direct relation with energy consumption. Energy efficiency improvement also has a role in reducing GHG emissions.

Energy efficiency has a cost that is not necessarily negligible. Quantity, quality and price of energy use along with the availability of primary energy resource will be important elements for any Action Plan on Energy Efficiency. One major reason for Germany and Japan to gain from energy efficiency measures is the high price of energy the consumer is willing to pay. In this case the benefits become evident.

Energy efficiency –and indirectly, improved material efficiency– alleviates the conflicting objectives of energy policy. Competitive and low (but full cost) energy prices support economic development. But, they increase the environmental burden of energy use. They also increase net imports of conventional energies and so tend to decrease the diversity of supply. Using less energy for the same service is one way to avoid this conflict.

The industry sector and the residential sector, besides the transport sector, are major consumers of energy, where energy efficiency measures can considerably reduce energy consumption and thereby the greenhouse gas emissions. Besides the industry sector specific technological options, there are substitute technological options and fuel switching options that can lead to GHG mitigation as well as lowering the energy consumption. In general, in the industrial sector, approximately 50% of the potential energy use saving can be accounted for by substitute technologies.

With the increasing availability of natural gas, industries have had the option to switch to natural gas based operations. For small scale industries, especially in the developing countries, the possibility of switching from fossil fuel to producer gas has also been attractive.

Energy efficiency measures in the industrial sector also have some co-benefits due to reduction in fuel and material use, leading to reduced emissions by air pollutants, solid wastes and waste water. In addition some options also lead to improvement in the quality of product.

The commercial sector provides opportunity for energy conservation through reducing total electricity loads for space heating, space cooling and refrigeration. Energy use in residential and commercial buildings also varies significantly across income groups, building construction typology, climate, and several other factors. Energy saving potential for heating in colder climates, specifically in UK has been estimated at 50%, through combined heat and power units or solar passive interventions. Cooling loads in space air-conditioning and refrigeration in warmer regions of developing countries could provide similar opportunities through solar passive architecture and renewable energy based active systems. Some leading builders are already paying attention to it in India and several other countries. In energy deficient states in India new office, commercial and educational complexes have to establish their own electricity supply. An efficiently designed system will not only reduce load for the user but will also substantially reduce the local pollution.

A general impression is that energy savings can be achieved only through technological improvements. Additional, and some times major, energy savings can be realized by looking at energy using systems in a broader sense. Aspects of this systematic review will include the following [16]:

- Optimising the transport and distribution of energy. Commercial energy use is often highly decentralized, yet the energy is produced in centralized plants.
- Optimising the location of energy users to avoid transporting goods or people.

- Supplying suitable forms of energy, say heat at the needed temperature and pressure, or by exploiting opportunities for energy cascading.

Certain general obstacles in introducing energy efficiency measures have been observed even after active focus of the last 36 years. These can be broadly categorized as follows:

- Lack of knowledge, know-how and technical skills and high transaction costs.
- Lack of access to capital and historically and socially formed investment patterns.
- Disparity of profitability expectations of energy supply and demand.
- Impact of grid-based price structures on efficient energy use.
- Legal and administrative obstacles.
- Other market barriers.

10.1 R&D for Energy Efficiency

Attention is focused on energy efficiency in large industrial and commercial systems to take advantage of material saving and financial saving. The building sector that has a large potential for energy efficient equipment is actively seeking opportunities to measure and rate building energy efficiencies and to develop systems and building designs to greatly decrease their environmental foot prints.

Specific actions are necessary for development of energy efficient products for the following applications:

- Create substantial potential for reduced mobility by intelligent city planning that does not divide an urban area by functions and related sections.
- Explore switching between fuels and use cheap fuels.
- Design intelligent buildings that optimally relocate the energy load.
- Develop simulation software to predict the energy use in buildings.
- Develop energy-efficient building and building components.
- Develop low-cost insulation material.
- Develop energy efficient appliances.
- Develop very-low-energy-consuming circuits for stand-by power.
- Develop low-cost light-emitting diodes (LED)-based lamps for space lighting.
- Develop low energy intensive air conditioning systems.

