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Croatia energy planning and Kyoto Protocol

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Abstract

Croatia as an Annex I country of the UN Framework Convention on Climate Change and a country that has pledged in the Annex B of the Kyoto Protocol to reduce its GHG emissions by 5% will have to envisage a new energy strategy. Compared to the energy consumption collapse in some transitional countries, Croatia has passed through a relatively short-term reduction of GHG emissions since 1990 because of higher energy efficiency of its pretransition economy. It is expected that in case of baseline scenario, it will breach the Kyoto target in 2003. 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 forcing the compliance with the Protocol with measures only in power generation sector by the construction of mainly zero emission generating capacity 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. The case of including the emissions from Croatian owned power plants in former Yugoslavia is also discussed.

Keywords: Greenhouse gases; Kyoto protocol; Energy planning

1. 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 188 countries, while Kyoto Protocol is signed by 134 countries and ratified by 119 Parties, representing 44.2% of Annex I Parties emission (UNFCCC, 2002), (Hyvarinen, 2000). The Protocol shall enter into force on the 90th 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 (UNFCCC, 2002). As an Annex I country, Croatia has signed Kyoto Protocol in 1999 and accepted the obligation to reduce emissions of greenhouse gases by 5% 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

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sources into referent emission (HED, 1998) and has included them in the First National Communication (MEPPP, 2001). 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 assess the potential of the power generation sector in complying with the obligations under the Kyoto Protocol, several scenarios of power generation were 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 forcing the compliance with the Protocol with measures only in power generation sector by the construction of mainly zero emission generating capacity in the future, while decommissioning the old plants as planned, and is compared to the others from the GHG emissions point of view. 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. The nuclear power plants were chosen only because of the ENPEP model used, which handles only two types of zero emission power generation, hydro and nuclear. The paper does not suggest that nuclear power plants should be built. The other energy sectors will continue business as usual (Duić et al., 2002), which 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, but we consider it acceptable since the main message of this paper is that measures and policies in power generation only will not enable compliance with the Kyoto Protocol.

This paper takes into account only CO_2 emission while neglecting the other greenhouse gases, applying the IPCC methodology (IPCC, 1996). That is acceptable, because of qualitative results and conclusions of this paper.

The paper shows that by limiting GHG emissions reductions only to electricity generation, it will not be possible to satisfy the Kyoto targets in Croatia. The importance of energy planning as a way for emission reduction was highlighted by Olerup (2002), Lund et al. (2000), Bauer and Quintanilla (2000), and Jaccard et al. (1997).

2. Current situation

The Republic of Croatia has an area of 56,538 km^2, 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 20.3 billion USD in 2001 or some 4600 USD per capita. Converted to purchase power parity that made some 9000 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 50% share of total primary energy supply, gas 30%, hydro energy 7%, imported electricity 3%, combustible renewable sources 4% and coal 6% in 2001 (Fig. 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.

The total primary energy supply was, including the imported electricity, 7.88 Mtoe in 2001, or 1.8 toe per capita, similar to the world average. Using the nominal GDP for 2001, the economy energy efficiency of 2.6 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.

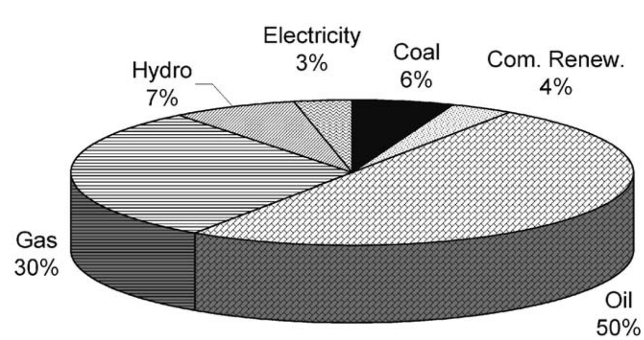

Fig. 1. Energy share of TPES in 2001 (Vuk, 2002).

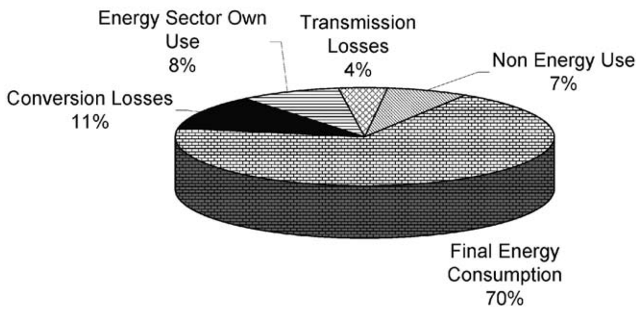

Fig. 2. The use of TPES in 2001 (Vuk, 2002).

