ICONE 13
Thirteenth International Conference on Nuclear Engineering

THE 13TH INTERNATIONAL CONFERENCE ON NUCLEAR ENGINEERING

May 16-20, 2005 Beijing, China

ABSTRACTS

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内 容 简 介

“第十三届国际核工程大会”于2005年5月在北京召开，会议由中国核学会、美国机械工程师学会、日本机械工程师学会共同主办。国际核工程大会始于1991年，已轮流在美国、日本和法国连续举办了12届，是国际核工程领域最具影响的大会。在北京召开的这次会议，为中外核工程领域的专家交流最新技术和信息提供了一个重要的平台。该文集收录了经国内外专家评审后入选的论文，适合于相关领域学者和工程技术人员以及学生阅读、参考。

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NUCLEAR ENERGY -AN ESSENTIAL OPTION FOR SUSTAINABLE DEVELOPMENT OF GLOBAL ECONOMY

Tokio Kanoh
Member, House of Councilors, Japan

FOREWORD

I would like to offer my heart-felt congratulations on the opening of the 13th ICONE conference, the first ICONE conference ever to meet in Beijing, China. If I may, let me start off by putting the conclusion first of my presentation today, which is: Increased use of nuclear energy is an essential option for us to take the sustainable development of the global economy. I would like to present some facts to support that position.

1 CHINA TO EXCEED THE USA IN OIL DEMAND (CHART 1)

Chart 1 has population horizontally and per capita annual oil consumption (unit consumption) vertically. Multiplying per capita consumption by population, you get total amounts of oil consumption by country as represented by sizes of circles as shown in the chart.

As of 2002 the USA was by far the largest oil consumer of all countries in the world, consuming about one billion tons of oil yearly, or approximately one fourth of the total oil consumption of the world, while its population accounted for only 4.5% of the global population but what made a difference was the huge number of the unit consumption which stood at 3.4 tons, or nearly six times as much as the world average.

In contrast, China has a population of 1.3 billion, or about 20% of the global population, but its per capita oil consumption is only 0.2 tons, or one tenth of Japan and one seventeenth of the USA, adding up to 258 million tons in total, way below those of other major countries. (C_0)

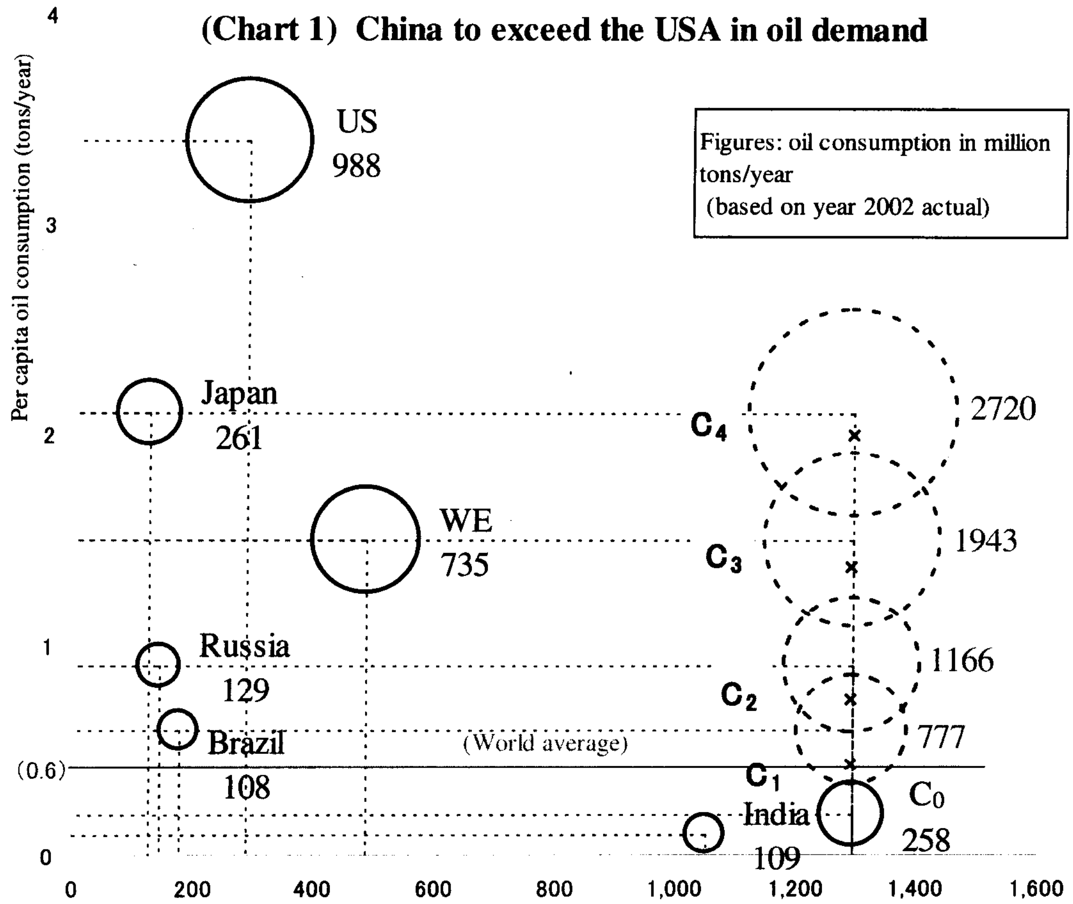
The recent economic growth of China is remarkable and it is expected to continue to fuel industrial development, raise people's standards of living and accelerate motorization, all these combining inevitably to increase per capita consumptions of oil and other energies. Assuming no change to take place in the present population size of 1.3 billion, when China's per capita oil consumption reaches the current world's average of 0.6 tons which is comparable to that of Brazil, its total oil consumption will come to 777 million tons to exceed the total consumption of all West European countries put together, that is 735 million tons. (C_1)

Similarly, when China's per capita oil consumption catches up to present Russia at 0.9 tons, its total oil consumption will far exceed that of the USA today, i.e., 988 million tons, to make China the world's largest oil consuming country. (C_2).

