Climate Change and Nuclear Power

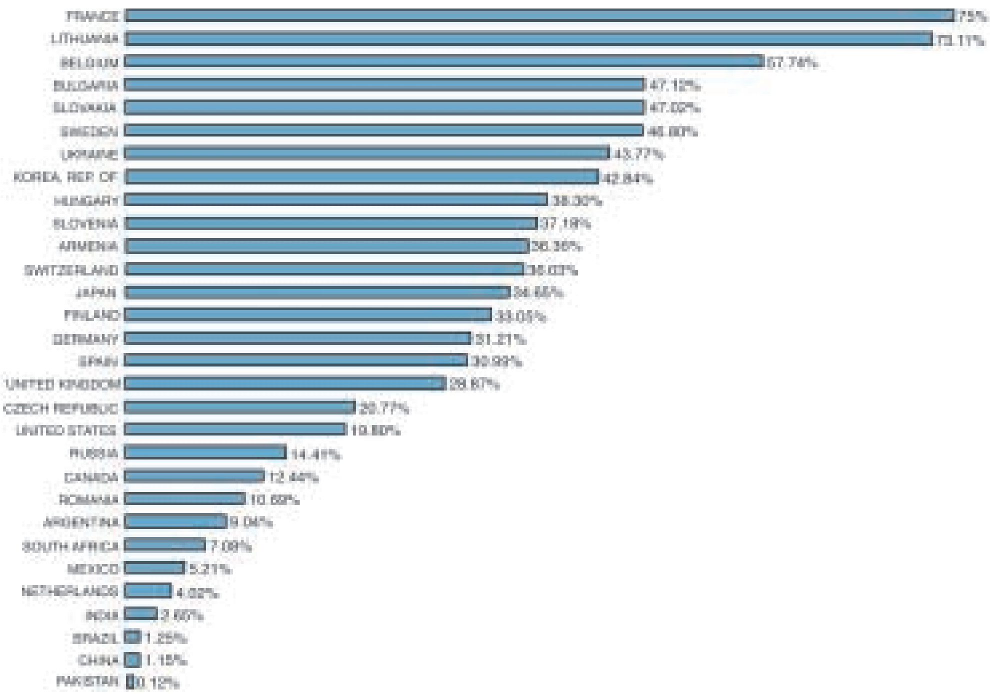
International Atomic Energy Agency

NUCLEAR POWER STATUS AROUND THE WORLD

	REACTORS IN OPERATION		REACTORS UNDER CONSTRUCTION	
	No. of units	Total net MW(e)	No. of units	Total net MW(e)
ARGENTINA	2	935	1	692
ARMENIA	1	376		
BELGIUM	7	5 712		
BRAZIL	1	626	1	1 229
BULGARIA	6	3 538		
CANADA	14	9 998		
CHINA	3	2 167	7	5 420
CZECH REPUBLIC	4	1 648	2	1 824
FINLAND	4	2 656		
FRANCE	59	63 103		
GERMANY	19	21 122		
HUNGARY	4	1 729		
INDIA	11	1 897	3	606
IRAN			2	2 111
JAPAN	53	43 691	4	4 515
KOREA, REP. OF	16	12 990	4	3 820
LITHUANIA	2	2 370		
MEXICO	2	1 308		
NETHERLANDS	1	449		
PAKISTAN	1	125	1	300
ROMANIA	1	650	1	650
RUSSIAN FEDERATION	29	19 843	3	3 375
SOUTH AFRICA	2	1 842		
SLOVAKIA	6	2 408	2	776
SLOVENIA	1	632		
SPAIN	9	7 470		
SWEDEN	11	9 432		
SWITZERLAND	5	3 079		
UNITED KINGDOM	35	12 968		
UKRAINE	14	12 115	4	3 800
UNITED STATES	104	97 145		
WORLD TOTAL*	**433**	**349 063**	**37**	**31 128**

*This total includes Taiwan, China where six reactors totaling 4884 MW(e) are in operation. Two units are under construction. Table reflects status as of April 2000 as reported to the IAEA.

