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Nuclear Power in the World Energy Outlook

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In this presentation, I shall discuss nuclear power in the context of the International Energy Agency's World Energy Outlook.[1] I shall also draw on the implications for nuclear power of three major energy policy issues: sustainability, climate change and electricity market competition. Those issues were addressed in detail in a recent IEA publication, entitled "Nuclear Power".[2]

The World Energy Outlook is a biannual publication of the IEA that provides key energy trend projections and discusses the main issues affecting world energy demand and supply over the medium term. The most recent edition was published in November 1998.

The analysis of global energy issues in this edition is done in the framework of a Business-as-Usual (BAU) projection and covers the time horizon to 2020. It assumes that patterns of energy demand and production carry on smoothly from the recent past. It also supposes that energy policies existing before the Kyoto Conference of December 1997 remain in place and that no new major policies are adopted to reduce energy-related greenhouse gases.

The analytical tool that is used to derive these projections is the World Energy Model (WEM). The model consists of a suite of regional modules that provide energy supply and demand balances for 10 world regions (of which three are in the OECD) for coal, oil, gas and electricity.

On the demand side, the model uses conventional econometric techniques, based on several economic indicators and fuel prices, to project future paths of energy use in all sectors. On the supply side, a power generation model built for each region allows us to determine the future mix of capacity and generation. The model uses least-cost criteria to determine the optimum fuel mix. For new plant, the choice is made based on levelised costs. Short-run costs are used to determine the merit order of existing plants.

A conventional oil supply model has been prepared that takes into account increases in recoverable reserves of conventional oil arising from the reduction in uncertainties over time as new information on oil reserves becomes available and from the application of new technologies. Gas and coal supplies are projected separately on a regional basis.

A key message of this outlook is that fossil fuels will continue to dominate the energy mix. Indeed, 95% of the additional energy demand between 1995 and

2020 will be met by fossil fuels. In absolute terms, some 92% of total primary energy demand in 2020 will be fossil-fuel based (see Figure 1).

The share of solid fuels, mostly coal, remains unchanged. Three quarters of additional demand for solid fuels will be in the power generation sector. Growth is fast in China and South Asia, which are expected to develop further their indigenous supplies of coal. Oil continues to be the dominant energy source. Most of the increase in oil demand will stem from additional demand for transportation.

Demand for gas increases fast, particularly in the OECD regions. Natural gas is the preferred fuel for many applications, especially for new power stations. Gas consumption nearly doubles over the outlook period.

World nuclear power remains almost static. During the outlook period, the retirement of several units will offset the increase in nuclear output from construction of new plants. Hydro power is expected to show moderate growth, with most of the increase coming from outside the OECD.

Finally, the use of other renewable energy sources increases steadily, but remains at low levels. Under BAU assumptions, the share of non-hydro renewables will be around 1% of the primary energy mix by 2020.

Our projections show that world energy demand could grow by 65% between 1995 and 2020. This is equivalent to an average annual rate of 2% over the projection period. Two-thirds of the increase in energy demand over the period 1995–2020 is in China and the other developing countries (see Figure 2). By 2020, China could be the second largest energy consuming region in the world, after North America.

A structural shift in the shares of different regions in world energy demand is, therefore, likely to occur, and the OECD share of world energy demand will fall. Electricity generation grows strongly in all regions, particularly in the developing world. Despite the high growth in developing countries — on average 4.5% per annum, compared with 2% in the OECD — electricity generation continues to be dominated by the OECD.

Coal is projected to retain a strong position in power generation. It is the favoured fuel where domestic resources exist and gas is unavailable or expensive. Coal-fired generation increases strongly in China and India as these two countries are expected to continue using their abundant coal resources (see Figure 3). Electricity generation from gas increases rapidly, at an annual average rate of 6% during the projection period. By 2020, gas becomes the second largest source of electricity, at a world level.

Within the OECD, gas-fired generation quadruples over the outlook period. Outside the OECD, gas is expected to be increasingly used in the Transition Economies, particularly in Russia. It will also grow in several countries in Eastern Europe where many of the existing inefficient coal-fired plants could be replaced by modern gas-fired plants. Strong growth in gas-fired generation is also expected for Latin America, East Asia, the Middle East and the northern part of Africa.

Some increase is expected in oil-based output. Oil will grow in use for standby or peaking plants and for use where seasonal variations in price make other fuels (especially gas) uncompetitive at certain times. Because of the relative ease and low cost of oil storage, it is an ideal generating fuel for remote locations where other fuels are difficult or costly to obtain.