Furthermore, when this per capita figure goes on to the present level of European countries, or 1.5 tons, its total will jump to double the current total oil consumption of the USA (C_3) and close to triple, at Japan's current per capita level of 2.1 tons (C_4). China then will emerge as an incredibly huge consumer of oil.

China is only one example. Look at India where its population is on a sharp rise topping by now one billion and it is expected for sure to catch up and get ahead of China to become the world's most populous country before long. Chart 1 focuses on oil but the same thing can happen to other sources of energies and carbon dioxide emissions as well.

(Chart 1) China to exceed the USA in oil demand



Source: DOE/IEA data, converted to tons oil equivalents
Chart: Office of Tokio Kanoh

Obviously each and every developing country is entitled to its own growth and development and it is their inherent right which no industrially developed countries are allowed to infringe by obstructing their growth in any way. At the same time, we should realize that both of us, developed and developing, are rowing the same boat. This chart shows the need for measures to achieve the dual goal of helping the growth of developing countries on one hand while ensuring energy security and environmental conservation on a global scale on the other without letting one disrupt the other.

2 POST-KYOTO PROTOCOL CHALLENGES (CHARTS 2 AND 3)

On February 16 of this year, the Kyoto Protocol based on the Framework Convention on Climate Change took effect after Russia ratified the accord clearing the 55% requirement of carbon dioxide and other greenhouse gas emissions from Annex I countries.

There is growing concern about climate change due to increasing emissions of greenhouse gases (GHG) consisting mainly of carbon dioxide, in view of a high incidence of natural disasters like torrential rain, hurricanes, droughts, unusually high temperatures, high tides, as witnessed frequently in many parts of the world in recent years.

There is agreement in general on the need to prevent climate change but one wonders if the Kyoto Protocol, now in place but as it is, can be an answer to it. There are questions about its effectiveness.

The first question about the accord is that major carbon dioxide emitting countries are not participating. Chart 2 shows the shares of carbon dioxide emissions by country. Individual countries are compared and listed below according to their performance in a manner of the Olympic Games.

(Emitting Race)

		CO_2 emissions share	Kyoto Protocol.
Gold medalist	USA	24%	Pulled out
Silver	China	13%	Not signatory
Bronze	Russia	7%	Ratified
4th winner	Japan	5%	Ratified
5th	India	4%	Not signatory

The above listed five countries alone account for 53% of CO_2 emissions of the whole world. The USA having withdrawn itself from the accord and India and China not being signatories, the Kyoto Protocol was ratified by Russia and Japan, which together represented only 12% of share.

It is vitally important at this stage to introduce a new framework that involves more developing countries led by China and India, ranking winners of this emitting race, not to mention the USA, the gold medalist, that is, the world's biggest emitter.

A second question relates to the effectiveness of the Kyoto Mechanism. The mechanism has the clean-development mechanism, or CDM, as part of it, which is designed to encourage developed countries to help developing countries in their efforts to reduce carbon dioxide emissions and, in return, to reward them, when successful, by sharing the resulting benefits. Investment to be made in developing countries under this formula is expected to be far more effective than if made domestically for the same purpose. CDM, however, does not apply to nuclear energy due to the opposition of anti-nuclear environmentalists in Europe. This is clearly a case of inconsistency and therefore should be corrected by making nuclear energy applicable to this scheme.

A third question concerns the Kyoto Protocol itself. The protocol aims to reducing GHG emissions to stated levels between 2008 and 2012 from 1990 levels as a base. But it must be noted here that there are significant differences among countries in levels of efforts made prior to 1990. Namely, in some countries, per capita GHG emissions had been greatly reduced by 1990 thanks to their strenuous efforts to save energy and shift emphasis to nuclear energy while in others per capita emissions remained still at high levels due to low energy efficiency prevailing in practice with energy conversion from coal to natural gas yet to be fully implemented at this point in time. And it is not fair to set the target limits across the board without taking such differences between countries fully into account though there are slight differences, if any, in rates.

Instead, it should be more practical to let individual countries set their own targets in terms of GHG emissions per GDP, for example, with developed countries respecting the 'pledge and review' process and developing countries pushing for more voluntary efforts.

Chart 3 shows correlation between economic growth and carbon dioxide emissions. From the chart can be seen a broad trend in which carbon dioxide emissions per GDP decrease as the economy grows. At a closer look, interestingly enough, the chart shows two distinct groups of countries separated by the trend line, one group appearing above the line and the other group below the line. What separate these two groups are the differences in:

-automotive oil consumption due to sizes of land area, and

-additionally,

-development of public mass transit systems,
-application and promotion of energy saving technologies,
-types of fuels for power generation and their shares.

It is hoped that efforts to reduce carbon dioxide emissions per GDP will be planned realistically by taking into consideration such conditions that are particular to the respective countries.

