

Vision of energy sector development, relationships and influences in Croatia by 2050

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PRELIMINARY COMMUNICATION

The paper reviews a possible vision of the Croatian energy sector by 2050, various relations and influences that could impact energy development. The analysis has been made on a qualitative level by taking into consideration energy markets, energy efficiency, conventional and renewable energy sources. In the end, the paper presents recommendations for further energy system development.

The authors advocate a new concept of development platform based on energy efficiency, new technologies and renewable energy sources. Croatia has all resources for its realization. The new development platform can also create additional opportunities for the development of science and economy.

Key words: energy sector, vision 2050, energy efficiency, new technologies

1. Introduction

Croatia is about to face significant social, political, economic and other changes in the imminent future. On 1st July 2013 it will become a full EU member with its legislation harmonised with *Acquis Communautaire*.

At the same time the European Union and entire world are confronted with historical challenges: climate change, environmental protection, technological advancements and energy efficiency. These challenges involve all segments of the society and affect each and every citizen and household.

Today's CO₂ concentration in the atmosphere is about to exceed ecologically acceptable limits, while on the other hand we have growing population, higher standard of living, and consequently, higher energy consumption. Undeveloped and island countries will be most affected by climate change and consequences such as sea level rise in coastal regions, erosion, inundation, and storm surge. Response to these challenges must include a shift in human behaviour toward the environment. The change of attitude means change of our value system, setting of new development platform, but also redistribution of energy cost structure in favour of environmental protection and use of clean technologies.

The current energy development platform concept, adopted more or less by all developed countries, is based on measures focused on protection of the environment, use of clean technologies, improvement of energy efficiency, which should ensure additional effort on top of measures enforced by laws and regulations and financial subsidies. The European Union energy targets to be met by 2020 known as '20-20-20' targets include: reduction in EU greenhouse gas emissions of at least 20%; 20% of EU energy consumption to come from renewable re-

sources; a 20% reduction in primary energy use compared with projected levels, to be achieved by improving energy efficiency. This is the only feasible solution in the situation when a leading development philosophy mantra is "maximum profit at minimum costs" but on the expense of the environment and resources. A feasible solution is presented in the document called: Roadmap 2050 a Practical Guide to a Prosperous, Low-carbon Europe published by European Climate Foundation in 2010. A new development platform must take into account the cost of climate and environment protection and incorporate it into real economic relations, while enforcement of laws and regulations and subsidies should be used only for acceleration of some processes, but not as an underlying mechanism for a change of our value approach to the environment. However, it will not be possible to achieve necessary reduction of anthropogenic greenhouse gas emissions on global level without participation of all countries, particularly the USA and fast growing countries like China and India.

The international community has not reached yet a global agreement on reduction of greenhouse gas emissions to acceptable level so as to mitigate the rise of global average temperature (by maximum +2 °C) by the end of the century. Developed countries commenced preparations for adjustments by investing considerable funds in development of new technologies for generation of energy from renewable sources. At the UNFCCC conference held in Cancun (Mexico) in December 2010 it was agreed that the developed countries would set up a fund in order to assist developing countries to meet their emission reduction obligations through transfer of state-of-the-art technologies for renewable energy production. The decision on quick start of ten billion dollar

fund has been made, but final goal is to ensure the funding of 100 billion dollars annually by 2020. Obviously, these are considerable funds to be invested in developing countries, but it also means that several times higher funds need to be compiled for the development of new technologies and equipment in developing countries, particularly in fast growing countries (China, India, S. Korea...).

According to IPCC projections, developed countries should reduce GHG emissions by 25-44% against the 1990 level by 2020, while by the year 2050 global GHG emissions should be reduced by 80-95% (*European Climate Foundation: Roadmap 2050 a Practical Guide to a Prosperous, Low-carbon Europe, 2010*). Reduction of anthropogenic GHG emissions of minimum 50% on global level by 2050 is a precondition for realization of IPCC's optimistic scenario which foresees stabilisation of concentration of greenhouse gases at 450 ppm and rise of average temperature around 2% by 2100 compared with 2000 average temperature. If such emission reduction is not achieved, by 2100 the concentration of greenhouse gases could increase to 1 000 ppm and temperature even by 6 °C, with unprecedented impacts on climate.

It is essential to design adequate policies now, policies that will enable meeting of goals aimed at preservation of climate and the environment. All relations in the energy sector are interlinked and it is not possible to build parallel programmes without unambiguous link. This link is the price of energy which includes all elements from cost of generation, transmission, distribution and supply of energy, as well as realistic costs of environmental and climate protection and which, by itself, drives economic interest for development based on new philosophy of energy management and application of new technologies.

Radical abatement of CO₂ and other greenhouse gas emissions by 50% or even 95% in entire energy sector would have significant impact on all phases in energy value chain: from energy generation, transformation to other desired form of energy, transport/transmission, distribution, management, appliances and consumers, consumers' needs and their use of energy.

A new development platform should ensure meeting of preconditions for expected growth and improvement of public and personal standard, and at the same time, meeting the conditions for preservation of climate and the environment. Technology advancement is a key component of the new development platform, because current technology level does not enable meeting of set goals for climate preservation and for achieving security of energy supply.

Apart from climate and environment preservation and security of energy supply, the new platform should also ensure creation of a new value added in the Croatian economy to be achieved through technology development and greater participation of domestic industry and service sector. Certain aspects of the development platform will be commented in the light of their contribution and impact on the following issues:

- economic development
- preservation of climate and the environment

- technology development
- energy efficiency improvement
- wider use of renewable energy sources
- use of smart grids and their benefits
- energy costs
- security of supply.

As a full EU member, and the member of international community, Croatia will be obliged to reduce GHG emissions by at least 50% by 2050 compared with the reference year. For Croatia it is important to deploy such an approach as its own choice, and to pursue it as its basic orientation. Realization of this goal is possible but it is necessary to design a new strategy which will evaluate more realistically economic impacts of environmental protection and climate change and create assumptions for technology and industrial development, improvement of energy efficiency in all economic activities, improvement of public and personal standard of living, use of renewable resources and technologies which reduce detrimental effects on the environment, and to enhance transport, agriculture and tourism development.