Renewable energy and efficient energy use, called the “twin pillars” of sustainable energy policies, need be developed in order to stabilize and reduce carbon dioxide emissions. Efficiency slows down energy demand growth so that rising clean energy supplies can make deeper cuts in fossil fuel use. Unless clean energy supplies come online rapidly, slowing demand growth will only begin to reduce total emissions. Reducing the carbon content of energy sources is also needed. Improvement in energy use efficiency will certainly result in receding targets for renewable energy development. Any serious vision of a sustainable energy economy thus requires commitments to both renewables and efficiency.

11. NUCLEAR ENERGY

The Chernobyl accident in April 1986 -a typical case of a particular design requiring strict observance of operating procedures without enough safety margins to foreseeable human error, and a demonstration of lack of safety culture- caused public opinion to force a slowdown or ban on the power reactor construction programs around the world. Nevertheless, nuclear energy has about 5% share in global primary energy supply and provides about 15-17% of the global electricity generation [17]. Current technologies for nuclear power plants, designed for 40 years' lifetime, have been able to extend their lifetime up to 60 years with refurbishment of specific equipments and systems. A worldwide weighted average of capacity factors of nuclear power plants has risen from 74% to 80% in the period 1991-2008 [18]. In June 2009, the number of operating nuclear power reactors was 436, with a total installed capacity of 370.2 GW, and 49 under construction, with additional 42.9 GW [18].

One positive side of the nuclear power generation is its contribution to abatement of climate change effects and energy security. The nuclear industry is facing a severe challenge for adding capacities at the rate predicted, and at costs projected, by IEA. Going by the Blue Map scenario of IEA Energy Technology Perspectives Report which has projected that, to halve the GHG emissions by 2050, the installed capacity should increase four-fold, nuclear power generation will have to increase from 2,606 TWh in 2007 to 9,857 TWh in 2050. In order to achieve this, the report states that 32 large reactors (of 1,000 MW size) would have to be built every year from now to 2050. Whether this target can be physically achieved is a technological challenge [19].

The IEA scenario assumes an investment cost of US $ 2,100 per kWe. However, recent estimates put the cost of current nuclear investment on higher ranges: the latest cost estimate for the first French EPR pressurized water reactor being built in Finland is US$5,200 per kWe, although this figure corresponds to a first-of-its-kind project, and in the US the Center for Energy and Environmental Policy Research of MIT considers US$ 4,000/kWe a right figure [20]. The average time for building such reactors is now estimated to be in the range of 5 years [20].

IEA has also observed that even by implementing the challenging nuclear scenario, the contribution of nuclear power to reductions in GHG emissions from the primary energy supply sector will represent about 10%, the rest will be due to end-use efficiency (58%), increased renewables in power generation (20%), fuel switching in end uses (7%) and changes in the fossil-fuel mix in power generation (5%) [21].

Fusion energy technology is in the stage of research and will take considerable time to be developed and demonstrated.

Regarding fission technology, the European Renewable Energy Council and Greenpeace in their Report titled Energy Revolution: A Sustainable Global Energy Outlook have quoted different sources to present four generations of nuclear reactors as follows [7].

11.1 Nuclear Reactor Designs - Evolution and Safety Issues.

At the beginning of 2005 there were 441 nuclear power reactors operating in 31 countries around the world. Although there are dozens of different reactor designs and sizes, there are three broad categories either currently deployed or under development [22]. These are:

- Generation I: Prototype commercial reactors developed in the 1950s and 1960s as modified or enlarged military reactors, originally either for submarine propulsion or plutonium production.
- Generation II: Mainstream reactor designs in commercial operation worldwide.
- Generation III: New generation reactors now being built.
- Generation IV: Include the so called advanced reactors.