NUCLEAR SHARE OF ELECTRICITY GENERATION as of April 2000



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Contents

Introduction

The possibility of widespread climate change resulting from an increase in greenhouse gas (GHG) concentrations in the atmosphere is a major global concern. A principal source of GHGs, particularly carbon dioxide, is the fossil fuels burned by the energy sector. Energy demand is expected to increase dramatically in the 21st century, especially in developing countries, where population growth is fastest and, even today, some 1.6 billion people have no access to modern energy services. Without significant efforts to limit future GHG emissions from the energy sector, therefore, the expected global increase in energy production and use could well destabilize the global climate.

To reduce the risk of global climate change, industrialized countries (Annex I)[1] have made commitments to reduce GHG emissions under a protocol, negotiated in Kyoto, Japan in 1997 as an addition to the 1992 United Nations Framework Convention on Climate Change (UNFCCC). In the so-called Kyoto Protocol, industrialized countries have agreed to reduce their collective emissions during 2008-2012 by at least 5.2% below 1990 levels.

Nuclear power produces virtually no GHG emissions. It could, therefore, be an important part of future strategies to reduce GHG emissions. Nuclear power is already an important contributor to the world's electricity needs. In 1999, it supplied more than one sixth of global electricity and a substantial 30% of electricity in Western Europe. Despite its present contribution, nuclear power's future role is uncertain. In an increasingly liberalized electric power industry, return on the investment needed to build a new power plant is critical in deciding which power technology to invest in. The high up-front capital costs for building new nuclear power plants, their relatively long construction time and payback period, and the lack of public and political support in several countries for new construction can make nuclear power a less attractive alternative than fossil-fueled power plants.

The nuclear industry is working to reduce costs and increase political and public acceptance for nuclear power. The near absence of GHG emissions from nuclear power could further enhance its future competitiveness. This booklet summarizes both nuclear power's current status — including the issues of cost, safety, waste management, and non-proliferation — and its potential for contributing to desirable reductions in the world's future GHG emissions.

[1] Annex I includes the OECD (membership of 1990) plus Belarus, Bulgaria, Croatia, Czech Rep., Estonia, Hungary, Latvia, Lithuania, Poland, Romania, the Russian Federation, Slovakia, Slovenia, and Ukraine.

Current Status — Nuclear Power

At the end of 1999, there were 433 nuclear power plants in operation around the world. They represented a total capacity of 350 gigawatts of electricity (GW(e)) and, in 1999, produced 16% of the world's electricity. One hundred and fifty power plants, or 36% of the world's nuclear power capacity, were in Western Europe, where they generated 30% of the region's electricity supply. In North America, 118 reactors provided 20% of the electricity supply in the USA and 12% in Canada. In Eastern Europe and the Newly Independent States, there were 68 nuclear power plants. There were 84 in the Middle East, South Asia, and the Far East, where planning continues for a further expansion of nuclear power especially in China, India, Japan, and the Republic of Korea. Latin America and Africa account for less than 2% of global nuclear electricity capacity (IAEA, 2000a; IAEA 2000b).

In North America, no new reactors are under construction or on order. The same is true in Western Europe, where there is currently significant over capacity in the electricity sector. Where new generation capacity is required, investors generally prefer alternatives that are less expensive than the large, capital- intensive units now offered by the nuclear industry. In addition, Belgium, Germany, the Netherlands, and Sweden plan to gradually phase out nuclear power, while in Austria, Denmark, Greece, Ireland, Italy, and Norway national policy restrictions prevent its use. However, existing nuclear power plants, for which fuel and operating costs are low and initial investments have already been largely depreciated, can be very competitive sources of electricity supply. In both North America and Western Europe, this has arisen largely from improvements in plant output and created incentives for consolidation within the nuclear industry, as well as for investments in extending the lifetimes of existing nuclear power plants.

In Eastern Europe and the Newly Independent States, most nuclear power plants have already operated for more than half of their original design lifetimes and, in a number of countries, debates continue over the need to finish partially built plants. In several countries, expansion continues. The Russian Federation, for example, has three nuclear power plants currently under construction with plans for more. Economic conditions, financing, and security of supply considerations will determine the future course taken.

The main regions of the world where the use of nuclear power is expected to grow in the short term are the Far East and South Asia. However, the recent Asian financial crisis has slowed anticipated large regional increases in energy demand.