2. ENERGY MARKETS

After adoption of the Third energy package and its incorporation into the Croatian legislation, Croatia will have legal and institutional infrastructure for the development of open energy market. What will be the dynamics of market opening and what will be the impact of energy market opening, climate change, incentives for use of renewable energy sources and energy efficiency – these issues should be resolved in the new development platform.

Participants in the energy market have different interests:

- Buyers want secure supply of energy at reasonable price, right to choose, availability of technology and compliance with prescribed regulations
- Energy undertakings want depoliticized energy prices, access to infrastructure, efficient regulation and long-term strategy of all processes
- Government is obliged to implement adequate climate and environment protection policy, enforcement of laws and regulations and the obligation to safeguard security of supply.

Security of supply could be defined as a capability to deliver indispensable volumes of energy necessary for living and for protection of citizens, for functioning of necessary infrastructure and public services, running of institutions and businesses which need energy for their technology processes or if they make part of supply security systems, capability to ensure strategic and operational energy stocks necessary for national security and defence in case of serious disturbances or emergency situations. It is not so important what caused an emergency situation or disturbance in supply, but it is essential to assess consequences of such situations and their impacts on lives of citizens and operation of businesses.

From security aspect, transport/transmission and distribution lines play a key role as they ensure linkage to important transport routes. Overall investment environ-

ment and actual relations in economy are very important for security of supply, because appetite for investment is closely linked with possible return on investment and profit generation.

For crude oil and oil derivatives, European Commission set up a system of strategic stock keeping, the so called compulsory stocks, which is based on keeping necessary stocks of oil and derivatives required for 90 days consumption in each EU member state, including Croatia.

2.1. Electric energy

Although the reform of the Croatian energy sector started ten years ago with the adoption of the first package of energy laws, real functioning of the electric energy market has not been established. Formally, the market is fully open, but neither in power generation nor in supply there is sufficient number of participants to create real competition. The existing, exclusively bilateral power trading mechanism is inapt for market development and transparent setting of electric energy prices, and it certainly contributed to the domination of a single power producer.

Even in the European Union the electric energy market has not been fully opened, however, the degree of integration of national markets is increasing. In addition to the developed regional power exchanges like Nordic Nord Pool, we are witnessing the trend of market coupling and formation of regional markets. This model enables the existence of national power exchanges and their interconnection in daily trading. In this way they achieve the effects of integrated regional market, higher liquidity and price harmonization, but at the same time national market operators preserve their authority. It also eliminates the need of full harmonization of national regulations with interconnected markets which facilitates market integrations. Such interconnection with the countries in the region could have an important influence on the development of the Croatian power market with positive effects on both power producers and suppliers, but also on end consumers.

For the initial development of Croatia's power market after implementation of the third package, it will be very important to have depoliticized pricing policy and transparent functioning of relevant institutions, certain level of electricity market development in surrounding countries to which Croatia gravitates, interest for investment in new facilities and transmission system interconnected with neighbouring countries systems. Further development of electricity market will be impacted by climate protection policy and Croatia's obligations in this area, increased use of renewable energy sources, development of smart grids and management and technology advancements in all segments from power generation, transmission, distribution and consumption. Of course, in all phases of electricity market development, the economic development of Croatia and the level of public and personal living standard of its citizens will play an important role all the time.

Trading on exchanges has become a dominant mechanism for setting wholesale electricity prices, and it is also used as a reference for non-exchange transactions and

bilateral trading. Considering the size of the Croatian market, the biggest problem for the functioning of power exchange will be liquidity. Increased number of participants and traded volumes could be achieved by setting a minimum share that must be offered on the exchange by producers. Such a measure can be only temporary until more participants emerge in the market and increase its liquidity, at which point the obligatory share for trading could be decreased. Nonetheless, all European exchanges tend also to develop long-term electricity trading and/or its financial derivatives, enabling participants to manage risks in the mid-term.

Even if it is assumed that the third package goals referring to electricity market are fully realized, and the market becomes dynamic, transparent and efficient, while the institutions foreseen by the third package operate independently, the question remains what electricity will be traded, in what volumes, at what price, in the market with its own forces but also with the obligations stemming from climate change programmes. It is important to notice that certain processes are in conflict with each other. In particular, the idea of open electricity market development is in conflict with the idea of larger share of renewable energy sources stimulated through various subsidies. If we imagine an extreme situation in which all generation is renewable and it is entirely subsidized, it would exclude market as a development option. As a conclusion, we can say that if we want to ensure a sustainable development of electricity market, it is essential that renewable energy sources be normal participants in the market without subsidies, so that electricity price includes actual costs of climate and environment protection.

Electricity market development will be affected by economic growth, increase of public and personal standard of living (growth in electricity consumption) technology development reflected in larger number of appliances and automation in industry and service sector, improved energy efficiency in all segments, specifically in buildings, as well as efficiency improvements as a result of technology advancement. Eventually, it is possible that non-heat electricity consumption in housing and commercial sector will represent only a minimal share of traded volumes in electricity market.

Further impact that will affect electricity market will be the progress achieved in smart grids development, level of their use in grid management and efficiency improvement and capability to integrate renewable energy generated by buyers, cogenerations, fuel cells or other new technology solution. Possible development in this direction, if it receives economic support through realistic prices, will influence distribution and transmission grids design plans and level of power generation for the market.

Market liberalisation history teaches us that liberalisation augments the problem of security of supply, which is still present in Europe. Setting of power prices on exchanges in the short-term, creates insecurity and increases risks of long-term investments in generation capacity. Integration of renewables contributes to decrease of conventional sources working hours and erodes their competitiveness, while on the other hand,

due to their intermittency and variability, generation of renewables requires back up energy. Lower investments in technology intensive conventional power generation plants may result in less back up energy in the system and less security of supply. Centralised planning of new generation plants with the purpose of ensuring sufficient back up energy in the system is essential for security of supply and it should remain the responsibility of the regulator. In addition to the cost of generated energy, many European countries introduced the mechanism of capacity or availability charge by which they tend to mitigate risks and stimulate investments in new generation plants.

