KYOTO PROTOCOL OBJECTIVES IN CROATIA ENERGY PLANNING: NUCLEAR SCENARIO

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Abstract

Croatia as an Annex I country of the United Nations Framework Convention on Climate Change (UNFCCC) and a country that has pledged in the Annex B of the Kyoto Protocol to reduce its greenhouse gases (GHG) emissions by 5% from the pre-transition level by the budget period 2008-12, will have to envisage a new energy strategy. Compared to the energy consumption collapse in some transitional countries like Russia and Ukraine, Croatia has passed through a relatively short-term reduction of GHG emissions since 1990 because of higher efficiency of its pre-transition economy. It is expected that in case of business as usual scenario, as defined in this paper, it will breach the Kyoto target in 2003 since the demand for energy will be high, especially as the income continues to rise, particularly in domestic use for heating and for transport. Several scenarios of power generation are compared from the point of view of GHG emissions. The cost-effective scenario expects a mixture of coal and gas fired power plants to be built to satisfy the new demand and to replace the old power plants that are being decommissioned. More Kyoto friendly scenario envisages the construction of mostly nuclear power plants in the future, while decommissioning the old plants as planned, and is compared to the others from the GHG emissions point of view. The conclusion is that by measures tackling only power generation it will not be possible to keep GHG emission under the Kyoto target level, but that choosing the nuclear option might reduce significantly the cost of compliance. The case of including the emissions from Croatian owned power plants in former Yugoslavia is also discussed.

Keywords

UNFCCC, GHG, Kyoto Protocol, nuclear energy

INTRODUCTION

During the last two decades it became clear that due to human activities the carbon dioxide concentration in atmosphere has nearly doubled since the early nineteenth century. There are strong clues that carbon dioxide, due to the greenhouse gas effect, might significantly influence the global warming in the coming decades. Acknowledging that, the United Nations have started a mitigation process with signing the UN Framework Convention on Climate Change (UNFCCC) at the "Earth Summit" in Rio de Janeiro 1992. The process was later continued by yearly Conference of the Parties sessions starting in 1995. The Kyoto Protocol to the UNFCCC was signed in 1997 at its third session. The Convention is signed and ratified by 186 countries, while Kyoto Protocol is signed by 105 countries and ratified by 46 due to still open negotiations on some mitigation mechanisms [1], [2]. The Protocol shall enter into force on the ninetieth day after the date on which not less than 55 Parties to the Convention, incorporating Annex I Parties which accounted in total for at least 55 % of the total carbon dioxide emissions for 1990 from that group, have deposited their instruments of ratification, acceptance, approval or accession.

Republic of Croatia has signed the Convention in 1992 and ratified it in 1996. In accordance with decision 4/CP.3 Croatia, Liechtenstein, Monaco and Slovenia have been added to Annex I to the Convention in 1998 [1]. As an Annex I country Croatia has signed Kyoto protocol in 1999 and accepted the obligation to reduce emissions of greenhouse gases by 5 percent from the amount released to atmosphere in the referent year, chosen to be 1990. There is still another outstanding issue. Before the break-up of Yugoslavia in 1991 Croatian power system owned several power plants situated in other republics of former Yugoslavia, namely in Bosnia and Herzegovina, Serbia and Slovenia, consisting of 650 MW of installed coal fired thermal power and 332 MW of nuclear power. Croatia is still trying to negotiate inclusion of the emissions from those sources into referent emission [3] and has included them in the First National Communication [4]. We have here assumed the territorial approach without taking into account dislocated power plants that were previously part of the Croatian electric system, but have also discussed the repercussions of its inclusion.

In order to simplify the calculation, only CO_2 emissions were taken into account in this paper. Other GHG gases and CO2 sinks were not. According to Croatia's preliminary GHG emission inventory 24474 Gg of CO_2 was emitted on the territory of Croatia in 1990 [5], while according to the First National Communication the value is 30712 Gg of CO_2, including 7847 Gg of other energy emissions, lumping together dislocated emission and non-energy fuel consumption [4]. CO_2 emissions stemming from the non-energy fuel consumption were reported as 439 Gg of CO_2 in 1990 by the preliminary GHG emission inventory [5]. It is possible to deduce that the CO_2 emissions on the territory of Republic of Croatia, reported by First National Communication, were 22426 Gg of CO_2 in 1990.

