How to Plan Energy Policy Beyond 2030

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PRESENTATION FROM SCIENTIFIC AND EXPERT GATHERINGS

The paper deals with problems of energy system development planning under restrictive conditions, which will be imposed by global climate preservation agreements. It analyses the problems of planning and impacts of particular primary energy forms and technologies. In addition, it specifies risks, restrictions and planning conditions. Pilot investigations of possible consequences of development restrictions related to considerable reductions of CO_2 emissions on energy production and consumption structure are presented. Significant structural changes and cost increases are pointed out.

Key words: energy system planning, CO_2 emissions, climate and environment protection

Environment and trends

In July 2008 the price of oil on the world markets came close to 150 USD per barrel, and by mid-October it dropped to 70 USD per barrel. At the time of the highest oil prices some predictions said that oil price of up to 250 USD could be expected, and the darkest pessimists projected the oil price of up to 500 USD per barrel.[1] Similar projections referred to gas and its price increase of 100 percent, to 0,73 USD/m^3, while some forecasts anticipated prices of 1 USD/m^3.

In current considerations analysts state a number of following dominant factors as the most influential generators of crude oil price increases:

- Higher demand for oil accompanied by inadequate increase of supply,
- Geographic distribution of fossil energy sources (supranational level) and local character of renewable energy sources (micronational level),
- Speculative impacts on the oil market, since it is undisputable that dramatic price increase was not accompanied by adequate increase of demand for crude oil,
- Global financial crisis,
- Dollar exchange rate policy and its continuous depreciation towards other world currencies in the preceding period, and expectations of experts that dollar will strengthen in the future,
- Delay in modernization of refineries, which did not dynamically follow the introduction of higher quality standards for fuel and consequent impact of demand for „sweet light oil“,
- Political tensions between some oil producers and the developed countries, primarily the USA,
- Policy of developed countries' governments to retain special taxes on oil derivatives in spite of high oil prices,
- Subsidizing of prices for derivative and other energy forms in less developed countries,
- Inadequate technological development of generators which would use other forms of energy, rather than primarily oil derivatives,
- Frequent adverse weather conditions and natural disasters,
- Technical and other incidents in oil production, transportation and refining facilities,
- Terrorism.

Each of these factors of influence to a certain measure determines and participates in the formation of crude oil prices on the world markets, and their impact changes depending on the period. A similar analysis can be made for natural gas as well. Besides, determination of natural gas price is tied to crude oil prices.

The subject of this paper is not prediction of movements of oil prices, but occurrence of high prices and their impact on development and relations in the energy sector. It is quite realistic to expect that prices of other primary energy sources will also adequately follow the changes in oil and gas prices.

Oil prices and reserves are only one of the elements which make planning of energy future unreliable. Other elements and factors such as: opening of electricity and gas markets, uncertain technological development and above all climate changes also have to be taken into consideration.

The Kyoto protocol defines a new energy policy aimed at stabilization of concentrations of greenhouse gases in the atmosphere, which includes utilization of renewable energy sources and higher energy efficiency. Goals were set for a definite period (2008-2012), and their realization depends on legislative regulation in the area and financial support. Although the Kyoto protocol has been adopted by almost all signatory countries at declarative level, implementation of its guidelines is slower than expected.

[1] Statement of Mohammad Ali Khatibija, member of OPEC Council, on possible oil price increase to 500 dollars

The main problem of the Kyoto protocol is that only some 40 member countries of Attachment B to the Protocol have a quantified obligation to reduce greenhouse gases emissions. They include developed countries and countries with economies in transition, which are at the same time members in the Attachment and in the United Nations Framework Convention on Climate Change (UNFCCC). Therefore, China, India and undeveloped countries which recorded a growth in greenhouse gases emissions, do not have a quantified obligation to reduce emissions. Since climate changes are a global problem, efficient struggle with increased anthropogenic greenhouse gases emissions is not possible if all the countries, or at least most of the countries in the world that generate a major part of emissions are included. Therefore, inclusion of as many countries as possible, which would undertake obligations in line with their level of development and possibilities for reduction of emissions, remains one of the main goals of the new agreement. Adoption of the new agreement is expected by the end of 2009. The agreement should define the concept for reduction of greenhouse gases emissions beyond 2012 (post-Kyoto period).

Big changes in electricity and natural gas network systems, which are transforming from monopolies to open market systems, accompany processes related to the Kyoto protocol, such as introduction of trade in CO_2 emission rights. The process is slower than desired, and EU is preparing a third package of measures to accelerate the changes and create transparent conditions for electricity market functioning (In April European Parliament already voted to support new rules strengthening the EU internal energy market.)

In the former communist system countries, of which some are EU members, the energy market opening processes began later, and in some countries they were slower with strong social impact on energy prices. In addition to changes in functioning of energy market, a market for trade in CO_2 emission rights was also introduced, as one of the instruments for realization of set goals for reduction of greenhouse gases emissions.

Facts and factors of influence

Climate changes and restrictions that arise from it are the key factors which will affect the manner and results of energy sector development planning in the future. The planning concept so far took into consideration only national restrictions at the level of individual impact of each energy facility and industrial facility, or similar national restrictions in building construction. It made the planning system much simpler in comparison with future planning. The international (global) obligations to reduce greenhouse gases emissions mark a transition to a new system of cumulative obligations at the level of each country, whose fulfilment is no longer simple, since it depends on a number of influence factors which are partly above the national impacts and restrictions.