About 20 different designs are reported to be under development, most of them evolutionary designs developed from Generation II reactor types with some modifications, but without introducing drastic changes. Some of them represent more innovative approaches. According to the World Nuclear Association, reactors of Generation III are characterized by the following:

- A standardized design for each type to expedite licensing, reduce capital cost and construction time.
- A simpler and more rugged design, making them easier to operate and less vulnerable to operational upsets.
- Higher availability and longer operating life, typically 60 years.
- Reduced possibility of core-melt accidents.
- Minimal effect on the environment.
- Higher burn up to reduce fuel use and the amount of waste.
- Burnable absorbers to extend fuel life.

Of the new reactor types, the European Pressurised Water Reactor (EPR) has been developed from the most recent Generation II designs to start operation in France and Finland. Its stated goals are to improve safety levels –in particular, reduce the probability of a severe accident by a factor of ten, achieve mitigation of severe accidents by restricting their consequences to the plant itself, and reduce costs. Compared to its predecessors, the EPR displays several modifications that will allow a reduction of design margins for safety that include:

- reduced volume of the reactor building by simplifying the layout of the emergency core cooling system, and by using the results of new calculations which predict less hydrogen development during an accident;
- increased thermal output of the plant by 15% relative to existing French reactors by increasing the core outlet temperature, letting the main coolant pumps run at higher capacity and modifying the steam generators, and
- fewer redundant pathways in safety systems than the German Generation II reactors.

Several other modifications are aimed at providing substantial safety improvements to reduce the probability of a core melt down by a factor of ten and a ‘core catcher’ system to mitigate and control a meltdown accident.

Generation IV reactors are currently being developed with the aim of commercialization in 20-30 years.

12. CLIMATE CHANGE AND SUSTAINABLE ENERGY SUPPLY

Sustainability of energy systems is linked to climate change and in this regard the 15th Meeting of the Committee of Parties to the U.N. Framework Convention on Climate Change in Copenhagen, in December 2009, will be extremely important to set basic policy goals. WFEO will certainly play a leading and proactive role to evolve logical solutions and approaches to ensure a smooth mitigation and adaptation strategy. The key to future lies in not only developing engineering and technology solutions but in providing engineering support for discussions at international and national sustainable policy decision making meetings.

It is being recognized that UNFCCC and Kyoto Protocol related meetings are becoming increasing unwieldy and now have a total of six separate processes including;

i) the bodies of the UNFCCC and Kyoto Protocol;
ii) two subsidiary bodies focusing on implementation and science/technology; and
iii) two processes established to negotiate a new climate change agreement, one under the UNFCCC and the other under the Kyoto Protocol.

The negotiations are held under two groups:

i) the Ad Hoc Working Group on Long-term Cooperative Action (AWG-LCA) under the UNFCCC. The AWG-LCA negotiation has a broad mandate and includes all UNFCCC Parties including the United States;
ii) the Ad Hoc Working Group on further Commitments for Annex Parties under the Kyoto Protocol (AWG-KP). The AWG-KP has a much narrower focus and is only charged with agreeing new targets for developed countries that have ratified the Kyoto Protocol.

COP-14 at Poznan, Poland, in December 2008, showed slow progress and limited discussion on national targets. There was significant focus on what the target global level for emissions cuts should be. In both the AWG-LCA and KP there were repeated references to the IPCC 4th Assessment Reports’ 450 ppm CO_2 stabilization scenario. This scenario require a 25-40% cut in emissions by 2020 for developed countries, as well as a substantial deviation from business as usual emission from key developing regions. The apparent coalescing of countries around this scenario implies that Parties may seek as a de-facto target for limiting global temperature increase, a raise of no more than 2 degrees centigrade.

The financial crisis is far from over; but it has demonstrated how quickly governments can act when they believe in the seriousness of the crisis before them. The way governments chose to handle the global financial crisis should be followed when dealing with the threat of global warming. Governments have rightly identified the financial crisis as something requiring quick, concerted and substantial action and responded immediately –not with rhetoric but with action. After billions dollars within the first weeks; trillions came by the end of 2008; and more is on the way.