By reducing the amount stated in preliminary GHG emission inventory by 5 percent one gets 23250 Gg of CO_2 per year which is used in this paper as the Croatian target allowed by the Kyoto Protocol during the first budget period 2008-2012. In case of UNFCCC accepting the dislocated emissions approach the target would be 29176 Gg of CO_2 per year, and if not, only 21305 Gg of CO_2 per year. It is expected that in future budget periods the target will stay the same for economies in transition.

The projections shown in this paper are based on national strategy of energy development of the Republic of Croatia [6] and the strategy of developing the power system [7]. The strategies assume a very limited increase in population, to the contrary to the large fall of nearly 10% shown by the census of 2001, and overoptimistic long-term economic growth of 5% yearly [6]. The average growth during 1994-97 was indeed 6.3% [8], but after plunging to 59.5% of its 1989 level [8]. The growth slowed down in 1998 to 2.5% and further to 0.3% in 1999 [8] to increase after the change of government in 2000 to 3.7% [9]. That still leaves the average growth during 1994-2000 on the level of 4.6%, close to the predicted value, though it is probably too high to be sustainable for the longer period. During decade 1990-2000 the average growth was only 0.6%.

We have assumed a scenario in which most of the emission reduction burden will be passed to the power generation, by building nuclear power plants instead of fossil fuel thermal power plants, and that other sectors will continue business as usual. The assumption about other sectors is probably not true since the technology innovations in transport, renewable energy use, efficiency and rational energy use will certainly have a spill over effect on Croatia. Meanwhile, since our intention was to show what can be done with today's technology we shall consider first the power generation sector.

The most important source of GHG emissions was industry (31.6% in 1990 [5]). Many of the energy intensive industries have already been closed, and since large parts of the economy are not yet properly restructured, there is still space for significant rationalisation of energy usage especially waste heat recovery systems and retrofitting industrial furnaces for higher efficiencies. On the other hand, further rationalisation of the energy use in the industry will be offset by the expected future growth.

Even though the transport was a very important source (15.3%) of GHG emissions in Croatia in 1990 [5], since vehicles are imported goods, Croatia cannot do much to influence this technology. It would be highly improbable to expect a policy that would try to limit further car ownership (250 cars/thousand inhabitants) growth since the duties are being reduced under the aegis of the WTO membership, Stabilisation and Association Agreement with EU and free trade agreements with 26 European countries. As the economy grows there will be even higher growth in the cargo transport. Only emissions stemming from agricultural mechanisation is not expected to grow strongly.

The direct consumption (including residential consumption and services, 10.6% in 1990 [5]) is highly inefficient due to low insulation of houses. It will be hard to expect any improvements soon, since the replacement rate for houses is small, the regulation is lax and is mostly not applied for construction done by individuals, which is the main source of construction. Most of the new construction financed by state in the regions damaged by war was also of very low or dubious insulation quality. On the other hand, since only a fraction of space (26%, 1994 [10]) is currently heated due to low incomes, the high growth is expected as wages go up. The national strategy [10] envisages that the insulation will increase by an average of 10% during the studied period (by 2025). This is the most important non-generating energy sector where Croatia can significantly influence its GHG emissions, mainly by forcing better insulation of houses, but also by gasifying households. The national strategy envisages that by 2025 some 40% households will be supplied with gas [11].

This paper takes into account only CO_2 emission while neglecting the other greenhouse gases. That is acceptable, because of qualitative results and conclusions of this paper.

CURRENT SITUATION

The Republic of Croatia has an area of 56,538 square kilometres, of which forests and woodland cover 38%, permanent pastures 20%, arable land 21%, permanent crops 2% and built-up area and wasteland 19%. The northern half of the country has continental climate while the southern half has Mediterranean climate, with relatively cold winters. It had 4.3 million inhabitants according to 2001 census, with a population growth rate of 0.1%. The population growth is due to net immigration rate of 0.2%, otherwise the growth rate would have been negative.