2.2. Natural gas

The implementation of the third energy package will open up new opportunities for further growth and development of natural gas market. The gasification of Croatian regions that were not served is going on. There is also additional room for gasification of industry and public sector facilities through replacement of existing energy source, and of course through new projects. In the long run, the number of natural gas buyers will grow. In general, it is estimated that economic growth and higher public and personal standard of living will result in increased demand for natural gas.

Natural gas is used in power and heat generation and in households for all heating requirements. Natural gas demand will be influenced by several key factors that will stimulate or hinder consumption. The level of their impact will change gradually. The basic feature of natural gas is that it has lower CO₂ and other greenhouse gas emissions than most frequently used oil derivatives. Due to this advantage, in the first stage natural gas will be favoured in investments aimed at replacing boilers and equipment using oil derivatives with gas powered appliances.

The implementation of radical measures for reduction of CO₂ and other greenhouse gas emissions through improvements in energy efficiency of buildings and efficiency of appliances and equipment that use natural gas will result in decreased consumption of gas per unit of housing and business premises. In the scenario predicting the highest CO₂ reduction, it is assumed that natural gas consumption by end users will be partly or entirely abandoned. Instead, natural gas will be used for firing large centralised heat or cooling energy units, or for power generation, but with CO₂ sequestration and storage units.

The above facts point to the conclusion that gas market will change in the future and that climate protection programmes will have significant impact on gas market volumes.

2.3. Heat energy

Heat energy market is a typical local market and according to current experience in Croatia each heating system development project is a unique case. As a result of former political influence on setting heat energy prices, the entire sector is in quite unfavourable economic and financial situation with weak prospects for building new capacity.

About 10 percent of all households in Croatia are connected to the remote heating systems, while 12 percent of total energy is used for remote heating and hot water supply to housing sector. In most cases heating energy is mainly produced in remote heating systems powered by fossil fuels (heavy fuel oil and natural gas) with very small share of renewable energy.

The heating energy market does not exist in the situation with such small number of participants because there is no competition in heat energy generation.

Improved efficiency in buildings will result in reduced need for heating energy in apartments and business premises, however, a new opportunity for using heat energy for cooling should be exploited in the future, which was not the case until now. On the other hand, radical measures for CO₂ reduction could lead to higher use of remote system for heating and cooling because end users will be discouraged to use their own heating or cooling appliances.

Croatia should foster the development of remote heating systems and work toward enhancement of their energy efficiency, reliability and security of supply, which can be done with new state-of-the-art technology and increased share of renewables. This option involves solutions like cogeneration, biomass, use of pre-insulated piping, improved regulation of remote heating system on all levels, including consumption control and management. All these measures would have indirect positive impact on the environment.

2.4. Oil derivatives

The specific feature of oil derivatives market in comparison with other energy sectors is that it is marked by high level of competitiveness, mainly thanks to various transport possibilities. The supply is not constrained with transport through grids as is the case with natural gas, electricity or heat energy.

Similarly to many other countries, oil derivatives still have very high share in Croatia (almost 50 percent) in total direct energy consumption. It is estimated that this share will remain considerable in the next twenty years as it is not likely to expect dramatic shift in energy mix in short time.

Economic development usually brings higher standard of living, which also involves growing number of automobiles. From the aspect of derivatives consumption, growing number of automobiles does not necessarily mean that in the long run it will be accompanied by growing consumption of derivatives, because new fuels will gradually be used. This trend will be supported by technology advancements in car engines with positive impact on lower fuel consumption per kilometre.

Reduction of greenhouse gas emissions and meeting of set goals in this respect will require changes in use of oil derivatives, in a sense that they could be used in large production processes, industrial or for power generation, provided there is a possibility (or will be) for technically and economically viable CO₂ capture and storage. This will result in considerable changes on oil derivatives market because in this case derivatives will partly compete with natural gas, if prices are competitive.

In the long run, the derivatives market will decline, but the speed of changes will depend on the influential factors mentioned above.

2.5. Liquefied petroleum gas (LPG)

LPG is used as energy source for heating and as automotive gas for fuelling vehicles. Consequently, we can talk about two separate markets which are closely interconnected, particularly from the aspect of LPG pricing, but at the same time these are two separate markets impacted by different factors. Automotive gas market is strongly influenced by motor fuels prices, while LPG as a heating energy source depends on development of natural gas network and on heating oil prices.

During the last ten years Croatian LPG market has recorded significant growth reflected in continuous increase of consumption, both in traffic and in household sector. This is primarily the result of liberalisation of LPG prices which are now based on movement of derivatives prices in the Mediterranean market, which contributed to higher competition in the market and consequently to the development of infrastructure which stimulated more users to switch to LPG.

Considering the fact that LPG contributes neither to environment protection nor energy efficiency to a great extent, its use is not subsidized in most European countries. Hence, it is not expected that the share of this energy source will have significant growth in total energy consumption.

3. CONSUMPTION AND ENERGY EFFICIENCY

Energy efficiency should represent a key component of a long-term energy strategy and strategy of climate and environment protection. The following measures should be used for enhancing energy efficiency:

- enforcement measures, legislative measures that oblige investors and manufacturers to achieve target level of energy efficiency
- technology development in entire value chain from material, appliances, design and manufacturing
- incentives for acceleration of the above processes
- real economy that will stimulate energy efficient behaviour.

Energy efficiency is closely correlated with public and personal standard of living of each country, living standard of individuals, life style and climate situation. We learn from the experience that there are no generally accepted criteria for assessment and perception of efficiency, so it is not likely to expect that any kind of uniform value system can be built to measure efficiency of each human need. Therefore, achieving of energy efficiency goals should be fostered by setting realistic energy prices in combination with legislative enforcement measures and financial incentives.