Future Energy Needs and Resources

The drive for clean energy supplies would not be so urgent if energy needs were to remain at today's levels. But demand will rise substantially, driven largely by demographic and economic growth in today's developing countries. Of the world's six billion people, 75% live in developing countries, and consume only 36% of global primary energy, and 1.6 billion have no access to modern energy services (WEC, 2000). A growing global population will compound the problem. The latest median projection of the United Nations estimates an additional 4.4 billion people by 2100, an increase of almost 75% relative to today (UN, 1998).

A comprehensive picture of future energy needs is provided in the Intergovernmental Panel on Climate Change (IPCC) Special Report on Emission Scenarios (SRES) (IPCC, 2000). The report presents a set of 40 scenarios developed as reference projections of greenhouse gas emissions. The 40 scenarios reflect a broad range of different assumptions on population growth and economic development, environmental priorities, technological progress, and international cooperation on global energy use. However, none of the scenarios, by intention, includes any climate change policies.

The SRES shows that global primary energy use in these scenarios will grow from 1.7 to 3.7-fold between 2000 and 2050, with a median increase by a factor of 2.5 (Figure 1). Electricity demand grows almost 8-fold in the high economic growth scenarios and more than doubles in the more conservation-oriented scenarios at the low end of the range. The median increase is by a factor of 4.7.

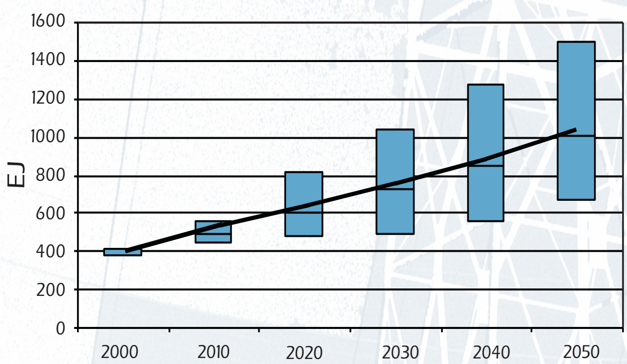

Figure 1. Range of future primary energy demand in SRES scenarios, 2000-2050. Solid line represents median. Source: IPCC, 2000.

The scenarios include substantial improvements in final energy intensities[2] of between 1% and 2.5% per year, with the higher improvement rates leading to lower total energy requirements, compared to the average improvements during the 20th century of some 1% per year. Thus, the scenarios assume that future potentials for further efficiency improvements continue to be exploited at a generally accelerating pace.

Most of the scenarios also include substantial increases in the use of nuclear power (Figure 2). Thirty-five of the 40 scenarios report results explicitly for nuclear power, not just "non-carbon technology", and the projections for 2050 range between current capacity levels of 350 GW(e) up to more than 5000 GW(e) (with a median of more than 1500 GW(e)). These projected growth levels would require added global nuclear power capacity of 50-150 GW(e) per year from 2020-2050, even without any policies to reduce GHG emissions. They could be higher if nuclear power were used to generate more than just electricity (i.e. chemical fuels and desalination).

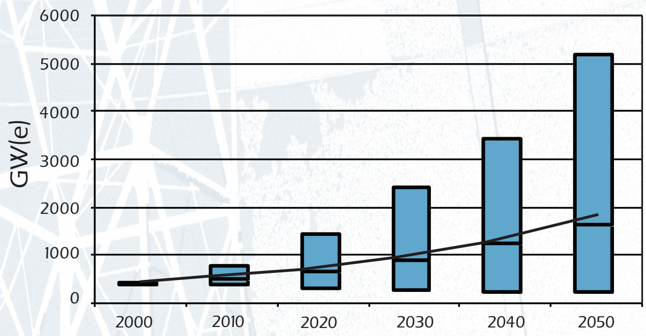

Figure 2. Range of nuclear power in SRES scenarios, 2000-2050.
Solid line represents median.
Source: IPCC, 2000.