The country generated a GDP of slightly more than 19 billion USD in 2000 or some 4400 USD per capita. Converted to purchase power parity that made some 7000 USD of GDP per capita. Agriculture generated 9% of GDP while formally employing only 4% of labour force. This datum should be taken with knowledge that up to 20% of population could be classified as agricultural in some extent, living of subsistence farming and mostly outside of the labour market. Industry and mining generated 32% of GDP while employing 31% of labour. The rest of GDP, 59%, was made in services. Main industries are chemicals and plastics, machine tools, fabricated metal, electronics, pig iron and rolled steel products, paper, wood products, construction materials, textiles, shipbuilding, petroleum and petroleum refining, food and beverages and tourism.

Using International Energy Agency methodology oil had 53% share of total primary energy supply, gas 29%, hydro energy 6%, imported electricity 4%, combustible renewable sources 5% and coal 3% in 1998 (*Figure 1*). While IEA and OECD use the methodology where hydro energy and imported electricity is converted to primary energy using its nominal factor of 1 TWh = 3.6 PJ,

Croatian energy statistics use around 9.7 PJ/TWh for hydro energy, which is creating confusion in data comparison.

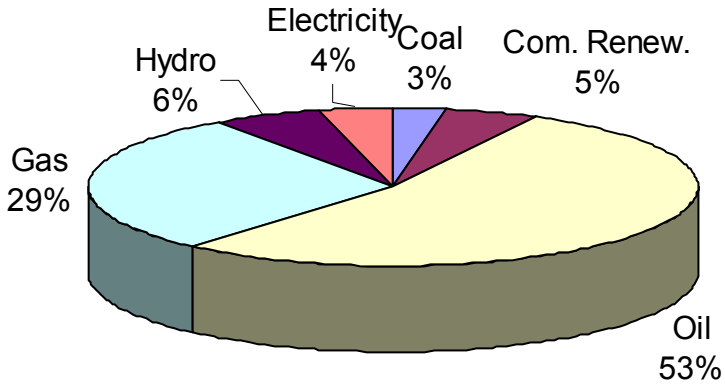

Figure 1. Energy share of TPES in 1998 [12]

The total primary energy supply was, including the imported electricity, 7.65 Mtoe in 1998, or 1.6 toe per capita, similar to the world average. Using the nominal GDP for 1998, which was 21.4 billion USD, the economy energy efficiency of 2.8 USD/kgoe was obtained, somewhat lower than the world average and half of the developed countries level, showing typical energy inefficiency as in other economies in transition.

As shown on *Figure 2* most of the primary energy or 66% goes to the final consumption, often after some kind of conversion, either to electricity or various liquid fuels. Around 17% of the primary energy is lost in the process, while 9% is used by the energy sector. Some 8% is put to non-energy uses, mainly in petrochemical industry.

Industry consumes 24% of the final consumption, transport 29% while other sectors take 47%, or 100 PJ (2.39 Mtoe), mainly households, 31%, services 9%, agriculture 4% and construction 2%. Households and services together spend 86 PJ (2.06 Mtoe) of final energy, nearly half of which goes to space heating [10]. Most of the final energy consumption in Croatia is used in the form of liquid fuels, 46%, electricity makes 19%, gaseous fuels 17%, heat 10%, combustible renewable 6% and coal only 2%, as shown on *Figure 3*.