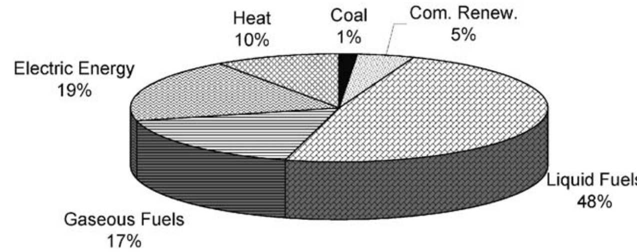

Fig. 3. Final energy consumption by fuel in 2001 (Vuk, 2002).

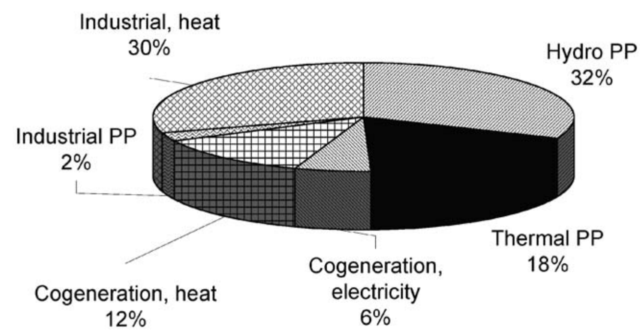

Fig. 4. Energy use in electricity and heat generation sectors in 2001 (Vuk, 2002).

As shown in Fig. 2 most of the primary energy or 70% goes to the final consumption, often after some kind of conversion, either to electricity or various liquid fuels. Around 15% of the primary energy is lost in the process, while 8% is used by the energy sector. Some 7% is put to non-energy uses, mainly in petrochemical industry.

Industry consumes 23% of the final consumption, transport 29% while other sectors take 48%, or 108 PJ (2.58 Mtoe), mainly households 31%, services 10%, agriculture 5% and construction 2%. Households and services together spend 92 PJ (2.21 Mtoe) of final energy (Vuk et al., 1999), nearly half of which goes to space heating (Kolega, 1998). Most of the final energy consumption in Croatia is used in the form of liquid fuels, 48%, electricity makes 19%, gaseous fuels 17%, heat 10%, combustible renewable 5% and coal only 1%, as shown in Fig. 3.

Most of electricity and heat is generated by the Croatian Electric Utility (HEP), while 32% is produced by industrial and public heating and cogeneration plants, mainly as heat (Fig. 4). Total electricity produced in 2001 amounted to 12.2 TWh (44 PJ, 1.05 Mtoe), more than half of that from hydro power plants, 31% in thermal power plants, 10% in HEP's cogeneration plants and 4% by autoproducers in industrial plants. The total amount of heat produced was 32 PJ (0.76 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.

Thermal power plants used 627 kt of coal, 170 million m^3 of natural gas and 405 kt of oil, while HEP's cogeneration plants used 431 million m^3 of natural gas and 115 kt of oil. In all, thermal power plants used 38 PJ (0.92 Mtoe) of primary energy, hydro power plants used further 24 PJ (0.57 Mtoe) and cogeneration plants used 19 PJ (0.46 Mtoe) of primary energy supply.

In order to simplify the calculation, only CO_2 emissions were taken into account in this paper. Other GHG gases and CO_2 sinks were not. According to Croatia's preliminary GHG emission inventory, 24,474 Gg of CO_2 was emitted on the territory of Croatia in 1990 (Sučić et al., 2000), while according to the First National Communication the value is 30,712 Gg of CO_2, including 7847 Gg of other energy emissions, lumping together dislocated emission and non-energy fuel consumption (MEPPP, 2001). 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 (Sučić et al., 2000). It is possible to deduce that the CO_2 emissions on the territory of Republic of Croatia, reported by the First National Communication, were 22,426 Gg of CO_2 in 1990.

By reducing the amount stated in preliminary GHG emission inventory by 5%, one gets 23,250 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 29,176 Gg of CO_2 per year, and if not, only 21,305 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 (Granić et al., 1998a) and the strategy of developing the power system (Granić et al., 1998b). 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 maybe overoptimistic long-term economic growth of 5% yearly (Granić et al., 1998a).