The key influence factors in future planning, which can positively or negatively affect the choice of solution, include:

- **Restriction of greenhouse gases emissions in the post-Kyoto period, as a result of global obligations from the agreement on mitigation of climate changes, whose consequence will be very strict obligations for the EU and its member countries with regard to emission reductions**
- **Increase of energy demand on global and European level, in the region and in Croatia:** demand for energy to increase personal standard and quality of living in general, and in particular to ensure development and minimum civilization needs in undeveloped countries[2] will continuously grow
- **Increase of energy demand in industry, services, transportation and households:** increase of energy demand will be partially mitigated by energy efficiency, but will significantly depend on technological development, legislative norms, standards, organization of business activities and economic strength of individuals, companies as well as each country as a whole
- **Development of energy market, establishment of uniform rules for market functioning, and efficiency of functioning of repressive mechanisms to observe uniform rules**
- **Technological development:** although development is expected in all spheres, from energy production to consumption, a particular challenge is development of greenhouse gases emission reduction technologies, nuclear electric power plants, renewable sources, energy efficiency, new appliances required by households and economy
- **Completion and construction of network infrastructure, connection of national networks and construction of transnational networks:** will affect the structure of sources and supply routes, with accompanying material and non-material costs
- **Harmonization of (global) energy policy with other policies:** primarily food production, science and technological development policies
- **Perception of people, acceptability and marketing of individual technologies**
- **Price of energy for the end user, which includes realistic environment protection costs**
- **Development of international relations, in particular development of institutional relations within the EU and the EU expansion process**.

Setting of restrictions on greenhouse gases emissions in production, transformation, transportation, distribution and consumption of energy, to reduce their concentrations in the atmosphere, introduces a new parameter in energy price: greenhouse gases emission reduction cost. It is quite certain that global emission reduction policy will increase energy costs and the price for green-

[2] Over two billion inhabitants of our planet have no access to modern forms of energy

house gases emission reduction will be a consequence of all previously mentioned influence factors. Forecasts of ultimate price are a thankless task, since in addition to global factors they are also affected by local ones, and forecasts for each country will be different.

Distribution of this price on all subjects participating in the energy sector will be partly regulated by the situation and relations on the energy market, and partly distributed to the State, energy undertakings, equipment producers and naturally on energy buyers. The ultimate price for reduction of greenhouse gases emissions will be paid by energy buyers, either directly through energy price or through state subsidies from taxes collected from sale of energy.

In a qualitative sense, the equation for solution of set goals for reduction of greenhouse gases emissions besides satisfying the energy demand should with standard market elements also include other factors, such as: security of supply, expectations from technological development and investments required for technological development, pilot projects and programs for reducing new technology costs, energy policies and measures for realization of such policies, as well as the time required for realization.

Current practice

In all models for planning of electrical energy or energy system developments, the function of the goal is an economic category, which combines investments and all operating costs, be they a result of energy and technological conditions or prescribed obligations of the State. Minimum cost is the criterion for determination of optimum solution, which will satisfy all set restrictions.

Although modelling of energy system development must be based on objective comprehension of processes and realistic costs, in the real energy system economy all elements are usually not evaluated from market aspect, and some are not even included. In the former communist block countries the social character of energy prices dominated, and the price only partly reflected the actual costs. The capital was not evaluated in market terms, maintenance was inadequate as a rule, and environmental impact was at the end of the list.

Due to high costs of equipment for production of energy from renewable sources and its relatively low availability, such energy could not compete with standard energy sources, production was stimulated by price incentives, and as preferred form this energy was taken over in full as a rule. Two market segments were formed on the basis of such concept: open market with all consequences for subjects and buyers, and market segment related to renewable sources, with guaranteed purchase and prices.

In the sphere of energy efficiency, including production of energy from co-generation and projects for reduction of energy consumption, realization of projects, i.e. results depended on the amount of incentive (through corresponding funds or directly from the State).

The simple conclusion is that relations between prices on energy market were not balanced under normal operating conditions and their balance was achieved through financial and administrative measures. Such approach is possible, but has limited scope, and results are usually modest.

Opportunities in the future

For realization of greenhouse gases emission reduction goal, as a result of global obligation prescribed in the new agreement on climate change which will come into force in 2013, each country besides real economy and legislation, has available other state measures and flexible mechanisms of the Kyoto Protocol (CDM, JI and ET). The self-regulating system is the one which through real economy and tax policy achieves the set goals. In modelling of possible development scenarios, besides the usual energy planning costs, direct and indirect health and environmental protection costs should also be included in real economic relations in the energy sector.

If we hypothetically set a goal of reducing the greenhouse gases emissions from the energy sector in the period from 2030 to 2050 by 50 percent, one can make a simplified assumption that 50 percent of energy production will be from renewable sources or „clean" fossil technologies with almost no CO_2 emissions. If we copy the present practice of financial subsidies to renewable energy resources in economic relations of that period, it is obvious that it cannot be achieved, since almost 50 percent of energy production would have to be subsidized, at the expense of other 50 percent of energy production present on the market.