3.1. Efficiency in buildings

Frequent amendments of strategic plans and EU directives with the aim of achieving further decrease of energy consumption, clearly point to the need for significant improvements in energy efficiency of buildings, the largest

single energy consumer. On one hand it is required that energy consumption is decreased by 20 percent by 2020, and on the other hand concrete goals are set for reconstructions and new builds with almost zero energy consumption. In addition, some experts warn that renewable and alternative energy sources are insufficiently used for ensuring energy needs in buildings and it is required that such solutions are taken into consideration in new construction and reconstruction plans. The only way to meet accepted goals for decrease of energy consumption in Croatia is to adopt integrated and systemic approach to reconstruction of the existing buildings and significant rise of new zero-energy buildings. Systemic and integrated approach to renewal of existing buildings will have a direct impact on improvement of living standard in buildings, boost of construction activities and economic development; it will foster industry and employment growth and provide significant contribution to reduction of energy consumption, environmental protection and higher competitiveness.

A new integrated approach to designing and building or reconstruction of buildings requires a range of multidisciplinary engineering knowledge and focus on building as a complex organism, including cooperation of all professionals in the process from design to building. The EU directive on energy performance of buildings – EPBD II. introduced more stringent requirements for energy performance of buildings and use of alternative and renewable energy systems in buildings. Energy certification of buildings, as well as national action plans for more buildings with almost zero energy consumption, should provide legal framework for boost of higher energy class buildings and instigate renewal of existing buildings.

Renewal of existing buildings should be focused on achieving low energy standards and A class buildings (<25 kWh/m²) and A+ (<15 kWh/m²) with obligatory integration of alternative and renewable energy systems. Detailed action plans for renewal of buildings should be earmarked for gradual but systemic rehabilitation of existing buildings by 2050, with CO₂ reduction as a key performance result.

In 2010 there were 149.38 million square meters of net surface in buildings registered in Croatia. Total surface of non-residential buildings was estimated at around 43.38 million square meters. Out of this number about 9.58 million sq m of net surface belongs to public buildings, representing 22 percent share in total non-residential surface, or 5 percent of total buildings surface. If it is assumed that 3% of building surface will be renewed each year, which is 5 million square meters per year, and that specific annual heat consumption decreases from average 200-250 kWh/m² to 25-50 kWh/m², plus contribution of 10 percent of new buildings with almost zero energy standard, in addition to more stringent regulations on energy efficiency, it will result in total savings of around 20.60 PJ by 2020. Thus we would come close to the national goal for energy savings of 22.76 PJ by 2020.

Accordingly, action plans must include elaborated financial mechanisms and incentives, and should be focused on:

- further development of proper regulations and incentives for construction of new buildings with almost zero energy consumption
- systemic energy renewal of existing buildings.

The implementation of the above goals requires annual investments of several billion kuna, however it also offers great potentials not only for energy saving, but also for creation of new jobs and boost of the entire economy.

3.2. Transport sector

The largest energy consumption of the European transport sector refers to oil derivatives. According to estimates and recent surveys, at the current consumption trends, the reserves of oil could last for about the next 40 years. Despite significant technology improvements achieved in internal combustion engines, the combustion of oil derivatives releases large volumes of carbon dioxide and other pollutants. Total carbon dioxide emissions from transport sector increased by 24 percent from 1990 to 2008, and they account for 19.5 percent of total greenhouse gas emissions in the European Union countries.

The EU target is overall reduction of CO₂ by 80 to 95 percent by 2050 compared with the reference year. The short-term EU goals by 2013 require all passenger cars manufacturers present in the EU market to sell vehicles whose emissions do not exceed 130 g CO₂ / km, while expectations by 2020 are much more radical and set the limit at 95 g CO₂ / km, compared with today's average of 150 g CO₂ / km. Current 27 EU members have enforced 1,805 measures aimed at achieving transport system sustainability.

According to the latest report released by the European Commission in early 2011, alternative fuels do have potentials to replace fossil fuels gradually, in part or fully, by 2050. The future energy needs of transport sector could be fully met by combination of electric energy/hydrogen and biofuels (as main alternative to oil derivatives), synthetic fuels (as a technology bridge between fossil fuels and biofuels), compressed natural gas/biogas (CNG) and liquefied petroleum gas (LPG) as additional alternative fuel.

Transport sector is one of the fastest growing sectors in Croatia. In the last ten years the number of newly registered cars grew by 5 per year, despite the fact that economic crises slowed down this growth rate in the last few years. On the other hand, transport sector's share in total national GDP is 10 percent. The data on average number of 336 cars on 1,000 inhabitants in Croatia, compared with 480 cars in EU 27, indicate that there is considerable potential for further growth of this market (it is expected that by 2020 Croatia will have over 2 million cars compared with 1.5 million today). In addition, transport sector is one of the largest energy consumers (its share in final energy consumption is over 30 percent). In the future, we can expect further growth of automobiles and passed kilometres, but also higher energy efficiency. Road transport accounts for 89 percent of total energy consumption in transport sector, and over 95 percent of this energy comes mainly from import of oil and derivatives.

For the time being, in Croatia there is only one document, a draft of 2. National Action Plan for improvement of energy efficiency which proposed 22 measures of financial, fiscal, organizational, legal, educational and infrastructure character.

Electromobility is one of the most efficient and ecologically acceptable individual transport solutions. Electric vehicles consume significantly less energy than equal type of cars using fossil fuels (~ 12 kWh/100 km compared with ~ 60 kWh/100 km). If we take into account the consumption of energy in electric car itself, plus energy required for their manufacturing and distribution, electric cars are twice efficient the most efficient fossil fuel-powered car, while CO₂ emissions are twice lower, when typical energy mix is used in electric energy generation.

It is important to mention a strategic importance of battery used by electric vehicles. For the time being the price of battery is still high, but with massive use of electric vehicles, batteries will obtain the role the other fuels have today. Would the technological and organizational development of electric vehicles go in that direction, for the first time we would have opportunity to store electric energy, which is particularly convenient in case of renewable sources like wind or solar energy. It could open up a possibility and need for the development of 'žsmart' grids for supply of filling stations and new way of planning urban electric energy systems, and programmes for this purpose are already in development.