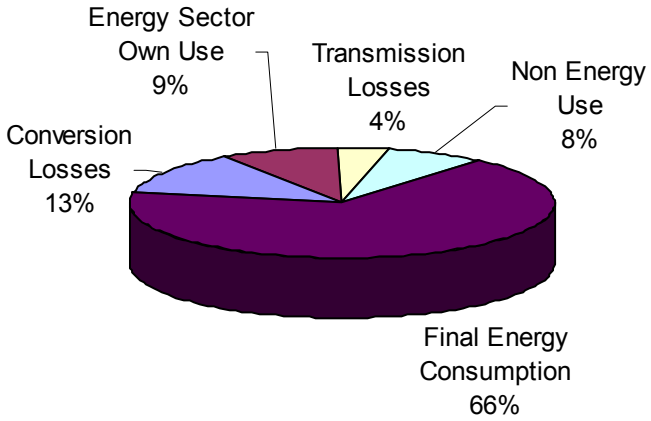

Figure 2. The use of TPES in 1998 [12]

Most of electricity and heat is generated by the Croatian Electric Utility (HEP), while 31% is produced by industrial and public heating and cogeneration plants, mainly as heat (*Figure 4*). Total electricity produced in 1998 amounted to 10.9 TWh (39 PJ, 0.94 Mtoe), half of that from hydro power plants, 36% in thermal power plants, 9% in HEP's cogeneration plants and 5% in industrial plants. The total amount of heat produced was 30 PJ (0.72 Mtoe), one third of it in HEP's cogeneration plants

and the rest in industrial and public heating and cogeneration plants. This paper will concentrate only on the electricity and heat produced by HEP, since the data is more easily available.

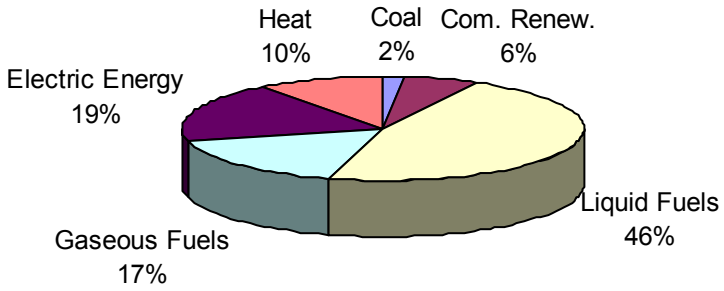

Figure 3. Final energy consumption by fuel [12]

Thermal power plants used 229 kt of coal, 177 million m^3 of natural gas and 656 kt of oil, while HEP's cogeneration plants used 280 million m3 of natural gas and 208 kt of oil. In all thermal power plants used 38 PJ (0.92 Mtoe) of primary energy, hydro power plants used further 20 PJ (0.47 Mtoe) and cogeneration plants used 5 PJ (0.11 Mtoe) of primary energy supply.

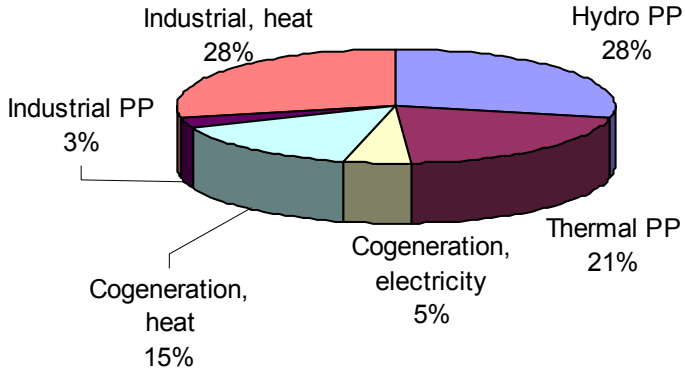

Figure 4. Energy use in electricity and heat generation sectors [12]

BUSINESS AS USUAL SCENARIO

Business as usual scenario for energy sector of Croatia is based on the middle scenario developed by Energy Institute "Hrvoje Požar" [6, 7 and 13] for the period until 2030. It is based on the assumption of 5% GDP long-term growth and a relatively quick recovery of Croatian industry after the collapse due to transition in early 90-ties. The recovery has indeed started in 1994 but has slowed down in 1998. The national energy strategy is based on predominantly commercial energy sources available in or around Croatia, with the plan to reduce the country high oil dependency with natural gas and coal. The strategy takes into account the possible use of wide range of renewable energy sources, but apart from moderate increase of hydro energy (333 MW planned to be built by 2030) it deems most of other not to be economically viable. It predicts that most of emissions (SO_2, NO_x) from the energy sector will be under control [6], while the greenhouse gases emission will sometime after 2000 breach the limit that Croatia promised to keep under the aegis of the Kyoto protocol but it does not propose solutions.