It is obviously necessary to develop a new economic system in the energy sector, which will discourage technologies and sources which contribute to climate changes, and promote technologies and sources favourable to the climate and environment. It will require inclusion of climate preservation costs (reduction of greenhouse gases emissions) to evaluate correctly each technology and each segment. One of the possibilities is to prescribe limits for CO_2 emissions for each technology, taking into account the whole production process, from production of feedstock and equipment, to energy production (Life Cycle Assessment).

If we were to optimize the energy sector development on the basis of consequences, taking into account all climate and environment preservation costs (direct and indirect), objective estimation of technologies and energy sources would become possible. Finally, it would enable stronger penetration of renewable sources, „clean" fossil technologies and significant enhancement of energy efficiency. On the other hand, it would increase energy costs by raising the cost platform to a higher level, with unavoidable consequences for the economy and living standard of citizens.

Planning problem analysis

In the long run, planning is based on the function of investigated parameter behaviour in the past period, which is supplemented by factors of current insights and short-term plans. Any long-term planning is therefore „uncertain" since the time frame includes a number of unknowns. Certain assumptions and expectations are proved unrealistic later on, and a series of new influence factors appear, whose impact was not originally re-

viewed. With setting of firm goals for greenhouse gases emission reduction, the problem of planning becomes even more demanding, since we wish to obtain the expected result with great uncertainty of influence factors.

The approach to planning of energy system development under the conditions of restricted emissions increases the complexity of modelling, since it requires not only balancing of energy at annual level, but also balancing of power and daily, weekly and monthly energy production and consumption schedules, possible measures and knowledge of actual status in all sectors in which certain measures will be implemented (for example, construction). Renewable sources, which depend on climate conditions and local predispositions, and without the solution of energy storage affect security and stability of operation of other electrical power plants, have to be reviewed comprehensively, with all their characteristics.

With regard to time schedule for achievement of results, realistic realization of greenhouse gases emission reduction goals will be affected by a large number of factors, and among them the following are most important:

1. Technological development is the most important factor for realization of greenhouse gases emission reduction goals, since existing technologies do not allow realization of ambitious goals. Time is the greatest unknown in the planning process, as it is very difficult to predict precisely the moment when certain technological improvement will be achieved. The development cycle of new technologies, from the idea to commercial technologies available on the market, lasts 20 or more years. Expected technological improvements are as follows:
   a. Technological solutions for existing and advanced energy production technologies which use fossil fuels (catching/separation and underground storage of CO_2)
   b. Technological solutions for nuclear energy (fission – new generation, safety systems, waste management)
   c. Technological solutions for renewable sources (photovoltaic systems, electrical power plants with concentrated radiation of the Sun, wind power plants, biomass in cogeneration, biogas, geothermal energy, second generation of biofuels) to increase utilization rate, use of new feedstocks and lowering of investments
   d. Technological solutions for transport (use of hydrogen, hybrid vehicles, systems for improvement of traffic organization)
   e. Technological improvements on the side of energy consumption
   f. Technological solutions for energy transmission and distribution (so-called smart grids)
   g. Technological solutions for efficient energy storage
   h. Long-term solutions for waste management systems and development of waste combustion technologies
   i. Development of materials, nanostructures, IT and communication technologies, etc.
2. Global, regional and local institutional ability of countries to achieve synergy in determination of: goals and obligations, responsibilities, legislative and other assumptions, and commitment to realization of greenhouse gases emission reduction goals
3. Acceptability of such approach to citizens, as well as increase of prices due to valuation of climate and environment impact costs
4. Means, human resources and organization
5. Time required for acceptance of new technologies.

Risks

The change of energy policy goals caused by restrictions for preservation of climate introduces big changes in energy management. We can estimate that today, in 2008, it is not possible to comprehend all the consequences and risks of the future.

Acceptance of global obligation to reduce greenhouse gases emissions to a level which will not jeopardize the climate, boils down the problem of energy policy to the following: how to implement it, when and at what rate, by which technologies and consequences for the environment, life and health of people. In the process, the question is not whether it will raise the level of costs, but how to find at a new higher level of costs an acceptable (most favourable) solution from the aspect of technology and environment.

The potential risks for realization of radical reduction in greenhouse gases emission include:

1. Insufficient or delayed development of technologies, which should, from the aspect of energy and economy, offer better and more efficient solutions than those available on the market at present. According to experience technological development needs time, and it is very difficult to define precisely the time frame due to a long path from the idea, prototype, pilot project to commercial product. The risk will increase without realization of high quality cooperation between the countries and companies which develop technologies in the energy sector. The risk will also considerably increase if investments into development of new technologies are not multiplied many times
2. The time required for big structural changes in the energy sector, in view of the long time required for constructing energy facilities and reaching the level of installation which affects supply structure, and possible amortization of inadequate existing technologies which have to be constructed as „interim“ solutions. It is important to point out that new technologies need time for change in behaviour and relations, both on the energy production and energy consumption side. A significant contribution of new technological solutions or advancement of existing technologies can be expected only after 15 or 20 years

3. Acceptability of certain technologies by citizens is not guaranteed, in spite of the fact that they could contribute to reduction of greenhouse gases emissions. It is realistic to expect resistance towards all new technologies, including renewable sources, and towards nuclear power stations in particular. Inadequate marketing of certain technologies and negative perception by citizens can greatly reduce the choice of solutions
4. Security of supply and proper functioning of the energy system and all subsystems
5. Economic availability of certain energy sources
6. The costs of new energy policy concept, which will objectively be considerably higher at the beginning, but in the long run even more favourable if technologies are significantly improved, can also be risky in realization of new energy policy
7. Responsibility of each country and capability to implement its own energy policies
8. Lack of global agreement on incorporation of environment and climate protection costs into the price of energy will direct the flows of global energy market to countries where energy is cheaper, slow down economic growth in countries which accepted new price calculations, and fulfilment of environment protection goals will become questionable.