3.3. Industry sector

Energy efficiency in industry is closely linked with technology development and pace of renewal of existing production capacity. Market opening, competition and technology advancements will have positive impact on continuous improvement of energy efficiency in industry. In particular, it is expected that the demand for electric energy will grow considerably as a result of trends in industrial products market and higher level of automation and even robotisation of processes.

Croatian industry's share in total energy consumption is around 20 percent. This is the sector with the highest long-term decline of energy consumption, which is partly the result of technology improvements (improved energy efficiency) and decreased industrial output. The latter decrease is a consequence of sensitivity of industrial production on financial crises, however, considering dynamic operation of competitive sectors and direct impact of energy on economic viability of industrial production, it is certain that energy efficiency will have a growing importance in industry. Use of renewables will also grow, particularly biomass, biogas and use of residues such as wood residue or residues in food industry or agriculture. Introduction of highly efficient cogeneration plants is very convenient for industry with balanced need for heat and electricity. With proper combination of incentives, growing benefits and rich offer of equipment, we can expect boost of cogeneration use. Systemic and comprehensive measures such as voluntary agreements, energy certification, networking, specific programmes for industry and similar, will have important role.

Higher energy prices, both electricity and other energy sources and imposing of emission taxes will provide essential economic stimulus for decrease of energy consumption and emissions, hence, these factors will press the need for improved energy efficiency and wider use of renewables. Well prepared projects with clear potentials for growth will have access to favourable financing, however, healthy operation and clear development prospects will be important precondition for funding.

Development and wider use of renewable energy sources opens up new opportunities for industry sector for manufacturing equipment for renewable resources exploitation. Croatian industry has capabilities for manufacturing equipment for use of biomass, biogas and biofuels, solar and wind energy and other, and it should exploit this strategic opportunity. In addition, there are potentials for manufacturing traditional energy equipment. These possibilities should be taken into consideration in designing national energy policy.

3.4. Service sector

Service sector is marked by several parallel processes: higher energy efficiency, increased capacity, higher energy consumption for heating and cooling, and higher number of power consumers. From energy aspect, the service sector has a growing trend which is proved by fast growth of energy consumption, despite the fact that in recent time it slowed down a bit.

In this sector we should consider commercial services and public sector services with their specific features. Commercial services participate in total energy consumption with about 12 percent, albeit with some oscillations, while public sector's share is only about 6 percent. The most important factor in commercial services is tourism, while public sector includes hospitals, schools, colleges and similar. Considering the nature of the above facilities, from energy aspect, they belong to building sector, however, there are numerous other ways of energy consumption (food processing, washing, etc.) and respective measures should tackle their specific consumption. Due to their specifics, commercial and public service sectors should be approached in different ways – in case of commercial services we can identify facility owners, while in public sector focus is on programmes proposed by government bodies or local governments. Due to this different approach, public sector was a leader in pursuing energy efficiency. Programme activities were directed toward building capacity for energy management and measures with lower cost of implementation such as training and informative projects. They rendered good results and significant energy and financial savings were achieved, so this could be a role model for commercial services sector and buildings in general. Various initiatives for setting up regional energy agencies were realized and they took active part in local energy activities within these sectors.

Service sector offers also an opportunity for development of energy services market, which is not sufficiently exploited in Croatia, although there are energy and economic grounds for providing of these services. A precondition for such development is proper regulation which would remove current barriers in implementation of

such projects. Moreover, since European Union has in place the directives that cover this area and they could be used as a model.

Service sector is certainly an area of dynamic development of energy usage with high growth potentials in the period of economic recovery. Commercial services will become growingly important part of economy, and they will certainly be motivated to pursue energy conservation measures. Public sector services will be under the influence of government bodies and local communities and their development will intensify when Croatia joins the European Union.

3.5. Energy management – smart grids

Management of energy consumption by smart grids offers new potentials for improving energy efficiency. Development of information and communication technology opens up great opportunities for the development of energy market and entrepreneurship in energy sector. In addition, smart grids can contribute to higher energy conservation, optimisation of appliance use and their energy consumption on the level of each household, changed concept in the development of energy infrastructure, lower costs and improvement of many other functions and business activities.

It is important to emphasize that energy management – smart grids do not represent new energy generation, but they provide information-communication solutions which contribute to better utilisation of all resources, more convenient use of appliances and consumers, energy efficiency and lower costs for energy buyers.

Already now there are numerous projects designed for energy independent buildings, town districts and smaller towns which ensure energy independence through implementation of energy efficiency and use of renewable energy sources. The questions that are raised in regard to the future of independent energy buyers, regardless their size, are related to the technology level they achieve, prices, possible scope of this type of energy management and their connection to public grids. Will such concept of energy supply to households, buildings, districts and smaller towns lead to lower needs for construction of public grids, primarily power grids, or will power grids be developed as if such option did not exist, or only as necessary back up, it remains to be seen.

4. CONVENTIONAL ENERGY SOURCES

Conventional energy sources are fossil fuels: crude oil, natural gas, coal and nuclear energy, which were dominant sources of energy supply until climate change issue has been raised. In case of fossil fuels, there is always a question for how long will they be available; when the issue of climate change was raised, together with significant detrimental contribution of fossil fuels to climate change, there was a problem how to continue use of fossil fuels without CO₂ and other greenhouse gas emissions. This is certainly a key technology challenge today. However, the trends are encouraging as technology development offered a new solution in the form of carbon capture and storage technology, which is expected to be in commercial production soon. It remains to be seen to what extent and scope can this technology be imple-

mented. It should be verified whether it is technologically possible and economically viable to capture and store CO₂ emitted by small consumers, households and business undertakings.

The dominant problem of nuclear plants is their safety, from the aspect of possible accidents to the problem of nuclear waste disposal. Hopes for technology breakthrough in fusion reactor development have not materialised and it is postponed for some future time. Despite technology improvements and new generation of fission reactors, there is considerable opposition to use of nuclear energy. On the other side, possible contribution of nuclear plants to reduction of CO₂ and other greenhouse gas emissions is desirable and necessary.