World nuclear power increases slightly to 2010 and then starts declining. In the OECD, some new nuclear plants are expected to be built during the outlook period, for example, in Japan. At the same time, some plants will reach the end of their operational life, leading to an overall decline of nuclear power in the region. Many of these plants will be replaced by gas-fired combined cycle plants. Outside the OECD, growth could be higher, with nuclear power increasing in Asia and in the Transition Economies.

Hydro power is expected to increase moderately. Within the OECD, most of the sites have already been exploited and therefore growth is expected to be limited to 0.7% per annum. Developing regions endowed with hydro resources will increase the use of this energy form to generate more electricity. China and East Asia are the regions where growth in hydropower is expected to be the highest.

The use of other renewable energy sources increases steadily, but remains at low levels. Among the different forms of renewable energy (wind, geothermal, solar, tidal), generation from wind power is expected to make the largest contribution, particularly in the OECD.

As already mentioned, the power generation projections in the World Energy Outlook are produced using a least-cost approach that involves a lifetime least-cost calculation for the choice of new plant and a short-run least-cost calculation for dispatching existing plants. However, nuclear and renewables are not modelled using least-cost economic criteria. Because investment in such plants is frequently determined on a semi-political basis, and in the case of renewables costs are highly site- and country-specific, new nuclear and renewable capacities in the model are determined by assumption.

The projections of nuclear power presented here are based on information on construction of new plants collected from a variety of sources, including the International Atomic Energy Agency (IAEA), the OECD's Nuclear Energy Agency (NEA), the US Department of Energy's Energy Information Administration, the French Commissariat a l'Energie Atomique (CEA), national sources, and the business and trade press.

This information is then carefully assessed by the IEA secretariat, applying expert judgement, to determine how nuclear power will evolve in the future under BAU assumptions. Growth in nuclear power capacity is expected only in countries that have firm nuclear expansion plans.

At a world level, nuclear electricity generation in 2020 is expected to be at about the same level as in 1995, the base year of our projections (see Figure 4). However, the generation profiles across regions vary. In the OECD and in the Transition Economies, an overall decline in nuclear electricity generation is expected, especially after 2010, when many of the nuclear plants

that exist today reach the end of their life. Nuclear power increases in China and in other developing countries, and particularly in Asia (Korea, although an OECD member, is included for modelling purposes in East Asia).

Within the OECD, nuclear power declines significantly, as new plant build is limited and several nuclear reactors reach the end of their design life (see Figure 5). I should mention here that the World Energy Outlook assumes as a general rule a 40-year lifetime for existing nuclear plants, unless a different lifetime is given for specific plants.

The most dramatic decline is expected in North America, where some of the oldest plants are located. By 2020, nuclear electricity generation could shrink to half of today's level, and its share in total electricity generation could fall to one third of what it is presently.

In OECD Europe, the decline is less pronounced. A number of nuclear reactors have been completed recently, and a few more that are under construction will come on line over the next few years. Plant upgrades in some countries will also add extra capacity. The share of nuclear in the electricity generation mix is nevertheless projected to be halved by 2020.

In the OECD Pacific nuclear electricity generation increases substantially, because several new plants are constructed in Japan. The share of generation from nuclear increases. Retirements in this region are less important, since the nuclear growth here is fairly recent compared to OECD Europe and North America. Indeed, between 1990 and 1997 nuclear capacity in OECD Pacific increased by more than 40%.

The reasons for this decline of nuclear in most OECD countries are partly economic — competition from fossil fuels and notably natural gas in combined cycle gas turbines (CCGTs) — and partly political. Several OECD countries have policies (often enforced by law) to restrict nuclear power.

This illustrates the political aspect of the issue. Restrictions imposed by several OECD member governments are intended to prevent nuclear plant build or to shut down existing plants. For most of these countries the duration of the restrictions is indefinite. Australia, Austria, Denmark, Greece, Ireland and Norway do not have nuclear power and have restrictions on new plant construction. Italy shut down its nuclear plants in 1990. Poland discontinued the construction of a nuclear power plant. Belgium, Germany, Netherlands, Spain, Sweden and Switzerland all rely on nuclear power but have decided not to build new plants or intend to phase out nuclear power.