Fossil fuels

Oil and gas

Oil and gas are basic forms of energy in the current structure of energy supply, whose share in total energy consumption exceeds 50 percent. From 1987 to 2007 proved oil reserves have increased by 36 percent, or from 145 billion m^3 (910 billion bbl) to 197 billion m^3 (1 240 billion bbl), and the ratio between consumption and proved reserves remained at the same level in the last ten years. Availability of oil on the market is higher in 2007 than in 1998, when the price was at record low level. In spite of these favourable indicators, expected increase of oil consumption in the future, speculations on the market and geopolitical instability (reserves are primarily in the Middle East) have caused an exceptional increase in oil prices in the last five years and, consequently, the increase of natural gas prices. Dramatic increase of oil prices and resulting increase for all other forms of energy, opened up the question of oil prices and its availability for growing consumption and indicated a lack of efficient mechanisms which could have an influence on such circumstances.

In the long-term planning of energy development within the energy policy concept with radical reduction in greenhouse gases emissions, the position of oil and gas will experience changes, both through higher efficiency of technologies (technological development of vehicles should reduce consumption by over 40 percent until 2050) and through substitution of fuels:

1. Oil, i.e. oil derivatives are primarily in the function of transport, and it is expected that they will retain their dominant position. In the energy sector the use of oil in generation of electricity is being abandoned, with the exception of special circumstances or only as a stand-by solution
2. Natural gas has replaced oil in generation of electricity, and in developed countries it is becoming dominant in the production of heat energy, and gradually starts to participate in transport.

Coal

In the total consumption of energy coal follows immediately after oil with a share of 25 percent, while it is a dominant fuel in generation of electricity with a share of 40 percent. Proved coal reserves in 2007 amounted to 847 488 million tons. Reserves are equally distributed with a share of about 30 percent between Europe and Eurasia, North America, Asia and the Pacific. Although the price of coal has considerably increased in the last several years, from the aspect of availability and production price coal continues to be the most favourable fuel. Existing capacities for electricity generation in the OECD countries will have to be replaced by new ones in the next 10 to 20 years, and if we take into account the increase of electricity consumption in developing countries, it is clear that decisions made in the next several years will have far reaching effects.

Reduction in CO_2 emissions is the basic determinant in development of new technologies for use of coal, and it is tried to be reached by the following measures: increase of conversion efficiency, co-combustion of coal and biomass and catching/separation and storage of CO_2. Coal could retain the present share in generation of electricity, or increase it with development of the following technologies:

- Conversion efficiency: advanced steam turbine technologies (supercritical and ultracritical) or integrated gasification combined cycle technologies (IGCC) should enhance average efficiency of coal-fired thermoelectric power plants from present 35 to over 50 percent by the year 2050
- Catching/separation, transport and storage of CO_2 – some catching/separation and storage technologies are already in the phase of demonstration, while others require further research and development in order to reduce the costs and enhance efficiency. The cost of catching/separation, transport and CO_2 storage system is estimated at 25 to 80 Euros per ton of avoided CO_2 emission. However, these technologies are not yet in wider use in the world due to relatively high costs of CO_2 extraction technologies, necessity for additional technological improvements of CO_2 separation and catching, and problems of finding suitable geological locations for CO_2 storage near the facility.

If technological development fails to provide adequate results or is delayed, the share of coal in total consumption of energy sources can decrease. In that case nuclear energy and natural gas will probably replace coal. In view of higher uncertainty in prediction of gas than coal prices, conversion from coal to natural gas will be dictated by changes in natural gas prices, while

substitution with nuclear energy depends on perception of the public, proliferation and development.

Nuclear energy

Nuclear energy belongs to low emission technologies, but with risks that accompany nuclear energy in operation and fuel disposal. Sensibility of the public is high, and the greatest risk is acceptability for the public and political implications arising from it. Due to long negative attitude of the public towards nuclear power stations development of new technologies was stalled, as well as education of experts and stagnation of production capacities in the whole nuclear cycle. The time required for preparation and construction of new electric power plants is nowadays estimated at 10 to 13 years.

On the other hand, nuclear technology imposes itself as a realistic solution in the greenhouse gases emission reduction concept. The current technological level has reached an enviable level of security, but low fuel utilization rate. Development of fusion can objectively open the doors wide to nuclear technology, but after the year 2050.

Although most frequent risks in trade with energy sources in the perception of public relate to oil, and recently to gas, it is realistic to expect that higher level of interest in nuclear technology will increase the pressure on nuclear fuel, which in addition to energy-related also has a strategic significance. Market impact is evident in the last four years, when raw uranium prices at first increased tenfold, and then gradually fell to fivefold level in comparison with the price in the last twenty years.

Renewable sources

The use of renewable sources has considerably increased in the last ten to fifteen years. Although the increase refers to installed power in electrical power plants, the impact of renewable sources on the structure of electricity generation is still far from significant.