The average growth during 1994–1997 was indeed 6.3% (BCEMAG, 2000), but after plunging to 59.5% of its 1989 level (BCEMAG, 2000). The growth slowed down in 1998 to 2.5% and further to 0.3% in 1999 (BCEMAG, 2000) to pick up after the change of government in 2000 to 3.7% (World Bank, 2001), and to 3.8% in 2001 (World Bank, 2003). That still leaves the average growth during 1994–2000 at 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 (Duić et al., 2002). The assumption about other sectors is probably not true since the technology innovations in transport, renewable energy use, efficiency and rational energy use will 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; Sučić et al., 2000). 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 (Sučić et al., 2000), 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; Sučić et al., 2000) is inefficient due to low insulation of houses. It will be hard to expect much 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. Some of the new constructions financed by state in the regions damaged by war were also of low or debatable insulation quality. On the other hand, since only a fraction of space (26%, 1994; Kolega, 1998) is currently heated due to low incomes, the high growth is expected as wages go up. The national strategy (Kolega, 1998) 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 (Pešut et al., 1998).

3. Baseline scenario

Baseline scenario for energy sector of Croatia is based on the middle scenario developed by Energy Institute "Hrvoje Požar" (Granić et al., 1998a; Granić et al., 1998b; Granić, 1998c) 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 90s. The recovery has indeed started in 1994, slowing down in 1998, to pick up after the government change in 2000. The national energy strategy is based on predominantly commercial energy sources available in or around Croatia, with the plan to reduce the country's 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 yet. It predicts that most of the emissions (SO_2, NO_x) from the energy sector will be under control (Granić et al., 1998a), 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 connect to natural gas grid 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 in the old buildings of 10% and the construction of new buildings according to the existing lenient regulation. There are signs that opinion is moving towards more action in this field, there are energy efficiency projects in service sector financed by ESCO schemes, and there is new energy legislation that stipulates the importance of energy efficiency.

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 (1×100, 1×200, 6×300 MW) and coal fired (1×350, $1 \times 500 \times$ 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 Fig. 5.

If the non-energy sources of CO_2 are also taken into account, the presumed Kyoto target for Croatia of

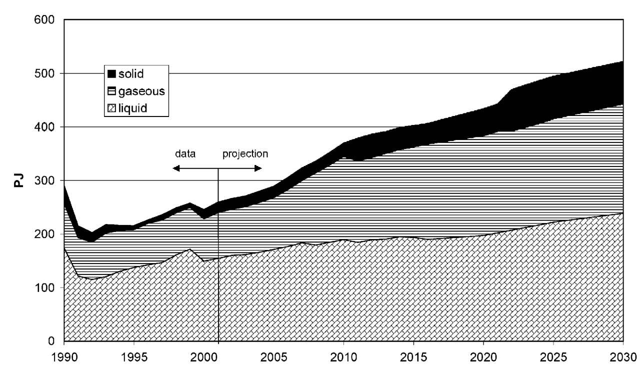

Fig. 5. Expected fossil fuel for all energy use, baseline scenario.

23,250 Gg of CO_2 will be breached by baseline scenario in 2005 as shown in Fig. 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 2017, making Croatia actually make money out of the first budget period, by selling the carbon certificates.

4. Minimised CO_2 in power generation scenario

In order to estimate if the well-designed planning of the electricity sector could 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 the baseline scenario, as well as all non-generating fossil fuel consumption. As a representative of non-fossil fuel electricity source, nuclear energy was chosen since ENPEP only allows large power plants to be taken into account, but one could think of renewable energy or importing electricity as a surrogate.

The best configuration calculated by ENPEP (Juretić, 1999) 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 baseline 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 Fig. 7, some 25% reduction in fossil fuel consumption has been achieved after 2015,

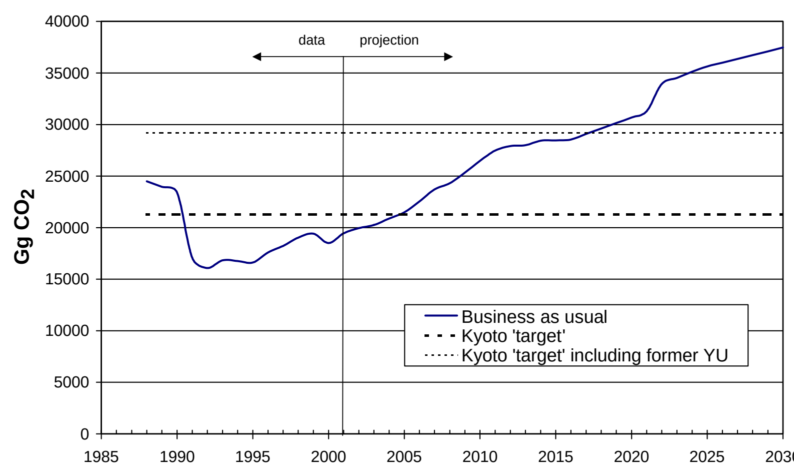

Fig. 6. Expected CO_2 emissions, baseline scenario.