4.1. Crude oil

Crude oil and derivatives participate in total Croatia's energy consumption with over 40 percent. This fact points to the importance of oil as primary energy source in meeting total energy needs, but also its impact on the environment as a result of emissions occurring during combustion of oil derivatives. Crude oil has the strongest impact on fluctuation of energy prices for justified, but also speculative reasons. Limitation of oil reserves and its production, including growing demand, make oil the most critical energy source in economic and social aspect.

Due to large share of oil in total energy consumption, both in Croatia and other countries in the world, abatement of harmful emissions will be one of the most serious challenges in achieving set targets for protection of climate and the environment.

Considering the fact that about 70 percent of oil derivatives are consumed in transport, this sector has significant impact on total CO₂ emissions, and consequently some radical changes are required in this sector from the point of view of energy source to be used. Significant decrease of CO₂ emissions can only be achieved by replacement of derivatives with 'clean' energy, electric battery, hydrogen or other. In such a case oil or oil derivatives would be oriented toward industry use or power generation, the demand for which will grow. This will result in wider use of CCS technology which should convert 'dirty' fossil fuel energy into 'clean'. Apart from changes in automotive industry, oil industry will also have to go through significant changes, particularly in refining, which will have to adjust to new market requirements.

4.2. Natural gas

Natural gas participates in Croatia's total and final energy consumption with around 25 percent. Development of natural gas transport and distribution systems in new areas will increase the share of natural gas both in final consumption (in distribution) and total consumption for power generation (mainly to replace liquid fuels).

According to projections, the reserves of unconventional gas are equal to conventional reserves, so it is expected that price of natural gas will be lower than foreseen before significant growth of unconventional gas production and consumption in the United States. Therefore, it is believed that in the near future natural gas will have important role in power generation (highly

efficient combined cycle systems with around 60 percent efficiency). In the scenarios with dramatic reduction of CO₂ emissions, consumption of natural gas is expected to decline by 15 percent in 2050 compared to current consumption. It is expected that consumption of natural gas in households and service sector will decline as a result of improved efficiency of appliances but also buildings, but in industrial sector it will remain at the same level. In final consumption it is expected that the demand will go up for heat pumps and CHP system in larger buildings.

In the situation when many countries have concerns about nuclear programme, when coal is not an attractive option because of high emissions and CCS technology is still not in commercial use, natural gas has considerable advantage and importance because of lower CO₂ emissions and availability of standardized equipment which can be manufactured rather quickly. Therefore, it is likely that the number of gas fired power plants will grow, particularly to provide back up capacity needed for balancing output from renewable sources.

In the long run, demand for gas will have periods of growth, stagnation, and most probably decline. In the first stage, the number of users will grow, but gradually fewer consumers will use natural gas, or even stop using it. However, natural gas will continue to be used in larger electricity and heat generation plants. This projected trend can change to a certain degree if technology solution is found for use of gas without combustion, or possibly with CO₂ storage even at small end users, if this becomes technically possible and economically viable.

In order to preserve important role of natural gas in the future, it is necessary to ensure secure supply through more interconnectors between countries, construction of transmission pipelines, LNG terminals and gas storages.

4.3. Coal

Coal participates in Croatia's total energy consumption with around 7 percent. Overall demand for coal is met from import since domestic production ceased in 1999. Coal is mainly used in power generation plants and industry. Despite high CO₂ emissions from combustion, key advantages of coal are: price (lower and more stable in comparison with crude oil and natural gas), availability and security of supply (on local and international market).

Similarly to other fossil fuels, coal will remain important energy source on global level thanks to its price competitiveness, but also due to relatively high geological reserves. In the context of set goals for climate and environment protection, use of coal will require implementation of CCS technology, which is expected to become competitive with emission taxes by 2030, which means that the price of disposal of one tonne of CO₂ will be lower than the amount of emission tax for a tonne of CO₂. In such a scenario realization of coal fired plants would be viable.

4.4. Nuclear energy

Recent accident in Fukushima nuclear plant (Japan) had further negative impact on public perception of nuclear technology, even in countries which have experience in

nuclear energy use. German government decided to close down all German nuclear plants by 2022, before foreseen operation termination. This will have significant impact on energy policy in the world, particularly in Europe. First of all, it may result in higher electricity prices in European markets.

Today's commercial reactors mainly belong to the 2nd generation reactors. Currently, construction of 3rd generation reactors is in progress, but the construction of the first 3rd+ generation has already commenced (ex. in Finland – the third reactor in NP Olkiluoto is ER type, in China – AP1000 and EPR). Considerable progress has been achieved with the 4th generation reactors (SCWR, VHTR, MSR, GFR, SFR, LFR) which are considered to be the future of nuclear energy. The first such reactors could be built around 2030.

According to IAEA estimates, current reserves of nuclear fuel are around 5.4 million tonnes of uranium, which should be sufficient for 90-year use in conventional reactors. Depending on price of uranium, but primarily depending on electricity price, these reserves may last several times longer.

Croatia gained experience in nuclear plant operation through the NP Krško, and it belongs to a group of countries that use nuclear energy. In the document *Energy Strategy of the Republic of Croatia* which is still effective, it is written that use of nuclear energy represents a development opportunity of Croatia's energy sector and entire economy, firstly as a stable provider of electric energy, but also as power generation that will contribute to abatement of greenhouse gas emissions. According to the strategy, Croatia intends to launch nuclear programme in the near future and respective decision thereon should be made at latest in 2012.

Building of a nuclear plant requires large investments, particularly for a small country like Croatia. Consequently, considerable attention is directed toward small (<300 MW) and medium reactors (300-700 MW). According to IAEA reports for 2010, 4 small reactors are being built in the world in addition to 9 medium ones (out of total 67 reactors in construction). Such reactors can make nuclear energy affordable even to developing countries with relatively small power network, insufficient infrastructure or limited investment capabilities. Small and medium reactors are particularly attractive for cogeneration and future advanced heating processes. They also provide good solutions for use in remote and isolated regions, and ensure higher flexibility in staged increase of capacity. Of course, unit costs are higher than in case of large reactors, but total investment is lower.