During the whole period renewable sources were accompanied by discussions about potential, technical problems, environmental impact, energy tax, taking into account the whole cycle of fabrication of equipment and appliances, and naturally, the price of energy.

There are three main reasons for bringing renewable energy sources into the limelight: limited reserves of fossil sources, lower energy dependence through domestic sources and problems for protection of the environment and climate changes. The third reason, protection of the environment and climate changes, is becoming dominant, since solution of climate changes problem will consequently lower the pressure on use of fossil fuels.

Financial and administrative solutions used in promoting the use of renewable sources included the regulation of positions and financial support which enabled the commencement of their utilization. The methods used opened up a number of questions related to existing planning methodologies, such as: relations with other sectors (food production), realistic energy tax within the context of the whole cycle, objective impact on protection of the environment, price of renewable energy, etc. Increase of energy production from renewable sources requires a new approach, which will be more economically, and less administratively oriented; more market-determined, and less subsidized (naturally, with much more financial resources invested into technological development).

The key conclusion is that present technological generation of appliances and equipment has no potential for significant substitution of fossil fuels, and it is necessary to intensify research, and in particular to pool the financial and human resources in realization of new generation technologies for use of renewable sources, which would have an impact on efficiency and financial profitability.

Electricity

In the preceding period technological development exerted the greatest pressure on use of electricity in every segment of human requirements and activities. Such trend can also be expected in the future and the greatest challenge will be finding technological solutions which will satisfy restrictions in greenhouse gases emissions in generation of electricity. The following period will be particularly demanding in several ways for development of electricity systems due to several reasons:

1. Development of technologies acceptable for production of electricity
2. Security of supply of certain primary sources of electricity
3. Multiple increase of complexity in electrical system control, under the conditions of extensive representation of renewable sources and distribution of low power production
4. Development of electricity market
5. Storage of electricity.

Transport

Transport is a particularly challenging sector for planning in the future. Transport growth is continuous and increases at high rates (fuel consumption at the level of the EU–25 has increased in the 1990 – 2004 period by 29%).[3] Depending on electrical energy production structure in individual countries, it is the first or second sector by the level of greenhouse gases emissions. Technological development in the sector is continuous, and new types of vehicles are more efficient. Consequently, average annual energy consumption growth rate in transport has decreased at the level of the EU 27 from 1,8 (in the period from 1990 – 2005) to 1,4 percent (in the period from 2000 – 2005).[4] On the other hand, quality of roads and economic power of individuals is in-

[3] Panorama of Transport, Eurostat, Edition 2007

[4] ODEX indeks, ODYSSEE - MURE database, May 2008.

creasing, and in spite of technological development, demand for mobility and consequent fuel consumption is permanently increasing.

The problems of transport are nowadays topical, primarily due to the price of oil derivatives, and unfortunately less due to the reduction of greenhouse gases emissions. The use of substitute fuels is not significant, and new technologies are not ready for stronger penetration. The use of most frequently mentioned biofuels (whose market introduction is the simplest) calls for fundamental analysis of unfavourable factors that biofuel production can have on availability and price of food, and added value of energy is questionable in comparison with energy consumption in production and total CO_2 emission in the production chain. Biofuels of the 1st generation do not have sufficient quantities of feedstocks for sustainable substitution of fossil fuels for transport, and technologies of 2nd generation biofuels are not ready for stronger penetration. The application of new technologies such as batteries or combustible cells will greatly depend on future development and cost reduction. The use of natural gas can mitigate the problem to a certain extent. On the other hand, use of natural gas in transport is a natural predecessor of hydrogen-based technologies.

In the long-term vision of the situation in this sector, greatest expectations refer to technological development of new generation fuels and generators, which will not happen so soon, and which will be gradual. Development of hybrid vehicles, electricity storage and use potential and advanced logistics in transport open up new challenges in planning.

Energy efficiency

Consumption of energy, and energy efficiency and quality of living in particular, is a result of a large number of influence factors, such as economic power of the society and citizens, technological development, historical heritage, culture of living, etc. Energy consumption quality is not a static value, and changes as a result of global and local influences.

If we were to set as the goal of energy efficiency satisfying of requirements, in line with financial abilities and at lowest possible energy consumption, it could be concluded that all three components from energy efficiency definition change with time:

- Demand for energy will grow with development of new appliances to be used by citizens and economy, with increase of general and public standard of living and with increase of quality of living. Increase of demand for energy due to increase of population is questionable, since trends are negative or slightly positive in the majority of European countries. Migrations of population can have a certain impact, but they are difficult to evaluate
- Technological development enables the use of new appliances and materials, which require less energy for the same quality of service
- Legal measures and economic interest will promote the construction of higher quality buildings, old buildings will be revitalized, management of processes and organization of work will be improved. It can be expected that in the future inadequate energy condition of buildings will be the starting point for initiation of processes for renovation of existing buildings as the largest consumers of energy, but it will be a long process. Introduction of energy certification of buildings can have significant affect on the increase of construction quality and modernization of existing buildings, and can contribute to reduction of costs during the lifetime of a building. The key factors which will have an influence on increase of energy efficiency are: introduction of energy classification for buildings, integration of renewable energy sources in buildings, improvement of quality of living in buildings, comprehensive approach and integration of technical, energy, economic, ecological and social parameters in the planning process, and long-term approach to analysis of buildings taking into account its full life span, including construction, use, maintenance, renovation and demolition.