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.

Conveniently, including the emissions from Croatia's 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 minimised CO_2 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 non-fossil 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 baseline, and to the Kyoto target in Fig. 8. As obvious from the figure there is no significant difference between the two.

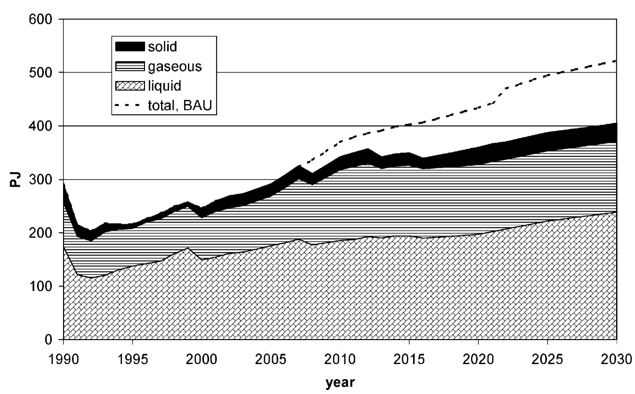

Fig. 7. Expected fossil fuel for all energy use, minimised CO_2 and cost in power generation scenario.

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. Such a procedure would burden the power generation sector with huge price of shutting down plants that still did not repay the investment. After 2012, 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.

5. Financial repercussions

The OECD study "Meeting the Kyoto targets" (OECD, 1999) concludes that in case of unlimited emission trading, the average price of CO_2 emission

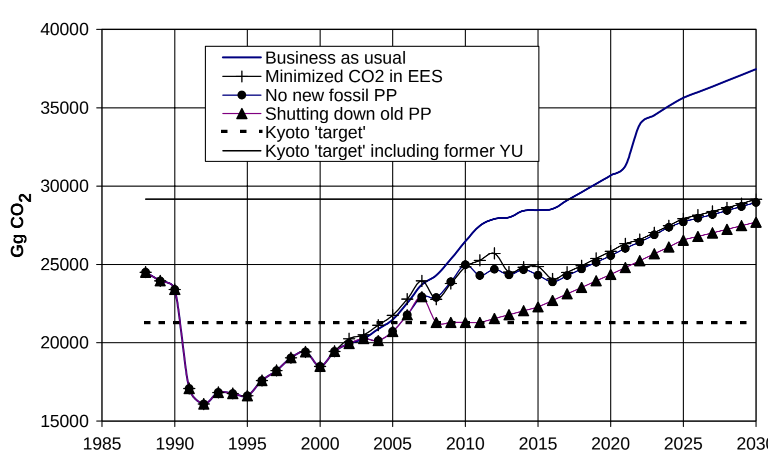

Fig. 8. Expected CO_2 emissions, comparison of different power generation scenarios.

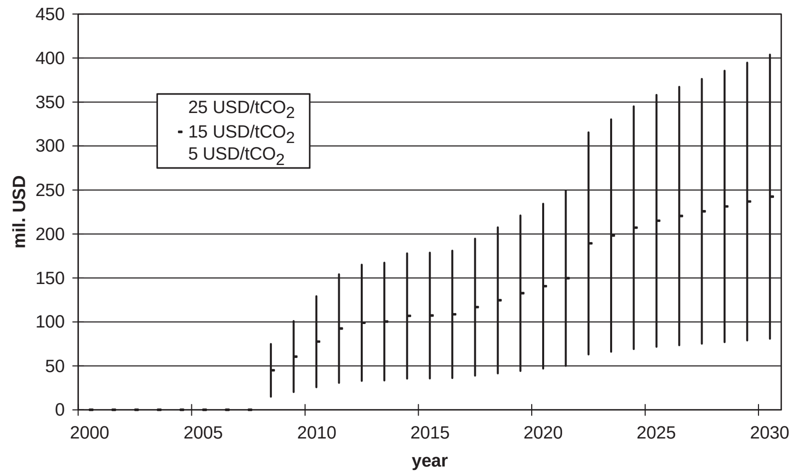

Fig. 9. Expected cost of non-compliance to the Kyoto target. The spread is between the minimal expected market price of CO_2 certificates, and the expected average abatement price, as forecasted by OECD (OECD, 1999).

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 baseline 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_2 which 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 in Fig. 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 baseline 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 Croatia's 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.

6. Conclusions

In case of business as usual energy system development in Croatia, the Kyoto Protocol target level will be breached in 2005. If the GHG emission abatement strategy concentrates exclusively on power generation, it would be possible to delay the breach until 2012 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.

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