On the economic side of the issue, let me show you some results of the electricity generating cost study that was published jointly by the IEA and the OECD Nuclear Energy Agency in 1998.[3] In this study, 18 countries — most of them in the OECD — were invited to provide cost estimates for plants that will be commissioned in the medium term.

Figure 6 shows the number of countries in which the three main technologies considered in the study were cheapest by a margin of 10% or more. This was 10 or 11 countries out of a total of 18 countries providing data for two options. Results are given at 5% discount rate and at 10%. The results

confirm the current cost advantage of fossil-fuelled power generation. In particular, they show the strong competitiveness of CCGTs for power generation.

Clearly, under BAU assumptions the contribution of nuclear power over the next two decades will be limited. However, potentially nuclear could have a larger role in energy supply than suggested by BAU. This should be seen in the context of three increasingly important energy issues: sustainability, climate change and electricity market competition.

A number of IEA member countries wish to retain and improve the nuclear option for the future, because of its potential contribution to sustainable development, since it is free of carbon dioxide emissions. This potential role depends on three key factors:

- Better use of uranium resources. With current technology reserves could last for 60 years. New technology will be needed to make better use of the energy resource, and that would entail uncertain costs.
- Environmental risks from nuclear must be reduced to the minimum. Problems such as the disposal of high level radioactive waste must be resolved.
- Nuclear will have to demonstrate its economic value in increasingly competitive electricity markets.

Throughout the OECD, governments are promoting competitive electricity markets. Competition in a liberalised electricity market is expected to bring reductions in generating costs through improved performance of plants, and nuclear power will not be immune to that. Nuclear's strong asset is its low operating and fuel costs, which explains why nuclear plants operate in baseload mode. In a competitive market, plants with low costs will thrive; plants with high costs may have to shut down.

Over the short- to medium-term, competition will give an incentive to existing plants to reduce their costs. This means that their output will be maximised (increased capacity factors) and extended in time to maximise revenues.

The assumptions on nuclear capacity factors in the World Energy Outlook already include improvements over time. But it is likely that as electricity market reforms proceed, some nuclear plants will seek to extend their licences. With continued investments and refurbishment, some nuclear plants may be able to operate for 60 years or even longer. Extension of the lifetime of existing plants would in turn help restrain growth in carbon dioxide emissions.

For new plants, the outlook is more uncertain. Competition could improve nuclear economics, if capital costs — nuclear's main economic disadvantage compared to fossil-fuel technologies — and operating costs are reduced. But fossil fuel technology is not expected to stand still either.

In December 1997, in Kyoto, Japan, the Conference of the Parties to the Framework Convention on Climate Change established an international commitment to reduce greenhouse gas (GHG) emissions by 2008–12.

The World Energy Outlook provides two stylised analyses to show the scale of emissions reductions required to achieve the Kyoto target, and to illustrate how policies (market-oriented or regulatory) to curb GHG emissions would affect patterns of energy demand and supply (see Figure 7). The first (Kyoto Analysis 1) indicates the scale of regulation that would be required by OECD countries to meet their Kyoto commitments. The second (Kyoto Analysis 2) indicates the "carbon value" that would need to be built into fossil fuel prices to meet the Kyoto commitments.

In both cases, about half of the required emission reductions are achieved by introducing uniform energy savings of 1.25% per annum (in Kyoto Analysis 1) or a carbon value of US$250 per tonne of carbon (in Kyoto Analysis 2). The other half of the emission reductions is achieved by substituting non-fossil for coal-fired power generation. More specifically, existing coal-fired power plants are assumed to be retired early and replaced by non-carbon emitting plants (nuclear or renewables).

The results shown in Figure 7 concern the power generation sector only. Because of its large contribution to carbon dioxide emissions (about one third of total), the sector will become involved in any effort to curb GHG emissions. Also, the power generation sector is perhaps one of the easiest and the most flexible sectors to tackle, compared for example to the transportation sector or to the demand for electricity. Unlike other sectors, it has the advantage of being able to use carbon-free fuels (nuclear and renewables) on a large scale. This means that if market-based mechanisms, such as a carbon value, are chosen to curb emissions, nuclear and renewables would benefit in the longer term. Regulatory measures would also establish carbon values, although implicitly.

The chart in Figure 8 shows the effect of a carbon value on the relative economics of fossil-fuel and carbon-free electricity generation, including capital costs. Note that the figures are illustrative only. The introduction of a carbon value would affect first of all the position of coal, since this is the most carbon-intensive of fossil fuels. This estimate shows that a US$20–25 carbon value would bring coal-fired generating costs to the level of nuclear generating costs.