Most governments have tagged climate change with the same rhetoric but they have collectively failed to match their commitments taken at the annual Conferences of the Parties to the Climate Change Convention –Montreal 2005, Nairobi 2006, Bali 2007, Poznan 2008- with the leadership and action required to effectively address them.

13. THE WAY FORWARD – TURN ADVERSITY INTO OPPORTUNITY FOR ENERGY SUSTAINABILITY

Governments are concerned that being a first mover in establishing strong energy sustainability policy settings, inclusive of carbon emissions trading, renewable energy targets and carbon emissions reduction schemes will reduce the competitiveness of their economies in relation to other economies that delay the introduction of similar initiatives. To introduce aggressive sustainability targets and the consequential negative impacts on economies are seen as being detrimental to political leadership futures.

13.1 WFEO Thrust on Sustainable Energy

In order to contribute to the search of solutions that are technically viable, WFEO set up the Energy Committee in 2003 to respond to the need of engineering solutions in the energy sector. The Energy Committee has the following Vision: "To be the recognised engineering reference for assessing the feasibility of energy technologies", and the Mission: "To provide the engineer with updated, unbiased and reliable information on the feasibility of different energy technologies based on scientific principles, engineering criteria and demonstrated technological development".

13.2 WFEO Energy Committee Role and Its Impact

WFEO Energy Committee has already published Reports on Feasibility Conditions of Wind-Power and Nuclear Power; and has setup Task Groups to study the feasibility of Solar Energy and Bio Energy. WFEO Energy Committee has also signed a Memorandum of Understanding with the World Energy Council to develop engineering inputs for solutions for energy applications.

WFEO Energy Committee organised the first International Conference on Engineering for Sustainable Energy held in Rio de Janeiro during August 15-18, 2007. Subsequently a World Engineering Congress Panel Meeting on Energy for Sustainable Development was organised on December 5, 2008 at Brasilia. Both conferences resulted in enhancing the quality of technology development and improving efficiencies of energy systems.

The thinking of the engineering profession expressed at the 1st International Conference on Engineering for Sustainable Energy is rendered by the following main Conclusions and Recommendations of the meeting [23]:

- the main challenges the world is going to face in the near future are centered on the explosion mainly in developing countries of energy demand, and on the constraints imposed by climate change on greenhouse gases emissions that will need to be drastically abated;
- to successfully respond to these challenges, based on the state-of-the-art of existing technologies, we need to be fully aware that we cannot afford not to use all feasible energy sources at our reach and, at the same time, that we ought to face a transition to economies based on low carbon emissions;
- in order to satisfy developing countries needs while observing the limitations on CO_2 emissions, it will be crucial to promote the development and deployment of renewable energy technologies and advanced energy technologies, including cleaner fossil fuel technologies; utilization of bio-fuels; implementing national and regional energy efficiency programs, and the use of nuclear energy under satisfactory operational safety conditions;
- Society and those responsible for decision making have to be mindful of the need of analyzing the feasibility and the technological availability of proposed energy options;
- determining the technological, economic and environmental feasibility of an energy option is one of the chief functions of the engineering profession;
- sustainable energy solutions for developed countries are not always necessarily adequate for developing ones due to the great differences in growth rate increase of energy demand in these countries;
- each country has its optimal energy mix that will depend upon the available natural resources base, population distribution, growth in energy demand, and the status of its technical and economic capacity;
- there is no uniform treatment for solving globally sustainable energy supply problems;
- renewable energies (solar, wind-power, low-head hydropower), even without the benefit of economy of scale, are ideal for use in situations where the energy demand does barely grow or in places far-off from large consumption interconnected centers;
- programs of electrification based on renewable energies, particularly in rural and remote areas of developing countries, will be essential to accelerate the access of the poor to sustainable energy;
- efficiency and economy of energy usage, a fundamental objective toward reducing greenhouse gas emissions, ought to be seriously pursued provided the economic conditions of the population allow for such actions considering

the higher costs associated with the use of more complex and uncommon systems and materials;

- the issue of the competition between the production of bio-fuels and food crops depends on the technologies being used and the conditions of land availability for agriculture exploitation;
- to deal with the complex situations developing countries will encounter when establishing sustainable energy policies, special capacity building efforts will be required to provide the engineering professional with updated knowledge on the diverse technologies for sustainable energy generation.