The national energy strategy stipulates to gasify most of larger urban conglomerations during the next 10 years. On one hand that should have a positive effect on GHG emissions since it would reduce the use of electricity for water and space heating, that is the prevalent situation in the coastal zone of Croatia. On the other hand, that will increase the total amount of energy used and GHG emitted, due to the fact that more people will be able to afford space heating.

Latest figure (1994) shows that only 26% of living space was heated. That was certainly dramatically increased since then, as the standard of living went up. The strategy envisages an increase

of insulation of the old buildings of 10% and the construction of new buildings according to the existing, quite lenient regulation. There are signs that opinion is moving towards more action in this field.

Most of the CO_2 emitted in Croatia comes from combustion, either from use of fossil fuels to obtain electrical, thermal or mechanical power, while only around 10-15% is from other sources, like industrial processes.

The fossil fuel consumption of all sectors but the power generation was taken from the national strategy, and the power generation was calculated by the Electric module of ENPEP program using the same rules as the one used for the national strategy. The strategy envisages that some six hydro power plants will be built (333 MW), and a mixture of gas fired combined cycle power plants (1x100 MW, 1x200 MW, 6x300 MW) and coal fired (1x350 MW, 1x500 MW) operating on imported coal, in total some 3300 MW by year 2030. The total consumption of all fossil fuels for all energy uses is given in *Figure 5*.