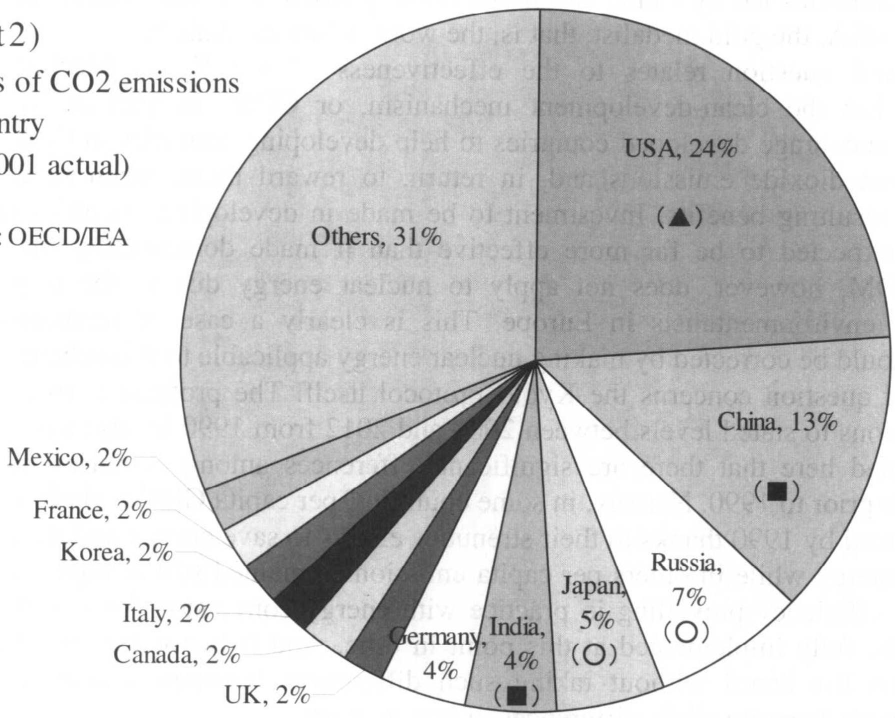
3 DE-CARBONIZATION (CHARTS 4 AND 5)

Chart 4 shows carbon dioxide emissions as related to power generation fuel structures. There are two things that can be seen from the chart.

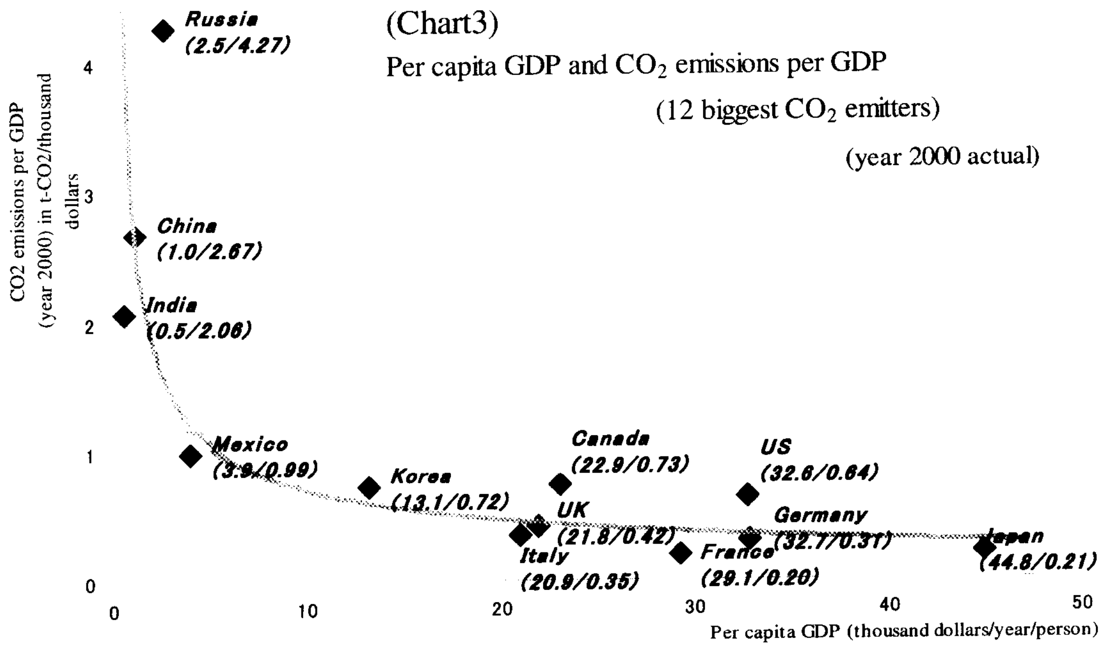
One is the presence of distinct reverse correlation between per capita carbon dioxide emissions and shares of non-fossil fuels in a fuel structure. From this perspective, increased use of natural and renewable energies such as hydro should be encouraged for countries with such resources in ample supply and, by the same token, nuclear power for those countries with advanced technological capabilities. By doing so, the positions on the chart will improve in a direction from upper-left to lower-right along the trend line.

(Chart2)
Shares of CO2 emissions by country (year 2001 actual)

Source: OECD/IEA



Note: Top five countries account for 53% of the world's total CO2 emissions. Of the five, two (O) ratified the Kyoto Protocol, representing 12% and three (two Non Signatory (■), one Pulled Out (▲)) account for 41%.



Source: OECD/IEA data Chart: Office of Tokio Kanoh

Secondly, you can see on the chart two groups of countries separated by the trend line. Countries with similar non-fossil fuel shares may have different per capita carbon dioxide emissions because they are different in:

-shares of coal, oil and natural gas in fossil fuels, and

-thermal efficiency of power plants.

Therefore, in terms of fossil fuels, thermal efficiency should be improved by converting fuel sources from coal to natural gas and also by adopting ACC (advanced combined cycle).

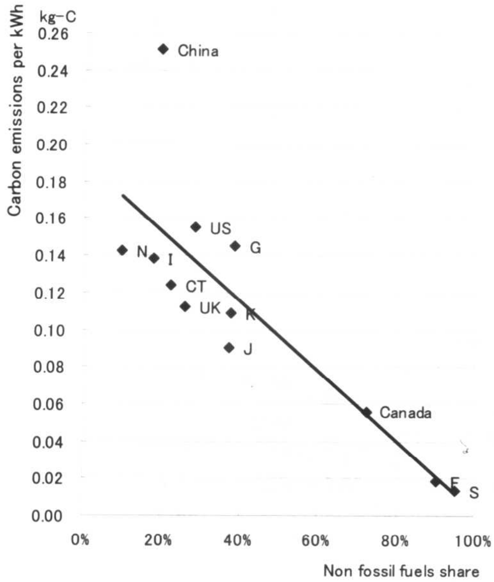
There are some among anti-nuclear people who argue: "They say nuclear power does not produce carbon dioxide but it's not true. It takes energies to build a nuclear power plant and to dispose of radioactive waste, and those energies include fossil fuels."