The SRES also concludes that the future will most likely not be determined by one or more sources of energy running out. Even the steadily increasing use of fossil fuels, which now supply 87% of the world's primary energy use and 63% of electricity use, is unlikely to exhaust estimated resources. Fossil reserves are generally agreed to be plentiful, especially if we look beyond conventional deposits and take into account continuing technological progress in exploration and production. The same is true of nuclear resources (see Table 1).

Renewable resources, including hydroelectric power, sustainable biomass, solar, wind, geothermal, and ocean energy, are virtually inexhaustible. However, their low energy supply densities compounded by often low conversion efficiencies drastically reduce their economic potential. Low supply densities also imply large land requirements and potential land use conflicts. In the case of hydropower, the best sites have

2 Final energy intensity is defined as the ratio of the sum of energy delivered to the end-user over gross domestic product (GDP) and serves as a proxy for energy efficiency improvements at the level of end-use, for structural economic change and for behavioural change. Low energy intensities usually result from a large share of electricity in the final energy mix.

already been used and further hydroelectric developments will, on average, yield lower supply densities. The intermittent availability of wind and solar energy makes these energy supply options unable to provide supply on-demand. A large dependence on solar or wind would require either back-up systems or extensive energy storage. The limitations of renewables, therefore, are not the magnitudes of their natural flows — indeed these are gigantic — but their diffuse nature and the associated difficulties of concentrating and converting these flows to energy services at the rate demanded by the market place. However, at favourable sites and locations, renewables can make an important contribution to mitigating climate change, particularly in rural areas with low demand densities.

Table 1. Summary of the world resource base — fossil and fissile resources (Source: Adapted from Rogner, 1997 and WEA, 2000)

Resource		Resource amount (stock) in ZJ (1,000 EJ)					
Type		Consumed by end 1998	Consumed in 1998	Reserves	Resources	Resource base[a]	Additional occurrences
Oil	Conventional	4.85	0.13	6.00	6.07	12.08	
	Unconventional	0.29	0.01	5.11	15.24	20.35	45
	Total oil	5.14	0.14	11.11	21.31	32.42	45
Gas	Conventional	2.35	0.08	5.45	11.11	16.57	
	Unconventional	0.03	0.00	9.42	23.81	33.24	930
	Total gas	2.38	0.08	14.88	34.93	49.81	930
Coal	Total coal	5.99	0.09	20.67	179.00	199.67	
Total fossil		13.51	0.32	46.66	235.24	281.89	975
Uranium	Open cycle in thermal reactors[c]	not estimated	0.04	1.89	3.52	5.41	2 000[b]
	Closed cycle with fast reactors[d]	–	–	113	211	325	120 000[b]

a Sum of reserves and resources
b Includes uranium from sea water and other fissile materials
c Calculated from the amount in tonnes of uranium assuming 1 t = 589 TJ (IPCC, 1996a).
d Calculated assuming a 60-fold increase compared with the open cycle: 1 t = 35340 TJ.

Meeting the Kyoto Challenge

The possibility of widespread climate change resulting from increased atmospheric concentrations of GHGs is now a major global concern. The 1992 UNFCCC states that its "ultimate objective ... is to achieve ... stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system." The emission limits established in the 1997 Kyoto Protocol are a first step toward that goal.

Progress towards implementing even this first step has been uneven. Among Organisation for Economic Co-operation and Development (OECD) countries, the best progress on limiting emissions has been made by the European Union (EU), where 1999 GHG emissions were only 0.4% above their 1990 level (WCI, 2000). Nonetheless, by the 2008-2012 Kyoto commitment window, the EU must actually reduce emissions to at least 8% below 1990. The situation is even less promising in other OECD countries. The USA is required to reduce its emissions by 7% between 1990 and the commitment window, but through 1999, emissions increased by 12.7% from their 1990 level (WCI, 2000). In Canada, emissions were up 12.4% in 1999, compared to a required 6% reduction. In Japan, the 1999 increase was 13.6%, compared to a required 6% reduction. Even in Australia, which is allowed an 8% increase, by 1999 the increase was already 15.4%. However, countries with economies in transition are, by and large, well below their Kyoto limits due to economic recession in the 1990s. Particularly important are the Russian Federation and Ukraine, whose Kyoto limits are equal to their 1990 emissions. Emissions during 1999 from economies in transition dropped collectively to 35.8% below their 1990 level (WCI, 2000).