It involves processes with contrary effects, and according to the experience in developed countries, the component of increase of requirements prevails over other two components. In undeveloped and less developed countries the growth of demand is even more pronounced.

It can be realistically expected that increase of energy efficiency will primarily have an affect on deceleration of growth, i.e. on reduction of energy consumption growth rates through introduction of new technologies and gradual substitution of older, less efficient technologies. The goals to reduce energy consumption in absolute amount in comparison with present or expected consumption in the near future will partly depend on technological development of appliances and materials, and mostly on economy of the whole project and distribution of costs that represent a public interest to the State and others, i.e. to entrepreneurs and citizens. Realistic energy price, which includes environment and climate protection costs, can speed up energy efficiency enhancement processes.

Progress in energy efficiency has to be achieved at all levels of technological cycle: production, transport, transmission, distribution, consumption and energy management.

Simulation of possible CO_2 reduction consequences in Croatia until 2050

This pilot analysis analyzes for the first time the period beyond the year 2030. All planning until 2030 so far was based on end-use modelling, using analogy with past events in economically developed countries, and on simulations. However, if we want to analyze what can be done in the long run and how to reduce CO_2 emissions radically, than such approach is unsatisfactory. It is necessary to apply a model which equally treats investments in energy efficiency, renewable energy sources and standard energy sources in search for minimum costs of construction and energy system operation, at the same time observing the current restrictions in CO_2 emissions. The MARKAL model was used with that purpose in mind.

The basic determinants are 4 million inhabitants in Croatia by 2050 and six fold higher GDP per inhabitant

of around 30 000 USD at prices from 2000. Alongside with increase of housing, it was assumed that new buildings will have twice better thermal characteristics in comparison with existing ones, which will continue to improve in the future. For currently existing housing facilities future heating requirements were estimated without improvement of heat insulation, because the model is aimed to estimate the required level of improvement. Consumption of energy in transport was modelled according to the estimates from WEC study for Europe until 2050, according to which energy consumption in transport per inhabitant will be slightly lower than today. In that structure the share of derivatives would be around 70%, and about 30% would be covered by hydrogen, natural gas and biofuels. Useful industry energy requirements were established according to intensity, and they have been at very low levels in West European countries for ten years now.

The first conclusion arising from the analysis is that energy efficiency is profitable even without CO_2 emission restrictions. Investment in improvement of thermal insulation in residential and business premises according to utilization of more and more expensive end energy sources, without restrictions on CO_2 emissions, was modelled. The result is that until 2050, even without requirements regarding CO_2 emissions, investing in improvement of thermal insulation in residential and business premises is twice more economical than today, but if we wish to halve the present CO_2 emissions from the energy system, then thermal insulation has to be improved at least three times. This additional improvement of thermal insulation in building construction due to the set goal to halve the present CO_2 emissions, is a result which competes with other CO_2 emission reduction possibilities, primarily in generation of electricity, but also in the change of final energy consumption structure by increasing the use of renewable energy sources and use of efficient technologies, such as heat pumps, etc.

Fig. 1. Projections of energy consumption in Croatia until 2050
Sl. 1. Projekcije o neposrednoj potrošnji energije u RH do 2050. godine

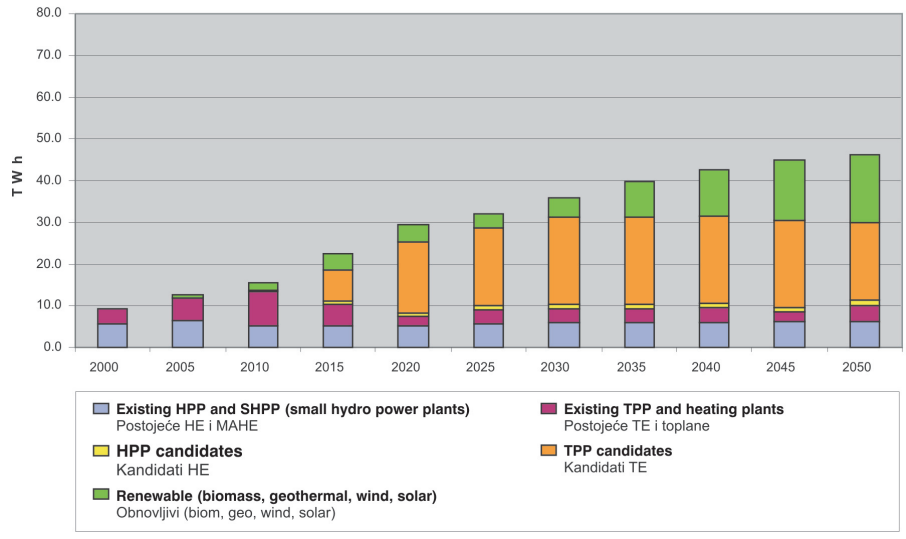

Fig. 2. Projections of required electricity generation in Croatia until 2050, without restrictions in CO_2 emissions.
Sl. 2. Projekcije o potrebnoj proizvodnji električne energije u RH do 2050. ne uzimajući u obzir ograničenje emisije CO_2

Total final energy consumption will relatively intensely increase until 2030-2035 (Figure 1), and afterwards will remain at the same level. In the scenario by which we want to halve the current emission of CO_2, final consumption will decrease towards the year 2050.