Further research in the area of fusion reactors is going on, however it is still in experimental phase. According to official data, the progress is made from design to construction phase. The most recent plans mention the first plasma to be obtained in November 2019, while the first 500 MW ITER reactor could be put into operation in March 2027.

5. RENEWABLE ENERGY SOURCES

Renewable energy sources have a significant share in total energy generation today, and should not be called al-

ternative sources anymore. Technology advancements on one side and various incentives on the other side, created favourable climate for boost of facilities that use renewable energy sources. Consequently, in some segments renewable industry has become the fastest growing sector today. In the initial development phase it was important to invest both in technology and market development, because it was important to ensure the market for guaranteed purchase of renewable energy and prices that ensured return on investment and sound profits.

From technology and economics point of view, renewable energy sources are faced with several challenges. The strongest impact is expected by the adoption and implementation of IPCC's policy on climate change and its overall influence on energy prices. Incorporation of actual costs for protection of climate and the environment in energy costs will put renewable energy sources in equal position with other conventional sources and it will have decisive role in development of energy market, particularly power market. Most probably it will accelerate technology development and provide a new dimension of renewables use.

5.1. Wind

During 2010 new 9.9 GW wind farms were constructed in Europe so that total installed wind capacity reached 86.3 GW. In the past five-year period wind farms became the most dynamic market in renewables industry. According to expectations, wind farm capacity in Europe should quadruple by 2020 to reach 230 GW which is close to EU 27 national action plans target (in total 213 GW). Realization of these plans will require huge investments of about EUR 200 billion. However, if implemented, wind farms would cover about 15.7 percent of EU demand for electric energy.

It should be mentioned that wind industry plans go beyond the above mentioned targets and recently a new goal for 2050 was adopted: 735 GW wind energy in Europe (onshore and offshore wind farms) and 50 percent share in covering total energy demand. However, such a large share requires a comprehensive restructuring of energy sector with new technology solutions and system management techniques, as well as radical breakthroughs in the area of energy efficiency. In addition, new solutions will be sought in the wind energy generation itself, primarily to increase unit capacity of wind generators (to 10-20 MW units), increased performance of generators through integrated technical optimisation, development of offshore technology and technology for low wind locations, enhanced integration into infrastructure system and other.

In the last two to three years investors showed great appetite for construction of wind farms in Croatia which resulted in a large number of listed projects in the Register of Renewable Energy projects with the Ministry of Economy and Industry. However, total realization of 89 MW by end 2010 is rather modest in comparison with other countries with similar potentials. On the other side, Croatia's electric energy system is relatively small and represents a limiting factor, more than wind availability or shortage of space. At this point, the Energy Strategy of Croatia foresees construction of 1200 MW wind capacity

by 2020 and 11 percent share in meeting gross electric energy demand in that year. This goal could be implemented if the measures aimed at easier integration of wind farms, primarily increase of regulation capacity within the system, introduction of forecasts on wind farms generation, dispatching and other. Strategy provides a framework and development goals by 2030 - 2000 MW of wind energy generation. Realization of emission reduction goals in energy sector will instigate further increase of wind farms capacity beyond 2020.

5.2. Solar

The main reason of low utilisation of solar energy in heat or power generation units was the high price of solar equipment and relatively low price of other forms of energy. Relatively high subsidies for solar energy production (photovoltaic systems) have recently boosted interest for installation of such systems. Nevertheless, massive use of photovoltaic and heating solar systems will follow developments in government incentives and regulatory system. Increased use of solar systems led to generation capacity growth, and as a result, considerable investments in technology development, which then resulted in lower prices of equipment. Consequently, day by day solar systems become more convenient for use and are widely accepted. This trend will continue in the future. The concept of decentralised energy generation, as well as EU directives requirements on zero-energy buildings, provides new incentives for wider solar energy development, both in power and heat generation, but also for cooling in the future. In this perspective, from energy consumer, buildings will be transformed into energy producers, so, it is realistic to expect boost in use of solar systems in buildings.

Lower price of photovoltaic systems, particularly photovoltaic modules as the most expensive part of the system, as well as expected rise of electricity prices, will lead to significant growth of solar systems so that in the near future we can expect equalization of prices for electricity generated by photovoltaic systems and market price of electricity from other sources. When this happens, we could see significant growth in large capacity (over 10 MW) solar plants installation. Nevertheless, photovoltaic systems in buildings will need additional subsidizing even in future. In addition, due to seasonality of the resource (solar energy) it will be necessary to ensure energy storage capacity, particularly hydrogen.

The price of solar heating systems is not expected to fall in the near future, but the use of such systems will increase, primarily as a result of higher energy prices in general, and possible shortage of other resources. In this context it is expected that almost each family house and large number of buildings will use this technology for hot water supply and as a support to central heating. Wider use of solar heating systems is expected also in public building sector, particularly for buildings used around the year (hospitals, old people's homes) and in the hotel sector where such systems are traditionally used.

5.3. Hydro power

Hydro plants have been in use over hundred years and hydro generation proved to be mature and reliable tech-

nology that contributes to security of electricity supply. Some, but not significant, technology improvements can be achieved in hydro generation. However, the key constraints in further larger utilisation of hydro potentials lie in the sphere of environmental protection and not in development of new technologies. Despite the fact that hydro power plant has practically no harmful emissions during its operation, so it does not contribute to pollution of atmosphere, hydro plants can have significant impact on the environment because of considerable intervention in the space, particularly if larger accumulation lakes are necessary. It is to be pointed out that most of favourable locations in Croatia have already been exploited. New hydro plant constructions will be more and more difficult if we take into consideration more restrictive environmental protection regulations.