The combined total 1999 carbon emissions in the Annex I countries were 2 to 3% below their 1990 level, compared to a collective Kyoto requirement of 5.2%. But such apparent progress is illusory. It comes mainly from recession in countries in economic transition (WCI, 2000), a trend that will hopefully and most probably reverse[3]. In the EU and the major non-EU OECD countries, emissions have gone up since 1990, not down.

[3] Note also that the Kyoto Protocol sets emission limits for individual Annex I countries, and each is responsible for meeting its limit, regardless of whether emissions from Annex I countries as a group reach the 5.2% reduction target.

One final caveat concerning progress toward compliance with the Kyoto Protocol is that the Protocol covers only Annex I countries, and not the developing countries where future emissions growth will likely be highest. Globally, the SRES scenarios indicate a strong expectation that economies and energy use will continue to grow, but they also suggest that both economic and energy growth will be fastest among the developing countries. Thus, to reach the UNFCCC's ultimate goal of stabilizing the GHG concentration at a safe level, additional limitations beyond the Kyoto Protocol will eventually be needed.

Both for the Kyoto Protocol, and for any successor agreement, the energy supply sector will bear a major part of the burden of reducing carbon emissions. This will require large investments, technological ingenuity and innovation, and substantial contributions from all possible mitigation options, present and future. It means that, in addition to end-use efficiency improvements, the current mix of energy supplies will have to change. Such restructuring will of course mean added costs.

To help achieve the Kyoto limits most cost-effectively, there are three flexible mechanisms in the Kyoto Protocol: emission trading, joint implementation, and the clean development mechanism (CDM). All are relevant to nuclear power. Nuclear power plants in the Russian Federation and other economies in transition mean more emission reduction units available to trade. And Annex I countries could gain credits toward their Kyoto limits by investing in nuclear power plants in other countries, if these investments meet the criteria being negotiated for joint implementation and CDM projects.

Future Potential — Nuclear Power

Nuclear power generation produces virtually no GHG emissions, and the entire nuclear chain has among the lowest emissions per kilowatt-hour (kW·h) of any generating option including renewables (Figure 3 overleaf)[4]. Countries with large nuclear and hydroelectric capacities have markedly lower carbon dioxide emissions per unit of energy than do countries relying heavily on fossil fuels. Currently, nuclear and hydroelectric power each annually avoid GHG emissions equal to about 8% of the total global emissions from fossil fuels. Thus together, they avoid about 1.2 billion tonnes (gigatonnes) of carbon (Gt C) each year that would otherwise have been produced through burning fossil fuels.