Gas-fired combined cycle gas turbine plants are currently the favoured option for new power generation schemes in many OECD countries where gas is available, and they will continue to be in the medium term. As you can see from Figure 8, this type of generation is less sensitive to a carbon value. This is the combined effect of their high conversion efficiency and the low carbon content of natural gas.

The nuclear moratoria in some countries and the long licensing and construction periods for new nuclear plants will prevent significant new construction in the near-term. However, if commitments to reduce GHG emissions are extended beyond the Kyoto time horizon, in the longer term nuclear power could clearly have a comparative economic advantage over fossil fuels, especially if fossil fuel prices begin to rise and if more cost-effective ways to reduce emissions are not sufficient.

Conclusions

The World Energy Outlook shows that under Business-as-Usual assumptions, demand for energy will continue to grow steadily. The world will continue to rely on fossil fuels to meet its energy needs.

Under these assumptions, the role of nuclear power in OECD countries over the next 20 years will be a declining one. It is possible, however, that competition will encourage life extensions of existing nuclear plants. This may slow the potential decline in nuclear capacity within the OECD and contribute to efforts to curb CO_2 emissions.

Over the longer term, the role of nuclear could be very different compared to that foreseen in the Business-as-Usual scenario. Sustainable development, climate change and competition are three issues which could have a profound, potentially positive effect on nuclear's role in energy supply. The challenge to proponents of nuclear power is to find ways to leverage its positive contributions, and to change the apparent course of Business-as-Usual.

REFERENCES

1. *World Energy Outlook 1998*, International Energy Agency/OECD, Paris, 1998.
2. *Nuclear Power*, International Energy Agency / OECD, Paris, 1998.
3. *Projected Costs of Generating Electricity – Update 1998*, Nuclear Energy Agency / International Energy Agency/OECD, Paris, 1998.

Figure 1. Projected world primary energy demand.

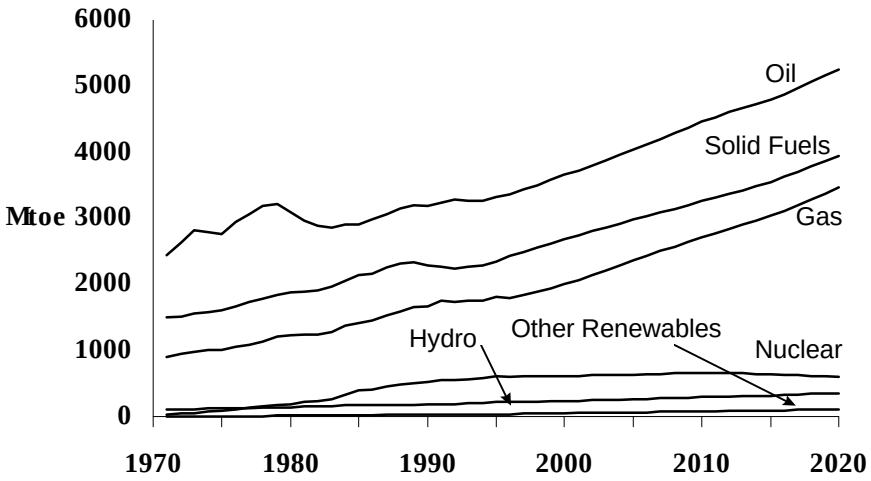

Figure 2. Projected change in world energy demand, 1995 to 2020.