Chart 5 is to make the case against such argument. The chart shows carbon dioxide emissions produced throughout the entire process not only of operating stages but of its 'life cycle' from nuclear fuel material exploration, building of facilities to disposal of radioactive waste, as compared with other types of power generation. It can be readily seen from the chart that the unit carbon dioxide consumption of nuclear power is extremely small as small as hydro and geothermal, and only 1/20 to 1/40 of fossil fueled power generation.

4 ERA OF HYDROGEN TO COME (CHART 6)

Hydrogen is drawing much attention as a new energy source of great promise. The development of fuel-cell powered motor vehicles is getting under way in full gear, using hydrogen as an energy source to replace traditional gasoline and light oil, i.e., the oil products that have served exclusively as fuels for motor vehicles for over one hundred years. Research and development is also under way for possible applications of fuel cells not only for transportation but in areas like energy systems for housing and commercial buildings and, coupled with nano-technology, for PCs and other electronic equipment.

(Chart4) Reverse correlation between non-fossil fuels share and per capita CO2 consumption



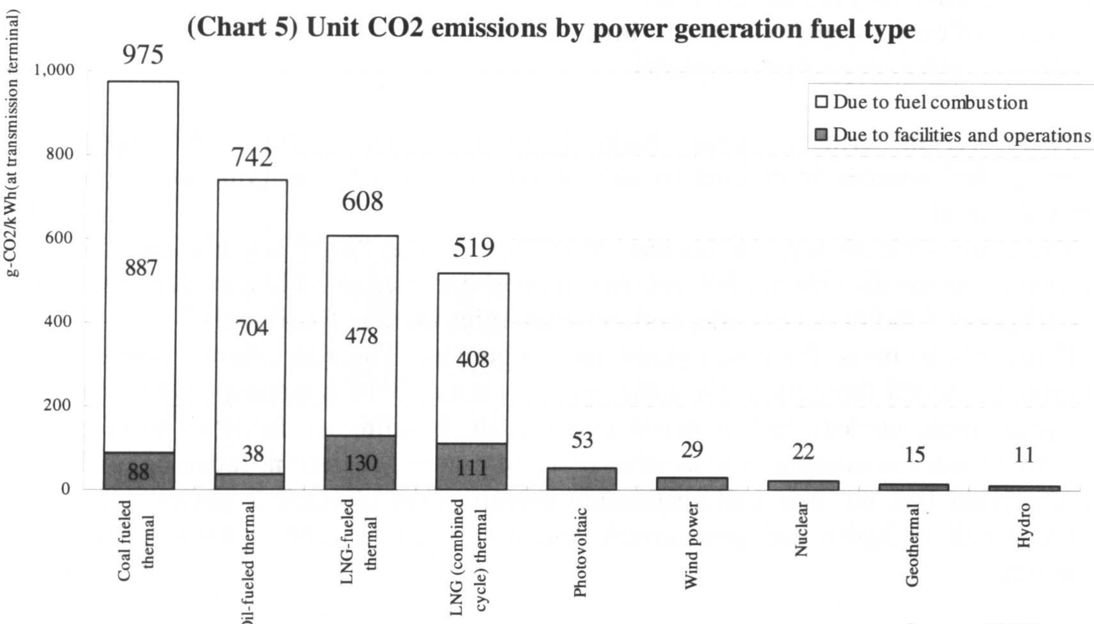
(Shares of non fossil fuels) As of year 2002

	Nuclear power	Hydro,etc *	Total
U.S.A	20.1	8.3	28.4
U.K.	22.9	3.0	25.9
Germany	29.1	9.2	38.3
France	78.7	11.7	90.4
Itary	0.0	18.0	18.0
Canada	12.6	59.7	72.3
Japan	27.1	10.3	37.4
Netherlands	4.1	5.6	9.7
Sweden	46.3	48.7	95.0
Korea	36.4	1.2	37.7
Chinese Taipei	19.1	3.1	22.2
China	1.5	17.7	19.2

*: Hydro, Geothermal, Combust. Renew.&Waste

Chart: Office of Tokio Kanoh
Source: Energy Balances of OECD/Non-OECD Countries 2001-2002, IEA
CO2 Emissions from Fuel Combustion 2001-2002, IEA

(Chart 5) Unit CO2 emissions by power generation fuel type



Source: CRIEPI

Chart 6 proposes a concept of an energy system in which hydrogen and electricity serve as secondary energies with similar traits that enable them to share many applications with each other. Both are CO_2-free and therefore clean. Both can be generated either from fossil fuels such as crude oil, coal and natural gas, or from natural and renewable sources and nuclear power (uranium) as well, thus sharing the same primary energy sources. In addition, they are convertible from one to the other. By using non-fossil fuels for primary sources, it becomes possible to create a totally clean energy system in which both primary and secondary energies are clean.

In the era of hydrogen, nuclear power can contribute in two ways. One is hydrogen production by electrolysis of water in conventional light water reactors powered by less costly late night electricity and the other by paralysis using high temperature gas produced in a High Temperature Testing Reactor (HTTR). The Japan Atomic Energy Research Institute (JAERI) has successfully produced hydrogen by paralysis of water using 900° C gas in the High Temperature Testing Reactor. The GIF, an international forum for research and development of fourth generation nuclear reactors, launched by the initiative of the US Department of Energy, has chosen the Very-High Temperature Reactor, or VHTR, for its development project with Japan, USA, and France as lead promoters, with a view to hydrogen production by nuclear power.