The CO_2 emission reduction goals will have the strongest impact on generation of electricity. In the scenario without restriction of CO_2 emissions, total demand for electricity in 2050 will amount to 45 TWh (Figures 2 and 3). However, in the scenario with reduction of CO_2 emissions by 30% and 50% until 2050, total demand for electricity significantly increases, as a result of most economical reduction of CO_2 emissions through higher penetration of electricity on coverage of heating requirements, and mobility. Naturally, in that case electricity is generated almost without CO_2 emission. It means that the share of electricity production from renew-

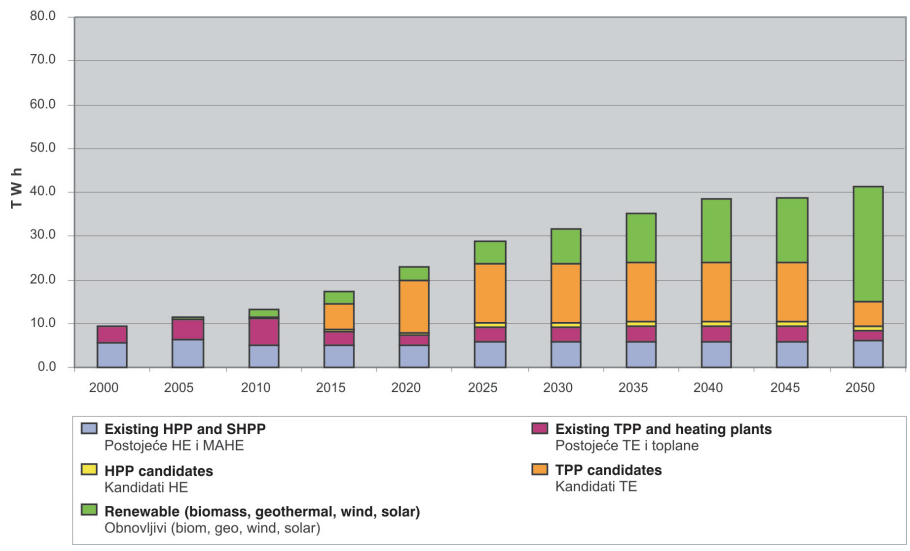

Fig. 3. Projections of required electricity generation in Croatia until 2050, under the assumption of improved thermal insulation in buildings
Sl. 3. Projekcije o potrebnoj proizvodnji električne energije u RH do 2050. pod pretpostavkom poboljšanja toplinske izolacije objekata

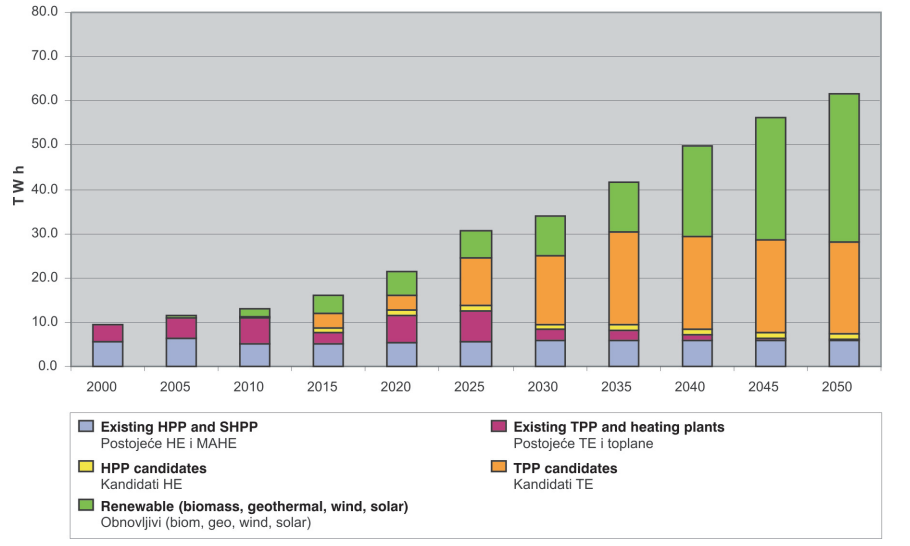

Fig. 4. Projections of required electricity generation in Croatia until 2050, under the assumption of improved thermal insulation in buildings and reduction of CO_2 emissions by 30%
Sl. 4. Projekcije o potrebnoj proizvodnji električne energije u RH do 2050. pod pretpostavkom poboljšanja toplinske izolacije objekata i smanjenja emisije CO_2 za 30%

able sources, including large hydroelectric power stations, could increase by as much as 50%, depending on realistic possibility for such production by wind power, biomass (plantation-source biomass) and solar power, and general acceptability of nuclear energy at the level of Europe. Production of electricity in thermoelectric power plants implies nuclear energy and natural gas and coal fired thermoelectrical power stations using liquefaction technology and storage of produced CO_2. With the goal of reduction of CO_2 emissions by 30%, total consumption of electricity in 2050 will increase to 60 TWh, and in the 50% reduction scenario to 70 TWh (Figures 4 and 5).