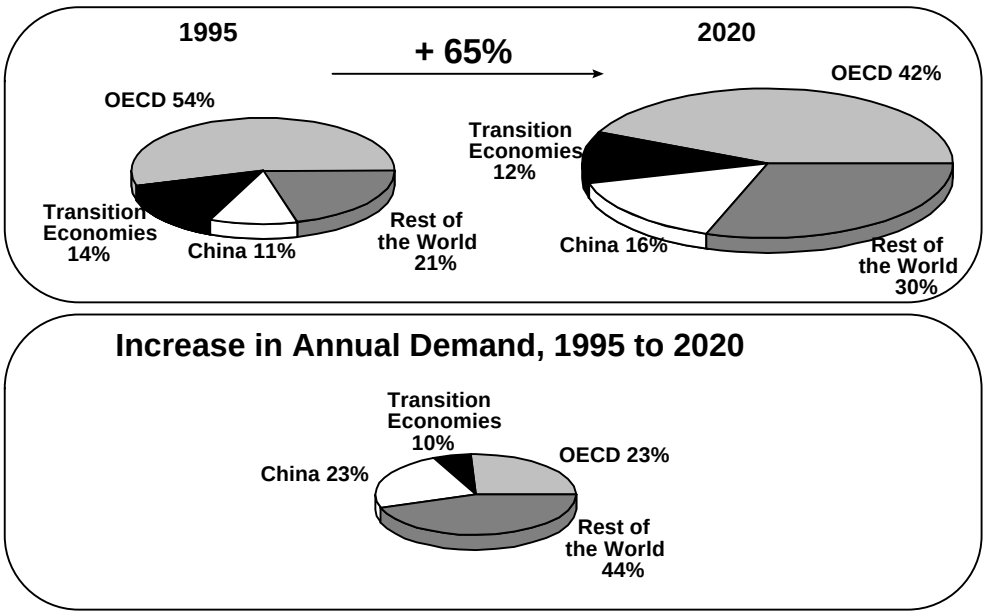

Figure 3. Projected changes in world electricity generation by fuel, 1995 to 2020.

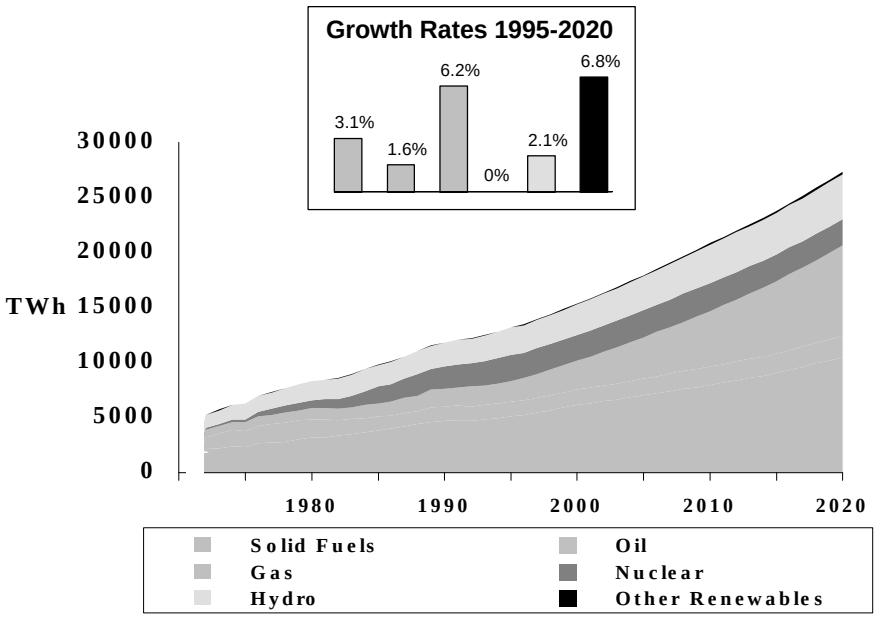

Figure 4. Nuclear electricity generation by region.

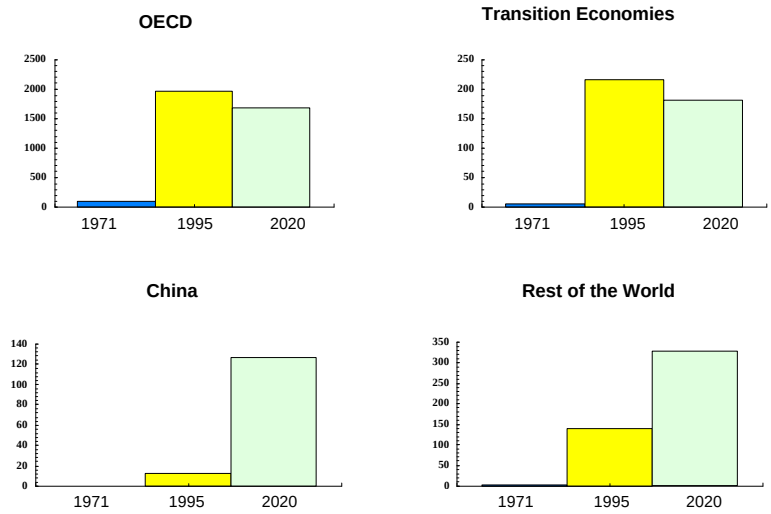

Figure 5. Nuclear electricity generation in the OECD.