For all that, many challenges lie ahead on the road to the hydrogen energy based society. But issues to be dealt with pertaining to hydrogen are being identified in terms of its production, transportation, storage, applications and regulations, to permit a realistic approach to these efforts.

5 CO_2 EMISSIONS TO BE REDUCED 40% BY INCREASED USE OF NUCLEAR POWER (CHARTS 7, 8 AND 9)

In November 2004, the reactor development committee of the JAIF released 'Nuclear Power: 'Visions and Road Map to 2050.' As far as it concerns Japan, the road map is highly ambitious as it is informative. Chart 7 shows its visions of energy consumption in the specific sectors, i.e., private, transportation and industry as development and diffusion of energy conservation technologies and fuel conversion advance. Their projections include:

- End energy consumption in 2050 will be reduced to 1990 levels,
- Share of oil will fall from present 50% to 23%,
- Weight of electricity will increase substantially from 24% to 31% as electrification further advances,
- Natural gas will increase its share to 25%, and
- Hydrogen will start increasing around 2030 to reach 11% by 2050 and, combined with electricity, 42%.

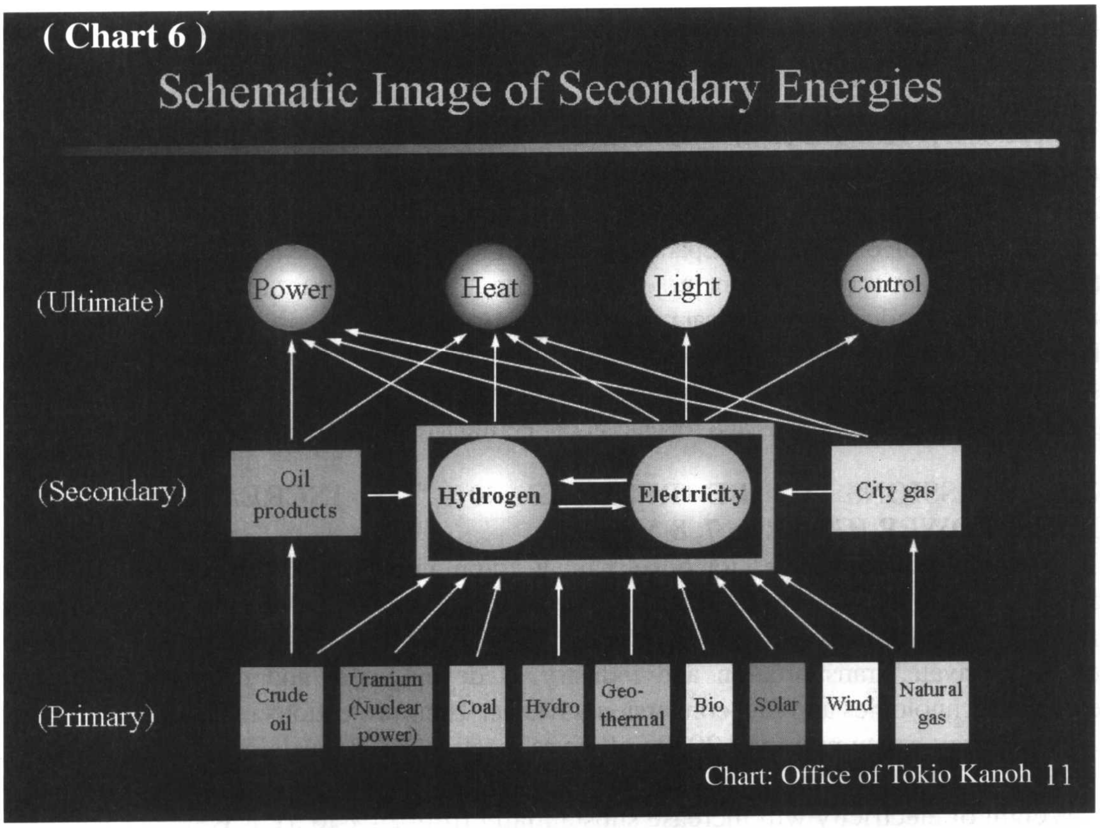
Electric power consumption will increase nearly 50% from 1990 to 2050. What is striking about this projection is types of fuels in use for power generation at that time which will consist of 60% nuclear, 10% hydro and 10% of other renewable energies as shown in Chart 8. In other words, nearly 80% of fuels will be non-fossil sources.

Chart 9 shows what happens to carbon dioxide emissions as nuclear power increases its use as assumed above. These projections are based on increasingly wide use of nuclear power in the coming years, which is expected to double the present output to 90 million kW by 2050 with high temperature nuclear reactors for hydrogen production coming into practical use around 2020 and producing 20 million kW (thermal output) by 2050.