The WFEO Energy Committee's Panel on Energy and Sustainable Development held on December 5, 2008, in the framework of the World Engineering Congress 2008, in Brasilia, addressed the following issues:

- Will the looming world recession change the development and economic basis for energy demand growth? Will energy demand drop substantially all around the world?
- How unemployment and social unrest might affect the current strategies for sustainable development? Will there be less emphasis on sustainability at least temporarily?
- Will the need to implement sizeable infrastructure projects with large work-forces jeopardize policies to implement more renewable energy projects? Will large-sized centralized generation be privileged in terms of economy of scale?
- Will there be a return to proven energy options that imply less technological development and investment?
- Are we entering a period of non-compliance or of less compliance with goals set for reduction of CO_2 emissions?

Discussions focused on different continents energy supply situations arising from the global financial crisis of that moment [24].

Europe was presented as a mosaic of energy patterns and policies and the following issues were highlighted to give a common ground on sustainable energy matters in the region: growing concern about security of supply; significant commitment to new renewables in several countries; all scenarios retaining a high dependence on hydro-carbons, and nuclear energy being considered as an option in several countries. The European Power Matrix of 2005 shows a distribution of fossil 54.2%; nuclear 27.5%; hydro 15.2%; and renewables 3.1%. Renewable energy sources share of gross inland consumption has currently a differentiated distribution varying from 5% to 20%. In 2005, CO_2 avoidance from renewables has been of the order of 50 mtoe/yr. While technological progress is required to achieve some emissions reduction, increased deployment of existing, low carbon technology accounts for most of the CO_2 savings. The common policy is to reach, by 2020, 120 mtoe of CO_2 avoidance. By 2020 the targets are 20% of renewables; 20% reduction of CO_2 reductions; 20% efficiency improvement and 10% of bio-fuels for transport. Additionally, biomass based energy for at least 85% of residential and commercial applications, and for 70% of industrial applications will be promoted, and eco-labelling will be required for heat pumps. A project is underway to achieve 2 kW/capita in Switzerland by 2050 (current mean world consumption). Such targets will produce just 1 tonne of CO_2/capita/yr. The concept is based on the relationship between quality of life and per capita consumption of energy showing that countries with best Human Development Index (HDI) have highest values of per capita energy consumption. However, above a value around 100 GJ/capita.year (~3.3 kW/capita), there is flattening of the HDI improvement. Consequently, if countries now exceeding this limit would decrease per capita energy consumption, but still remaining above that limit, their level of quality of life would practically be maintained and world resources would be better preserved. Though this limit is 1.6 times higher than the targets set for Switzerland, the same concept was put forth in 2004 by the WFEO Energy Committee at the first International Workshop on the Role of Engineers for the Sustainable Development at Seoul on December 3, 2004 [25].

The US case was presented on the basis of the changing focus of its Energy Policy, which is largely a derivative policy with its roots in economic, national security and environmental policies and with shifting priorities over time among those policies. The total energy use, in the period 2008 to 2030, is projected to increase from 103 to 118×10^{15} BTU, an increase of about 14.6%. Considering losses and thermo-dynamic requirements, energy flows in the US economy show the following distribution; useful energy 42.5% and unused energy 57.5%, mainly in cars (12.9%) and power industry (25.9%). This distribution reveals a significant potential for efficiency improvement and energy use savings. The main areas for technology and transformation change will be: energy efficiency; alternative transportation fuel; advanced coal fired power generation and CO_2 capture and storage; renewable electric power generation; electric power transmission, distribution, control and storage and nuclear power.