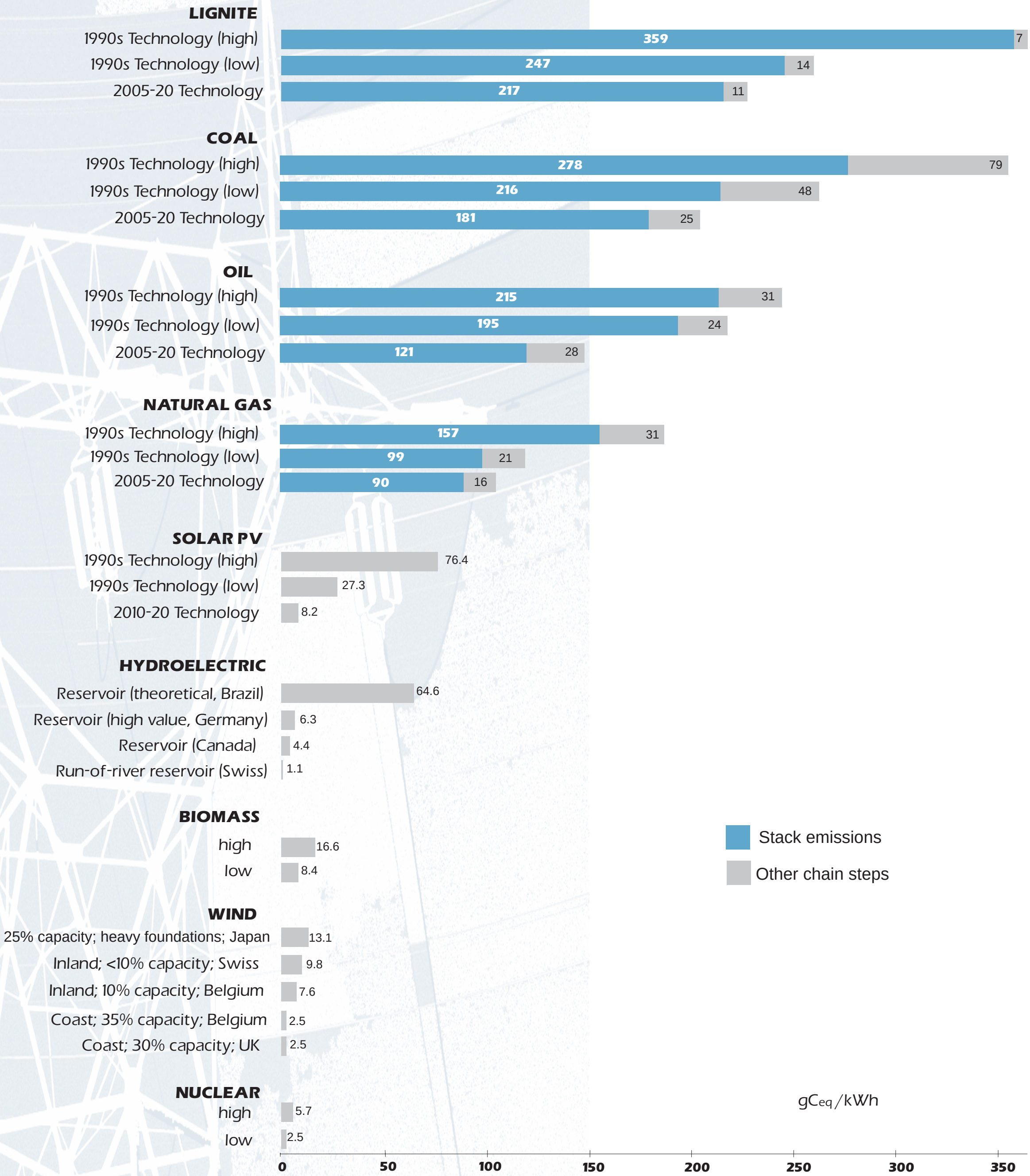

Figure 3. The range of total greenhouse gas emissions from electricity production chains (Source: Spadaro et al., 2000).

4 *Generally, fossil fuel technologies have the highest emission factors, with natural gas about half as much as coal or lignite and two thirds of the estimate for fuel oil. Nuclear, hydropower, and especially wind power, on the other hand, have the lowest GHG releases, 50 to 100 times lower than coal (depending on the technology). GHG emissions from solar power are in between, about an order of magnitude higher than nuclear or wind. As shown in the figure, most GHG emissions from the power sector occur when electricity is generated at a power plant ("stack emissions"). But various upstream and downstream activities, from mining fuel to decommissioning old power plants, add to the emission total.*

Substituting a single nuclear power plant for a coal fired power plant (assuming each has a capacity of 1000 MW(e) and an 80% load factor) would avoid stack emissions of 1.3-2.2 million tonnes of carbon (Mt C) annually (depending on both the quality of coal and the power plant technology.) The high end of this range is typical for developing countries with inexpensive domestic coal deposits, while the low end represents coal importing industrialized countries with strict air quality requirements. Over a normal 40-year plant lifetime, total avoided emissions would equal 50-90 Mt C. Substituting nuclear power for natural gas would avoid GHG emissions of 0.6-1.0 Mt C per year for a 1000 MW(e) plant, or 24-40 Mt C over 40 years.

To estimate nuclear power's global carbon mitigation potential, the above numbers have been combined with the OECD International Energy Agency's (IEA) projections of the future electricity generating mix (IEA, 1998). The IEA's business-as-usual scenario projects that 3000 GW(e) of new generating capacity will be needed by 2020, and that an additional 600 GW(e) of existing aging capacity will have to be replaced. Using the IEA's projected electricity generating mix, this translates into total global GHG emissions of 4.0 Gt C in 2020, 2.2 Gt C of which are from Annex I countries. In 2010, the mid-point of the Kyoto commitment window, total projected GHG emissions are 3.2 Gt C, 1.9 Gt C of which are from Annex I countries.