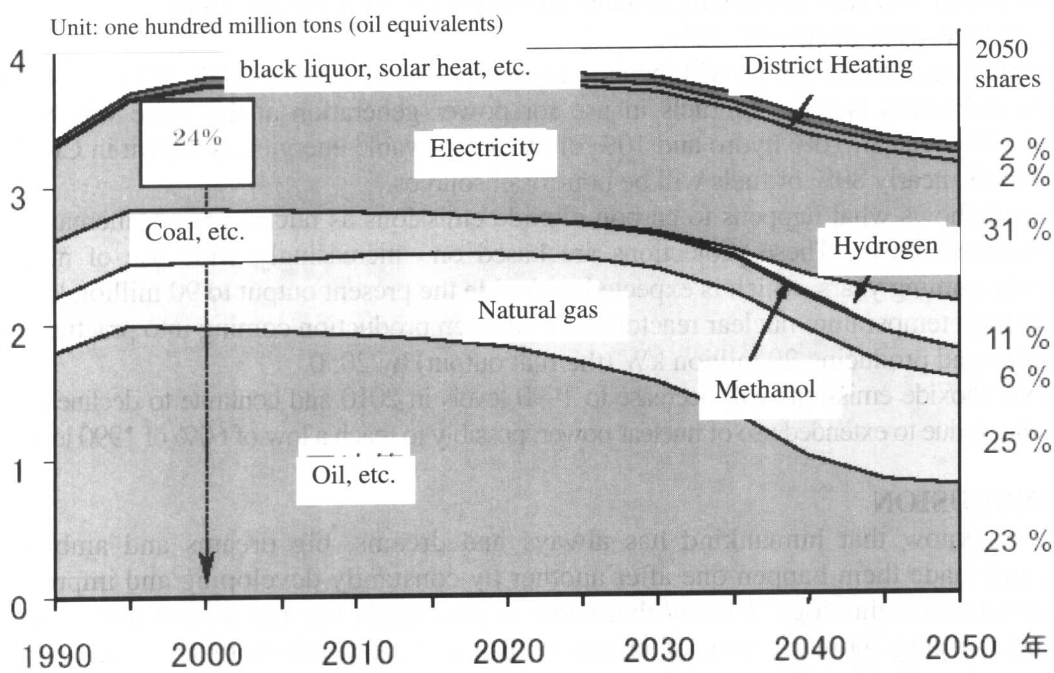
Carbon dioxide emissions will decrease to 1990 levels in 2010 and continue to decline every year thereafter, due to extended use of nuclear power, possibly to reach a low of 60% of 1990 levels.

6 CONCLUSION

We all know that humankind has always had dreams, big dreams and ambitious dreams, and made them happen one after another by constantly developing and improving their science and technology. I know that some of you might say my proposition is just a dream and nothing more by way of criticism. But I firmly believe that it's certainly a dream but the dream will come true for sure through our efforts of research and development and pursuit of the right policy options. The key to materializing this dream is held by nuclear power. Nuclear power is the option we need to pursue the sustainable development of the global economy.

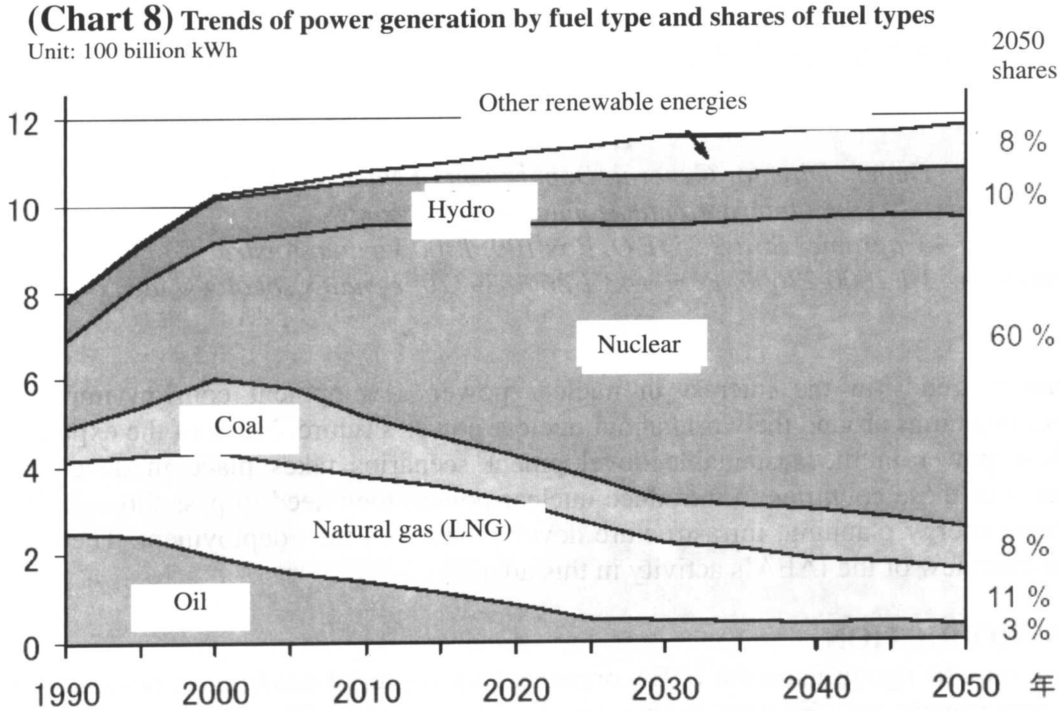


(Chart 7) Trends of end energy consumptions by energy type



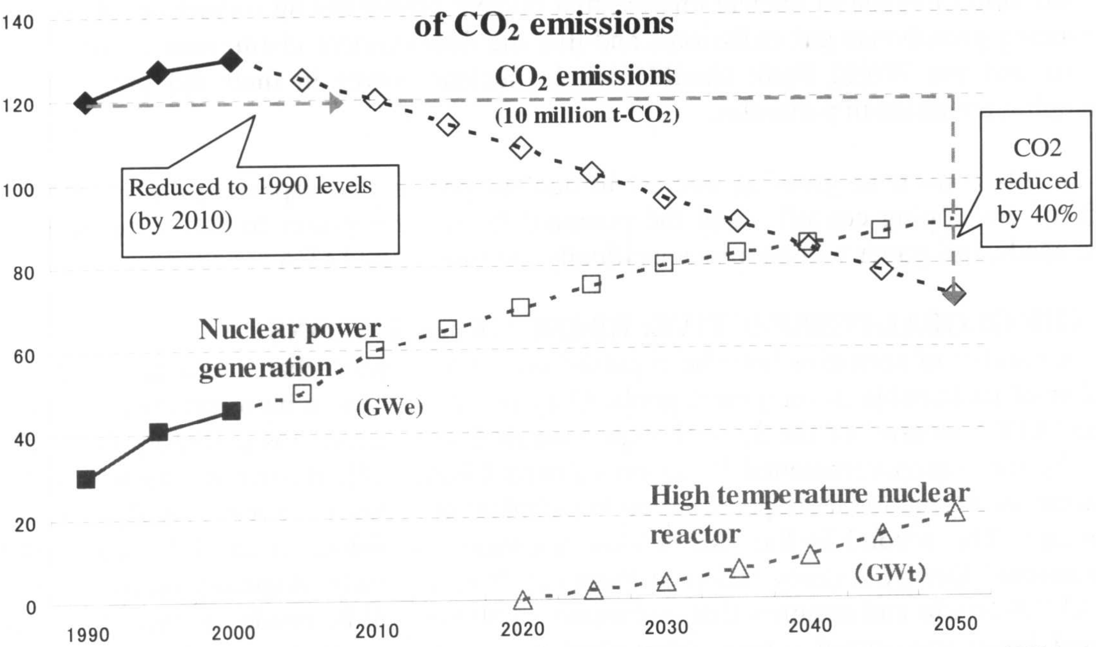
Source: JAIF, Nuclear Reactor Development/Utilization Committee, 'Nuclear Power: Visions and Road Map to 2050', November, 2004