The Asian case was presented with a thrust on renewable energy use. The total world consumption of commercial energy was 11.74 mtoe in 2006, with fossil fuels accounting for almost 80% of global primary energy supplies. The balance 20% was provided by nuclear, large hydro, traditional biomass and new renewables. In 2007, fossil fuel sources contributed around 72% of energy supply in Asia and the Pacific Region. Traditional biomass constitutes, by far, the biggest single source of energy for large numbers of people in developing countries, providing for a quarter of total energy consumption in Developing Asia. Some of the Asian countries have shown tremendous potential and determination to push forth the renewable sources. China realising the future air quality threat, has started investments in certain areas of clean energy technology, such as wind, PV manufacturing, solar thermal, biomass and bio-fuels. Also, nuclear power has a major role in this program to provide base-load power. China rank second for the amount invested in renewable energy in 2007, only trailing behind the leader Germany. The primary focus of China's renewable energy goal for international use is on the less expensive technologies, such as wind and biomass. China is a world leader in the manufacture of solar PV and its production of 820 MW in 2007 is second only to Japan. On the thermal side, solar water heater market has grown rapidly and accounts for 60% of global capacity in 2007. China is also the leading beneficiary from the United Nations CDM and has developed projects to reduce 900Mt of CO_2 emissions by 2010, valued at over US$10 billion. India had an installed generation capacity of 13,878 MW based on micro-hydro, wind and bio-energy, which is contributing to around 8% of the country's electric installed capacity. The government has also announced its intention to increase the share of renewable energy based power generation to 10% by the year 2022. Schemes for Solar Cities and Model Solar Cities have been launched to provide 10% energy supply by renewable sources. An indigenous national green buildings rating scheme has been announced to promote better energy efficiency and renewable energy based residential and commercial buildings. Similarly, other Asian countries are also launching major programmes for promotion of renewable energy use for consideration of climate change issue.

Brazil has undertaken to finance infrastructure expansion in different areas, particularly in the energy sector under the Development Acceleration Programme (PAC) established by the government in 2007. Energy generation shares by different sources has the following distribution: Petroleum and bi-products 37.4%; biomass 30.9%; hydro electricity 14.9%; natural gas 9.3%; coal 6.0%; and nuclear 1.4%. Within this composition, renewables represent nearly 45% of the total. Up to 2020 the share of renewable energy in the Brazilian energy mix is expected to remain near the current value of 45%. For that it is planned to increase the natural gas share from 9% to 15%, decrease the firewood and coal share from 13% to 5%; expand the share of bio-energy sources from 17% to 24%; and to maintain the contribution of renewable sources at 45%.

Main conclusions of this WFEO Energy Committee meeting stressed that energy demand, mainly in the developing world, will continue to expand and the need for clean energies will require adherence to the principles of sustainability. Climate change and energy systems will remain the driving forces towards sustainability. Investments must be focused on integrated sustainable production and efficient utilisation of energy across all sectors. The mix of energy sources in each country will require adjustments with a focus on efficiency and energy savings. In some cases, special attention will be required to provide the appropriate incentives for consumers to embrace new energy delivery technologies and to save energy.

14. CONCLUSIONS

The above mentioned World Energy Outlook 2008 from the IEA and the results of the WFEO International Conference on Engineering for Sustainable Energy, Rio de Janeiro (2007), and of the WFEO Panel on Energy and Sustainable Development, Brasilia (2008), clearly bring out the Engineer's viewpoint on the role of sustainability of energy supply.

The global financial crisis and climate change challenges represent an opportunity to create sustainable energy networks for sustainable development by fully using engineering solutions. The World Federation of Engineering Organisations with its network of specialized technical committees is the natural channel to provide such engineering solutions.

The mitigation stimulus packages of the global financial crisis should ensure that infrastructure is developed with sustainability at the forefront with the aim of being ready to provide for the needs of the eventual recovery. International cooperation similar to that seen to ameliorate the global financial crisis has to be implemented to deliver appropriate and sustainable energy development.

The engineering profession, being the link between science, technology and society, has a key role in implementing sustainable policies and should undoubtedly perform that role. Development of engineering and trade manpower skills to deliver the infrastructure required for sustainable energy development, as well as the ongoing development of measures, targets, monitoring and reporting of progress, needs to be continuously supported and expanded.

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