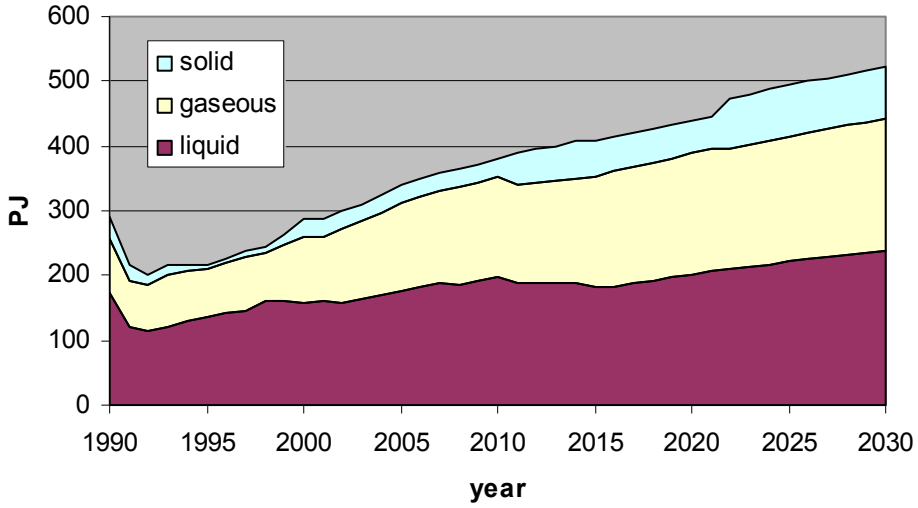

Figure 5. Expected fossil fuel for all energy use, business as usual scenario

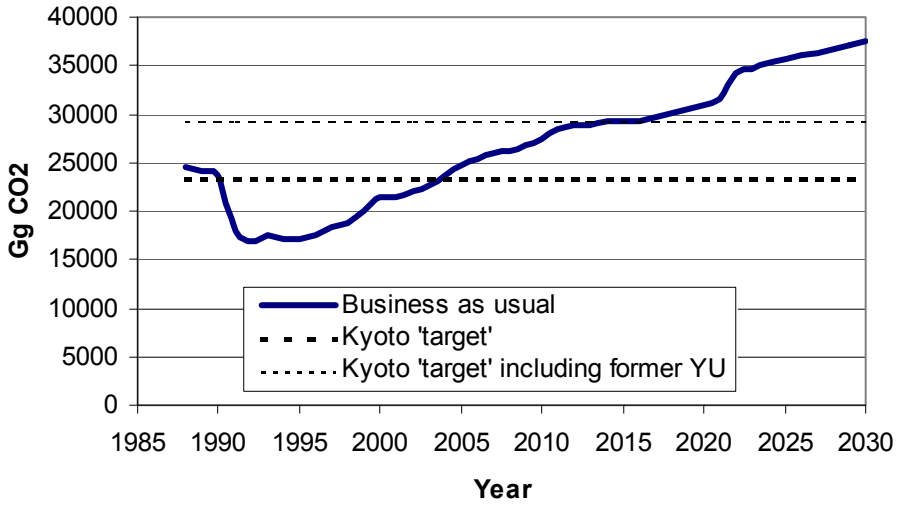

Figure 6. Expected CO_2 emissions, business as usual scenario

If the non-energy sources of CO_2 are also taken into account, the presumed Kyoto target for Croatia of 23250 Gg of CO_2 will be breached by business as usual scenario in 2003 as shown on

Figure 6. That means that after 2008 Croatia will have to buy certificates on the free carbon market, or somehow solve the problem of the excess GHG emission.

Conveniently, including the emissions from Croatia's power plants from other republics of former Yugoslavia, would postpone the breaching point into 2012, making Croatia actually make money out of the first budget period, by selling the carbon certificates.

MINIMISED CO_2 IN POWER GENERATION: NUCLEAR SCENARIO

In order to estimate could well-designed electricity sector planning significantly reduce CO_2 emissions and possibly keep them under the Kyoto target level, while still keeping the costs in reasonable and economically viable region, a new scenario was calculated. The same expected electricity demand and load peaks were used as for business as usual scenario, as well as all non-generating fossil fuel consumption. As cheapest available non-fossil fuel electricity source nuclear energy was chosen, but one could think of importing electricity as a surrogate.

The best configuration calculated by ENPEP [14] was to build only one gas fired combined cycle 200 MW power plant, three 660 MW and one 980 MW nuclear power plants, with the same hydro potential harnessed (330 MW) as in the business as usual scenario. Since most of the fossil fuel power plants are due to be decommissioned between 2005 and 2015, only the ones built recently will still work in 2030.

As can be seen from *Figure 7* some 25% reduction in fossil fuel consumption has been achieved after 2015, but the strategy does not show to be particularly effective during the first budget period of 2008-2012, due to the old fossil fuel power plants that will still be in function. One gas fired power plant had to be built since it would be impossible to build nuclear power plants quick enough to cover the lack of installed power before 2008.

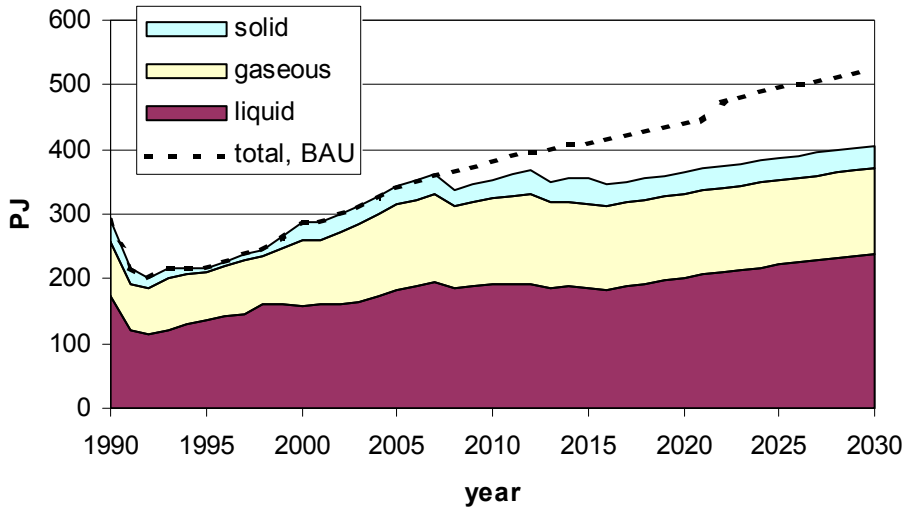

Figure 7. Expected fossil fuel for all energy use, minimised CO_2 and cost in power generation scenario