(Chart 8) Trends of power generation by fuel type and shares of fuel types
Unit: 100 billion kWh



Source: JAIF, Nuclear Reactor Development/Utilization Committee, 'Nuclear Power: Visions and Road Map to 2050', November, 2004

(Chart 9) Increased use of nuclear power and reduction of CO_2 emissions



Source: JAIF, Nuclear Reactor Development/Utilization Committee, 'Nuclear Power: Visions and Road Map to 2050,' November, 2004

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NUCLEAR POWER IN THE DEVELOPING WORLD

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Current trends in the interest in nuclear power development confirm important changes in opinions around the world about nuclear power's future. Much of the expansion of nuclear power in the sustainable development scenarios takes place in developing countries. For these countries to introduce nuclear power, they need to pass through three main steps: energy planning, infrastructure development and then deployment. The paper gives an overview of the IAEA's activity in this area.

1 INTRODUCTION

Two months ago in Paris the IAEA organized a ministerial conference, hosted by the French government, on "Nuclear Energy for the 21st century". The conference analysed current trends in the global expansion of nuclear power and confirmed important changes in opinions around the world about nuclear power's future. The President of the Conference Mr. Patrick Devedjian, France's Minister-Delegate for Industry, concluded in his final statement that the broad participation in the conference was a clear signal of renewed world interest in nuclear energy, that nuclear power has an important role to play in reducing greenhouse gas emissions, and that the development institutions of the United Nations and the World Bank should include nuclear power in their aid program, for developing countries in particular.

In this context of growing interest in nuclear power, and especially in the pressing needs of developing countries and the potential for nuclear power to help meet some of those needs, this paper will address specifically the role of the IAEA.

2 THE GLOBAL PERSPECTIVE: RISING EXPECTATIONS

A number of scenarios have been published in recent years that would largely meet a number of sustainable development goals. Only two of them will be mentioned here. One is the 'A1T Scenario' of the Special Report on Emissions Scenarios (SRES) published in 2000 by the Intergovernmental Panel on Climate Change [1]. It assumes strong positive advances in international cooperation, rapid technical progress and a low global population trajectory. The second is the 'SD Vision Scenario' published in 2003 by the OECD International Energy Agency (IEA) in Paris [2]. It is less technologically optimistic than the A1T Scenario and assumes that government policies will be needed to push the world beyond business-as-usual trends. In particular, it assumes policies are implemented to stabilize the atmospheric concentration of greenhouse gases, to diversify the energy mix away from oil and to assure access to affordable electricity by at least 95% of the world's population by 2050.

Figure 1 shows the primary energy supply mix for the two scenarios through 2050. For nuclear energy the significant result is that both scenarios project global growth in nuclear energy by a factor of 14, to approximately 5000 GW(e) in 2050. In both cases, the main centre of growth is expected to be the developing countries of Asia.

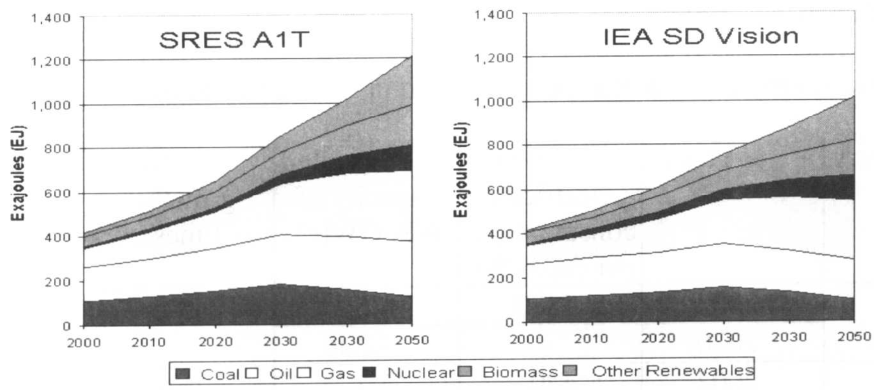

Figure 1. Primary energy supply mix through 2050 in two sustainable development scenarios.

In principal nuclear power is technically available to fulfil such a role. But, in reality, it is not expected to happen immediately. Rather, medium-term, more business-as-usual projections for nuclear power are much lower. Figure 2 shows the IAEA's latest projections through 2030 [3]. The low projection (dark green bars) assumes no new nuclear power plants beyond what is already being built or firmly planned, plus the retirement of old nuclear power plants on schedule. The high projection (light green bars) takes into account additional reasonable new proposals. The medium term projections in 2030 are 2-3 times lower than in the sustainable development scenarios in Figure 1. Thus a significant gap exists between the ambitions of sustainable development and the reality of business-as-usual policies.