The Kyoto Protocol's required 5.2% emission reduction for Annex I countries translates into emissions that are about 200 Mt C below their 1990 level[5]. If the power sector were to take a proportionate share of the reduction commitment, this would mean a cut of almost 500 Mt C from the projected emissions for the power sector in 2010.

– If Annex I countries were to substitute nuclear power for 20% of all fossil-fired power plant construction (for both new and replacement capacity) projected in the IEA business-as-usual scenario through 2010, and for 50% of fossil-fired power plant construction between 2011 and 2020, this would avoid carbon emissions of 90 Mt C in 2010 and 404 Mt C in 2020[6].

5 Based on IEA (1998) and information from 34 Annex I Parties that submitted their first national communications on or before 11 December 1997, as compiled by the UNFCCC Secretariat documents A/AC.237/81, FCCC/CP/1996/12/Add.2, and FCCC/SB/1997/6.

6 Based on thermal efficiencies (LHV) for coal of 45% in 2010 and 50% in 2020. Current new coal power plants in the USA have thermal efficiencies of approximately 40% (EIA, 1999). The corresponding efficiencies for natural gas are 55% and 60%. For current new combined cycle turbines in the USA the value is around 48%.

- Extending the calculation to non-Annex I countries, where nuclear substitutions might be partly financed as CDM projects, results in additional reductions of 97 Mt C in 2010 and 442 Mt C in 2020.
- Therefore, relative to the IEA's business-as-usual scenario, nuclear power has the potential to reduce emissions in 2010 by almost 190 Mt C or about 40% of the power sector's proportionate share of required emission reductions[7].

Over the complete 2008-2012 commitment window, the above calculations would result in a cumulative mitigation potential of approximately 935 Mt C for nuclear power. By comparison, substituting natural gas for coal would reduce emissions by only 300 Mt C.

Thus, although nuclear power is no more able than other mitigation options to single-handedly provide all the GHG reductions called for in the Kyoto Protocol, it can make a substantial contribution under a plausible expansion scenario — for example, at no time in the previous scenario would nuclear power plant construction rates exceed their peak historical value from the 1970s.

Cost Effectiveness, Safety, Waste Management, and Non-Proliferation

The electric power industry is a competitive industry, and is becoming ever more so as electricity markets are liberalized. For the nuclear industry, the top priorities include reducing costs while steadily improving safety, demonstrating waste disposal technologies that gain sufficient public support, and developing proliferation resistance to strengthen political and public acceptance.

Cost reductions involve, first, steady improvements in existing operations and technology. Progress in operational practices, engineering support, strategic management, fuel supply, and spent fuel disposition all lead to cost reductions, improved efficiency, and improved safety. During the 1990s, such collective improvements at nuclear power plants increased available power

[7] Given current cost ranges for different power plant technologies, substituting nuclear power plants for fossil-fired power plants as described above works out to carbon mitigation costs ranging from slightly below zero to almost US$ 100/t C.

supply by 28 GW(e), the equivalent of building 28 new 1000 MW(e) plants. The greater challenge for the nuclear industry today is to reduce new nuclear power plant construction costs. Possibilities include innovative designs that are simpler and safer; that use on-site construction with factory built structures, components, and complete modular units for fast installation; that rely more on passive safety features; and that allow for smaller units to accommodate both liberalized electricity markets and smaller electricity grids in developing countries.

A strong focus on safety within the nuclear industry was one outcome of the 1986 accident at Chernobyl. Although Chernobyl represented an exceptional situation, numerous lessons were learned, particularly concerning the human role in plant operation. Since the accident, the industry response has resulted in steady improvements in nuclear safety and performance, although there is still work to do in upgrading certain specific facilities. New reactor designs seek to continue this trend through design simplification and a greater reliance on passive safety features. On the regulatory side, INSAG 12[8] suggests streamlined safety requirements that focus on results (no off-site exposure of the general public in the event of an accident) rather than on procedures. Generally, cost-effectiveness and safety now go hand-in-hand — investors would not back a plant that is unprofitable, and regulators would not approve a plant that is unsafe.