Conveniently, including the emissions from Croatia power plants from other republics of the former Yugoslavia would increase the gain from the excess of emissions during the first budget period, obtained by selling the carbon certificates. In case of nuclear scenario, the Kyoto target would only be breached in 2030, practically outside of the horizon of current energy planning.

One can also envisage that the lack of power before the first nuclear power plant could be commissioned could be covered from importing electricity, meaning that no new fossil fuel power plants would be built. Both scenarios' resulting CO_2 emissions are shown and compared to the business as usual, and to the Kyoto target on *Figure 8*. As obvious from the figure there is no significant difference between the two.

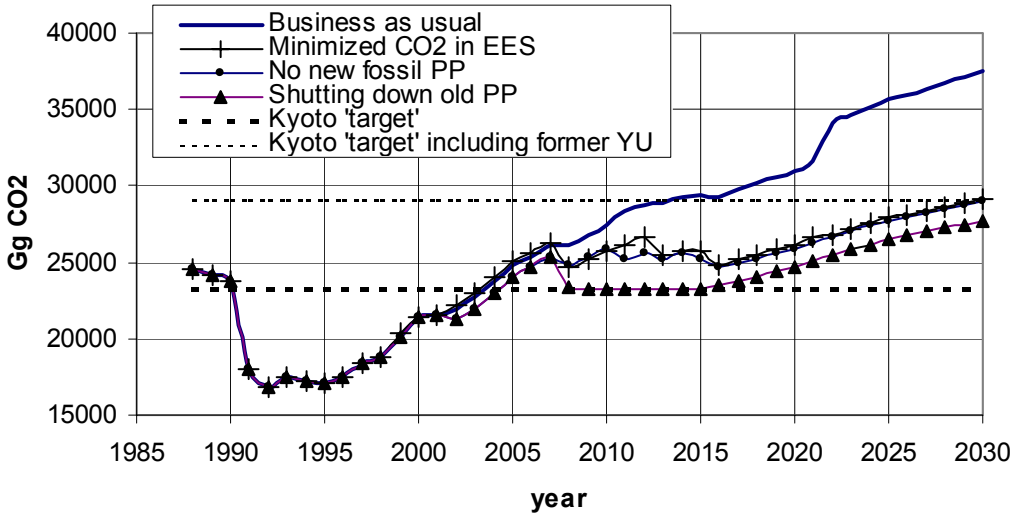

Figure 8. Expected CO_2 emissions, comparison of different power generation scenarios

The only way that power generation sector could further reduce emissions would be to start prematurely closing its fossil fuel power plants after 2008. By shutting down both oil-fired power plants and several smaller and older gas-fired blocks in 2008, the older coal-fired power plant (Plomin I) in 2009, and shutting all fossil fired capacity by 2015 it would be possible to keep the GHG emissions under the Kyoto target level during the first budget period, and for three more years. Such a procedure would burden the power generation sector with huge price of shutting down plants that still did not repay the investment. After 2015 it would not be possible to stay under the Kyoto target level even though the power generation would not emit any GHG gases.

It is clear that with currently predicted growth in energy demand it will not be possible to satisfy the long term Kyoto target by only forcing changes to the power generation sector.

Although there are many energy sectors where economies of scale in CO_2 reduction are offered, the most inefficient sector with biggest potential in the Republic of Croatia is probably space heating. Another large energy sector is transport. Any technological advance in that field, possibly a switch to fuel cells, most probably cannot be significantly influenced by Croatia. Heat generation and use by industry is probably a sector where some large inefficiencies could be found but that should be a subject of a wider analysis.