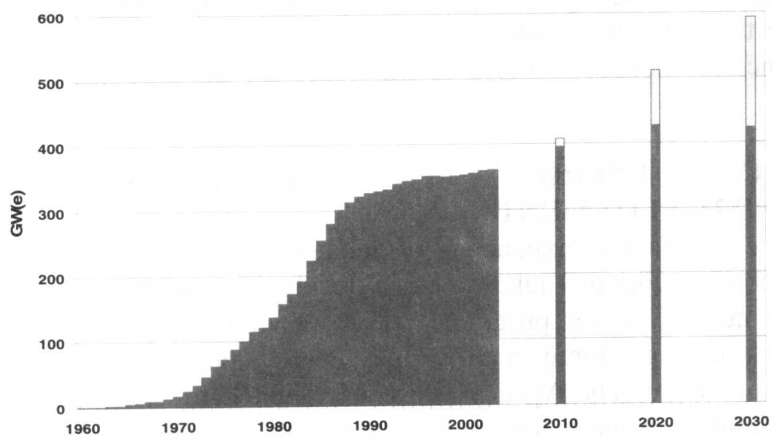

Figure 2. Global nuclear power capacity and IAEA projections through 2030.

There are different explanations, and their relative importance differs among countries. In developing countries these include lack of funds and infrastructure; in developed countries, public acceptance, changing regulatory requirements and investment risk; and for both categories, a lack of flexibility in nuclear power plant designs to meet diverse requirements, the need to manage wastes and others.

Table 1 shifts the perspective from global aggregates to specific countries and presents their national short-term nuclear power projections. The greatest projected growth is in the countries where annual electricity consumption per capita is currently small: China, India, and Pakistan.

Table 1. Projected nuclear power growth in selected countries.

Country	Years	Annual electricity consumption, per cap, kWh	Installed capacity of NP, GW(e)	NP growth, times
China	2002	1380	6,6	5-6
	2020		32-40	
India	2002	420	2,7	10
	2022		29	
Pakistan	2002	480	0,42	10
	2030		4,2	
Russia	2002	5370	22	2
	2020		40-45	
ROK	2005	6190	16,8	1,57
	2015		26,4	
USA	2002	12320	~ 100	~1,1 ?
	2020		~ 110	

In addition to these countries that already have their nuclear power programmes well underway, there is significant potential in countries that are now at the planning stage. Particularly for these countries, nuclear power is technologically ready to help meet energy requirements and reduce the risks of climate change, but these countries have additional needs. Time and assistance are needed to build up the necessary infrastructure, expertise and institutional support.

3 IAEA ASSISTANCE: ENERGY PLANNING, INFRASTRUCTURE DEVELOPMENT AND DEPLOYMENT

Again, much of the substantial expansion of nuclear power in the sustainable development scenarios shown in Figure 1 takes place in developing countries, a number of which do not now have nuclear power programs. For a country to introduce nuclear power, it needs to pass through three main steps: energy planning, infrastructure development and then deployment. The Agency assists Member States with each of these steps. It provides tools and assistance for energy planning; it supports infrastructure development; it provides support for effective deployment once a deployment decision has been made; and it also provides a forum for assessing innovative nuclear energy systems (INSs) as a part of the Agency's International Project on Innovative Nuclear Reactors and Fuel Cycles (INPRO).

With respect to energy planning, the IAEA helps interested Member States, often developing country Member States, build their capabilities for energy planning and analyzing energy systems. The Agency develops and transfers planning models tailored to the special circumstances of these countries. It transfers the latest data on technologies, resources and economics. It trains local experts. It jointly analyzes national options and interprets results. And it helps establish the continuing local planning expertise necessary to chart national paths to sustainable development. The IAEA is the only UN agency doing this kind of capacity building for overall energy-environment planning.

Table 2 summarizes the basic energy models the Agency has available for transfer and training. There are four basic mechanisms for transferring the models and for capacity building in general: (1) technical cooperation projects, (2) coordinated research projects, (3) regional and national workshops and training courses, and (4) the so-called 'Type-2 Partnerships', emanating from the 2002 World Summit on Sustainable Development (WSSD).

Table 2. Principal IAEA energy analysis models

Model	Full name	Description
MAED	Model for Analysis of Energy Demand	Evaluates future energy needs based on development scenarios in a country or region
WASP	Wien Automatic System Planning Package	Identifies the optimal long term expansion plan for a power generating system within constraints defined by the user
MESSAGE and ENPEP	Model of Energy Supply Systems and their General Environmental Impacts, and Energy and Power Evaluation Program	Formulate and evaluate alternative energy supply strategies for a country or region
FINPLAN	Model for Financial Analysis of Electric Sector Expansion Plans	Assess the financial viability of plans and projects
SIMPACTS	Simplified Approach for Estimating Impacts of Electricity Generation	Estimates environmental impacts and costs using minimum data input

Thirteen country studies were completed in the past year, in Bulgaria, China, Haiti, India, Indonesia, Republic of Korea, Lithuania, Mongolia, Nigeria, Pakistan, Philippines, Sri Lanka and Vietnam. In 2005 two new regional technical cooperation projects – one in Asia (with 13 countries) and another in Europe (three countries) – as well as five national projects: Azerbaijan, Columbia, Ghana, Guatemala and Nicaragua are being started.

The Agency also conducts regular inter-regional training workshops – held last year in the USA in partnership with the Argonne National Laboratory and in Europe at the International Centre for Theoretical Physics in Trieste – as well as regional training courses (two in 2004) and national training courses (nine in 2004) as well as 'training the trainers' courses. The number of people trained in these courses has risen steadily in recent years and last year reached a record high of 231 energy professionals from 43 countries. The number of countries using Agency models is now 102.

After energy system analysis and energy planning, the second category of IAEA assistance is infrastructure development, which can start with establishing the necessary