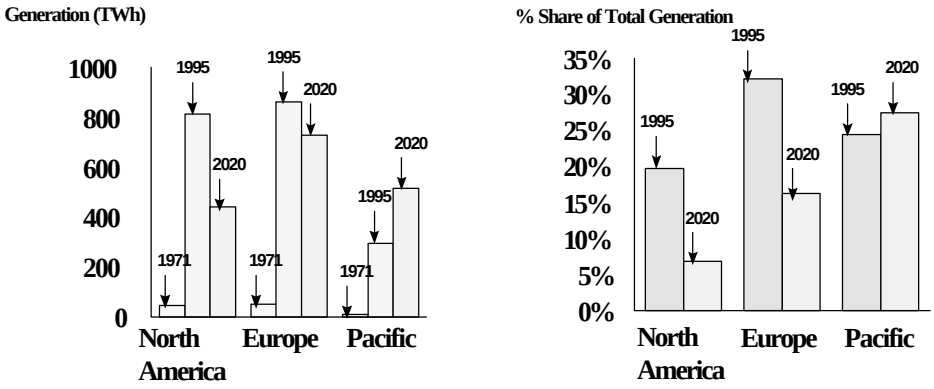

Figure 6. Comparative economics of new plants—countries where nuclear, coal and gas are cheapest at two discount rates (5% and 10%).

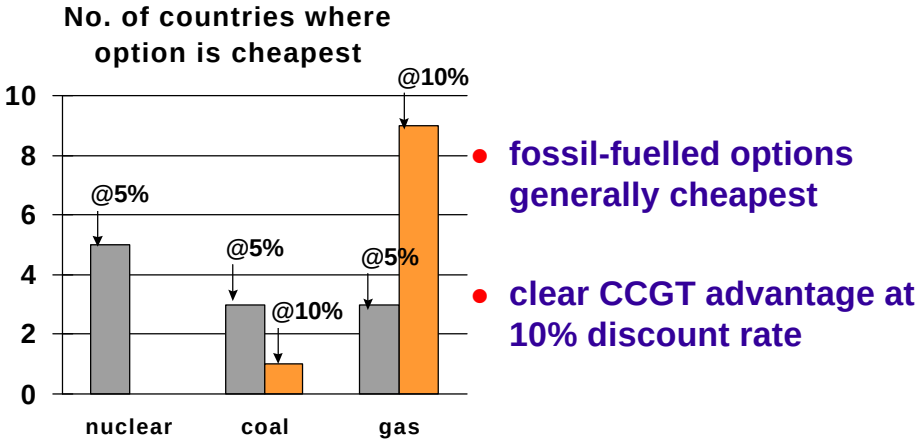

Figure 7. Analyses of the implications of the Kyoto Protocol.

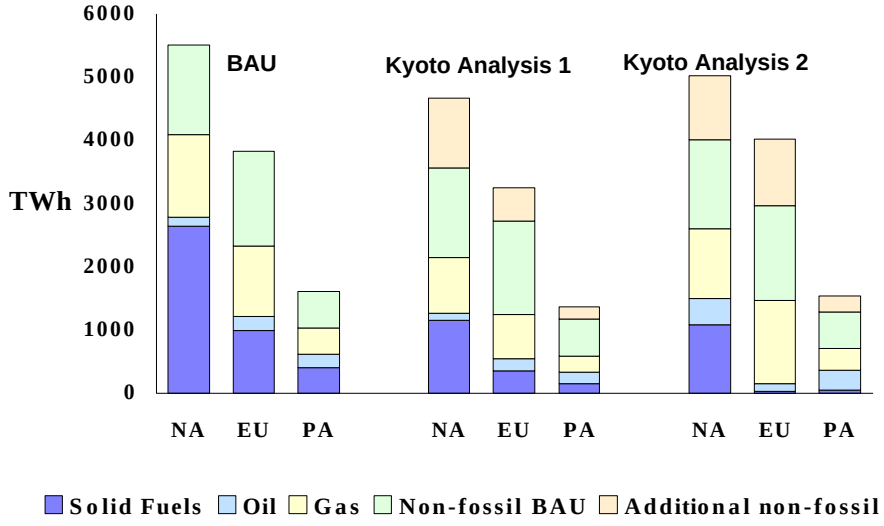

Figure 8. Effects on relative economics of a carbon value.