FINANCIAL REPERCUSSIONS

The OECD study "Meeting the Kyoto targets" [15] concludes that in case of unlimited emission trading the average price of CO_2 emission reduction would be 90 USD per tonne of carbon, or 25 USD/tCO_2. Generally forecasted price of certificates is between 5 and 15 USD/tCO_2. . The price of non-compliance is assessed for Croatia by giving the annual expense for buying surplus tonnes of carbon for business as usual scenario on the certificate market for prices of 5 USD/tCO_2, 15 USD/$tCO_2$and the theoretical abatement price of 25 USD/tCO_2which is the maximum price expected to be traded – any higher price would make local abatement cheaper. The comparison starting from the first year of the first budget period, 2008, is given on *Figure 9*.

The figure shows that whatever the price of the carbon certificates, a significant sum will have to be spent annually for non-compliance in case of business as usual scenario. That sum would justify investing in different energy strategies that would reduce GHG emissions, in power generating sector and other sectors.

The value of including emissions from Croatian power plants in other republics of the former Yugoslavia could have a yearly value between 35 and 175 million USD, depending on the carbon certificates market value.

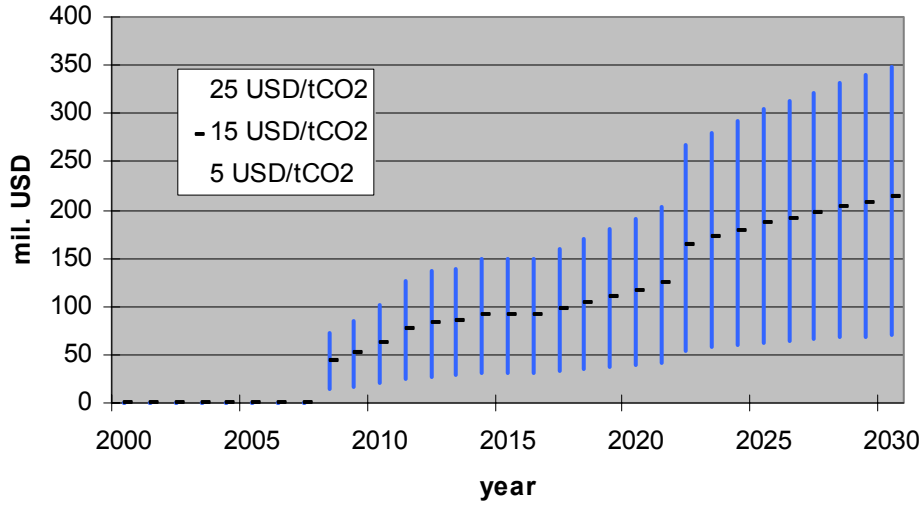

Figure 9. Expected cost of non-compliance to the Kyoto target. The spread is between the minimal expected market price of CO_2 certificates, and the expected average abatement price, as forecasted by OECD [15]

CONCLUSIONS

In case of business as usual energy system development in Croatia, the Kyoto Protocol target level will be breached in 2003. If the GHG emission abatement strategy concentrates exclusively on power generation it would be possible to delay the breach until 2015 only by very high cost, when even without any fossil fuel use in power generation the CO_2 emissions will be higher than the Kyoto protocol target accepted by Croatia. Therefore, it is clear that Croatia will need a new energy strategy if it seriously aims at satisfying the UN Framework Convention on Climate Change and the Kyoto protocol and reducing the cost of non-compliance. That cost avoidance would significantly justify many different measures of increasing efficiency of energy use, especially in industry and space heating. It could also justify larger investment into renewable energy sources.

The nuclear energy, from the point of view of the reduction of GHG emissions, is the most significant clean energy of the future. It is time to put it back where it belongs, as environmentally friendly way of generating power, and to associate it more with its positive impact on the reduction of GHG emissions and global warming. Although it might not be sufficient for solving the problem of GHG emissions reduction in Croatia, it could be the most significant single measure. It is time to measure the financial effects of Croatia's commitment to the Kyoto Protocol, and to take all options into consideration.

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