Naturally, in the scenario for reduction of emissions by 50% in the period until 2050, total investments in energy system, including installations at the consumer end, would cumulatively increase by 100%.

The results of research of pilot project indicate necessity for detailed analysis, since ambitious reduction plans significantly change currents views on energy sector development.

Conclusions

At the end, the following conclusions can be made:

1. Planning of energy system development, taking into consideration radical reduction of greenhouse gases emissions, represents a new approach in the development of energy system. Due to expected stronger penetration of renewable sources and distributed production, modelling must include detailed analyses and calculations in order to achieve calculation credibility. It will require development of new models and their integration, use of information technologies for information pooling and processing.

2. It is not possible to reduce the level of emissions on the basis of present technologies and all expectations are directed at new generations of facilities, equipment and materials. Technological development represents a key factor in possible changes of energy policy and its goals. Synergy in technological development (financial and among people) is crucial for success of new policy.

3. Big reduction in greenhouse gases emissions will change relations in the energy system. Significant increase of electricity consumption is expected, because it will be easier to solve the problem of emissions in small

production facilities than in individual objects in households, service sector and industry.

4. New energy policy will require considerably higher price level, due to incorporation in energy price of climate and environment protection costs at the level of global and local goals, and costs of technological development. Increase of up to 100% can be expected.

5. Stronger penetration of renewable sources is not possible on the basis of incentives and formation of double incentive-based and open markets, but on the basis of a single open market on which the real economy will generate self-regulating mechanisms for realization of energy policy goals.

6. A system of objective measurement and financial sanctions for exceeding greenhouse gases emissions must be established at the level of countries, according to real costs of emission reductions.

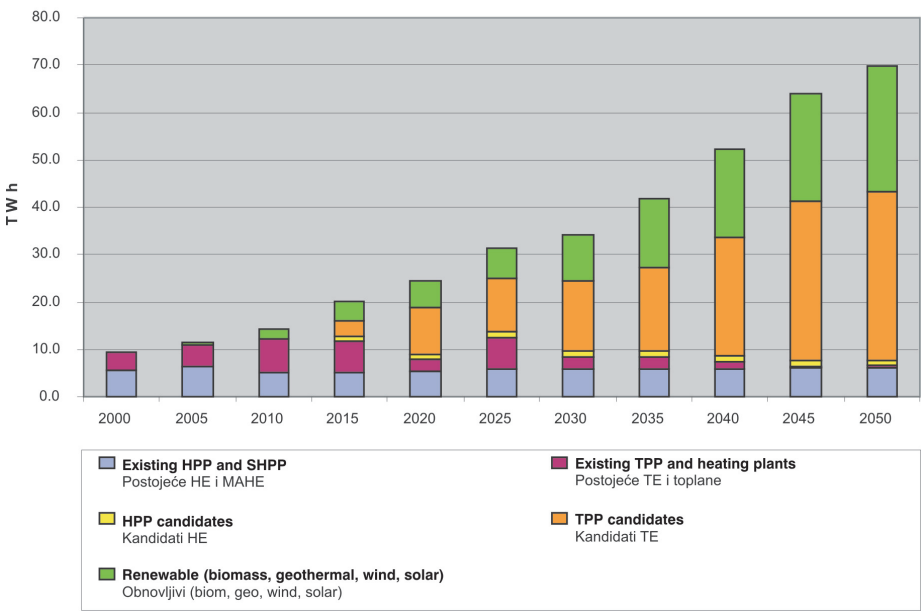

Fig. 5. Projections of required electricity generation in Croatia until 2050, under the assumption of improved thermal insulation in buildings and reduction of CO_2 emissions by 50%
Sl. 5. Projekcije o potrebnoj proizvodnji električne energije u RH do 2050. pod pretpostavkom poboljšanja toplinske izolacije objekata i smanjenja emisije CO_2 za 50%

7. Attitude of the public towards the success of new energy policy, which should enable reduction of emissions, particularly with regard to nuclear energy and systems for extraction and storage of CO_2, are of particular importance for its success.

8. Security of supply is a special dimension of planning in view of geographical distribution of primary energy sources and risks in supply of energy. Optimization of risks is necessary, and so is the incorporation of security of supply costs into the price of energy.

9. Limited time for big changes is the highest risk of ambitious plans for change in energy policy and for radical reduction of emissions of CO_2 and other greenhouse gases.

10. Availability of information under market conditions (controversy, since it advocates market competition on the one hand, and additional efforts in joint development and research and sharing of knowledge and resources on the other hand).

References

1. Granić, G…et al. Regija i Hrvatska u konceptu scenarija WEC-a // 16. Forum Dan energije u Hrvatskoj: Energetska budućnost u svjetlu odnosa i integracijskih procesa u Europi: zbornik radova. Zagreb, 23. studenoga 2007, str. 11-34.
2. Granić, G; Pešut, D; Jandrilović, i suradnici: Does the Energy Sector Reform Call for Reform? // 20th World Energy Congress - Rome 2007: Energy Future in an Interdependent World. Roma, November 11-17, 2007.
3. Granić, G…et al. Što se ostvarilo, a što su novi izazovi u energetskoj strategiji Hrvatske // 15. Forum Dan energije u Hrvatskoj: Energetske perspektive do 2050. Svijet-Europa-Hrvatska: zbornik radova. Zagreb, 23. studenoga 2006, str. 11-42.

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