All energy production chains generate waste — sometimes, as in the manufacture of solar photvoltaics, quite toxic wastes (IAEA, 1997). For nuclear power, the principal concern is radioactive waste. The amounts produced are relatively small, which makes it possible to manage nuclear waste through a confinement strategy. By contrast, the larger amounts of waste produced from fossil fuel combustion, including GHGs, toxic gases, particulates and heavy metals, make a dispersion strategy — diluting and releasing wastes to the environment — the most economic approach.

The bulk of the waste from nuclear power plants has low or intermediate radiation levels. Much of this waste is easy to manage and, because of its low radioactivity, requires simple or no shielding during handling or transportation. It can be disposed of near the surface, and radiation levels decay by a factor of 100, to natural background levels, within about 200 years.

8 The International Nuclear Safety Advisory Group (INSAG) advises the Director General of the IAEA in the fields of nuclear safety, radiation safety, and the safety of radioactive waste. The Advisory Group's 12th report (INSAG 12) was published in 1999 and is entitled "Basic Safety Principles for Nuclear Power Plants, Revision 1".

High level radioactive waste, resulting mostly from spent or used fuel, is the smallest proportion of nuclear waste, but it can remain radioactive over thousands of years and therefore requires appropriate disposal in order to isolate it from the environment. About 30 tonnes of spent fuel are discharged annually from a 1000 MW(e) power plant. The total accumulated spent fuel discharged worldwide through the end of 1999 is approximately 220 000 tonnes. Of this, about 75 000 tonnes have been reprocessed for reuse, leaving some 145 000 still to be disposed of, or reprocessed, after a cooling-off period in storage ponds (IAEA, 2000).

The scientific and technical communities generally agree that high level wastes or spent fuel can be disposed of safely in stable geologic formations. But in most countries developing such facilities, site selection is a major political issue, and no commercial facility has yet been authorized. The one operating disposal site for high level radioactive waste, the Waste Isolation Pilot Plant in New Mexico, USA opened in March 1999. Other countries are making progress. Belgium, Canada, Finland, France, Japan, Sweden and Switzerland are currently engaged in deep disposal studies. In Sweden, six municipalities have expressed interest in being the site for a national high level waste repository. In each case, early and continuing public involvement is essential if the process is to reach a generally acceptable solution.

Security of nuclear material is also important. In addition to the Treaty on Non-Proliferation of Nuclear Weapons, related IAEA safeguards, and export controls on nuclear materials, new reactor and fuel cycle designs can facilitate activities to safeguard nuclear material. They can make the technology more proliferation resistant by reducing the use of, and the need for, highly enriched fuel in commercial reactors, or by precluding the use of these materials for anything other than reactor fuel. Operationally, new designs that do a better job of taking into account the verification requirements of safeguards can enhance the effectiveness of the full International Atomic Energy Agency (IAEA) safeguards regime.

Summary

Today, the nuclear power industry is an established, experienced industry that generates one sixth of the world's electricity, one fifth of the USA's, and almost one third of Western Europe's. The recent SRES scenarios highlight that, even in the absence of policies to limit GHG emissions, meeting the energy needs and economic development aspirations of the 21st century will require the full range of energy supply options available including nuclear power. None of the world's available energy supplies should be excluded.

Fossil, nuclear, and renewable resources are all large, and the future evolution of the world's energy system is less likely to be determined by resource constraints than by active choices made by governments, the private sector, and individuals.

Nuclear power has the potential to fill a substantial part of the gap between where emissions from Annex I countries are now headed, and where they are required to be in 2008-2012 according to the Kyoto Protocol. If the CDM is taken into account, nuclear power's potential approximately doubles. And if the path charted by the Kyoto Protocol is to continue beyond the 2008-2012 commitment window, the potential importance of nuclear power only grows.

The best chance for sustainable development — for meeting the needs of the present generation without compromising the ability of future generations to meet their needs — lies in allowing all energy supply options to compete, improve, and contribute on a level playing field directly on the basis of cost-effectiveness, environmental protection, and safety.

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