However, modern concept of water management and economic development call for integrated approach to water resources, which means realization of a whole range of activities (protection against harmful effects of water flows, creating conditions for healthy food production through building irrigation systems, drainage systems, fish farming, but also water supply infrastructure building, building facilities for recreation, sports and tourism...) guided by polyvalent use of water resources. In the future we can expect realization of polyvalent projects on water flows, with possible power generation as a form of water source use. Building of larger number of small hydro plants could push economic development in rural and undeveloped regions where they could supply electric energy to smaller industrial plants on location with undeveloped transmission and distribution network, where ensuring access to transmission/distribution network would be too costly.

5.4. Biomass

Traditional use of wood is still very conspicuous in Croatia and even today 50 percent of households use wood for heating, in traditional manner with low efficiency. Use of modern products is in initial phase, although wood pellet manufacturing has considerable output. New generation biomass projects for power and heat generation based on state-of-the-art technology are in progress.

In the future, it can be expected that energy efficiency will increase in biomass utilisation through application of advanced technologies and products, and use of biomass for power and heat generation. Valuation of wood residue made available through sustainable management of forests, which can be used as biomass, instigated a number of energy projects. In combination with incentive measures, this opportunity was exploited in several cogeneration projects, some of them rather large and connected to local heat supply systems. Use of wood residue from wood processing industry is also developed and applied in cogeneration plants. Potentials for energy use of overall available biomass would thus open new possibilities for building significant power generation capacity, however, it is also important to ensure use of heat energy from such cogeneration plants. Heat energy suppliers prefer biomass as a fuel because of its availability and competitive price. Such development requires well

designed and sustainable management of wood biomass as a resource.

Similar situation is with biomass from agriculture, which was minimally used for energy needs, but in the future it could achieve significant growth.

The issue of resources for production of sufficient volumes of biomass for meeting Croatia's demand is the issue of sustainability concept and harmonization and balancing with other users of space and raw materials, primarily agriculture, wood processing industry, construction industry and others.

5.5. Biogas

Production and use of biogas commenced in Croatia some time ago. Introduction of eligible power producer status encouraged launching of several biogas cogeneration projects, as in case of biomass. Transfer of technology and new insights opened up the possibilities for use of a wide range of biogas feedstock, including potentials that have not been recognized yet. Hence, there are considerable potentials for biogas production, primarily through use of existing and available residues from livestock and poultry farms, agriculture and food processing industry, but also planting of crops for biogas production (corn, sorghum, etc.).

However, biogas production and usage concept should stem from the agriculture and livestock breeding development concept, as a value added in optimal utilisation of all potentials, but not in conflict with them. Also, further development of this renewable energy source and its use, will require harmonisation with the plans of food processing industry development, development of utilities, biological waste disposal and other fields.

5.6. Geothermal energy

Geothermal energy is not sufficiently exploited renewable resource in Croatia, particularly considering high geothermal potentials in the northern parts of the country. Currently, geothermal energy is mainly used for balneary and recreational needs in numerous spas, and there are only few examples of its use for other purposes (greenhouses for growing vegetables and other plants, fish ponds, house heating). More intensive use of geothermal energy in power generation is expected in the forthcoming period.

The main reason of such poor exploitation of geothermal energy lies in the fact that until today a comprehensive survey of geothermal potential on prospective locations has not been carried out, in addition to numerous administrative and legal barriers which slowdown development of geothermal projects.

Power generation is the most interesting mode of geothermal energy use because it can be used throughout the year. As there are many other options for use of geothermal energy today in industrial plants (drying paper, fruit, vegetables, fish, timber, wool, salt extraction, water distillation, milk pasteurization, etc.), available heat energy may be a driving factor for economic development of a region. Well positioned geothermal resources in the vicinity of a settlement are growingly used for heating and cooling systems in house blocks, business premises, shopping malls or even smaller towns. Maximum effi-

ciency is achieved in cascade use when heat is transferred to different users in several stages (power generation, drying facilities, cooling plants, greenhouses, fish farms).

In recent times geothermal resources are growingly used as closed loop systems which is a more environmentally friendly concept because the water extracted from the well is returned into the deposit to be heated again. Incentives for more intensive use of geothermal energy in Croatia would, apart from favourable effect on the environment, increase the share of renewable energy sources in total energy consumption. In addition, use of geothermal sources would contribute to security of supply of the Croatian market as we can rely on our own resources, which would decrease dependence on energy imports and global geopolitics.

6. CONCLUSIONS AND RECOMMENDATIONS

1. New energy policy requires new development platform to cover the period by 2050, probably even longer, because it is not possible to design appropriate solutions on the current platform and assumptions on energy system development, in terms of constraints imposed by climate and environment protection, numerous interactive factors and demands for long-term sustainability;
2. It is not possible to create and design a new energy policy as an isolated system, because it is interconnected with many segments of economy and society; energy policy should penetrate and be recognized in all activities on national, regional and local level and it should include all measures dealing with legislative, development and incentive aspects. An important component of energy policy is mobilization of scientific and industrial potentials of Croatia. The new development platform is an opportunity for engagement of Croatia's science and industry potentials, but it requires close cooperation between government, scientific community and economy;
3. The cornerstone of the new energy platform is improvement of energy efficiency in all segments of value chain from energy generation, transport/transmission, distribution to consumption, use of new technologies and renewable resources;
4. In the long run, energy generation should not be divided into market driven and subsidised components; it is important to foster integrated market based on actual energy costs which comprise climate and environment protection costs.
5. In the near future, and most likely until 2030, energy prices and costs will rise as a result of including into the price of energy all the costs related to climate and environment protection and development and application of new technology. After that period, higher costs will be offset by lower need for energy as a result of improved energy efficiency and effects of new technology advancements.

6. Higher energy prices and costs would become reality even without new development platform, as a result of limited availability of fossil fuels and growing demand for energy. The only difference in final outcome is that new development platform takes into account improved energy efficiency, implementation of new technologies and renewable energy sources, while the existing platform would result in higher negative effects on climate and the environment.
7. Croatia's resources, in combination with new technologies make the realization of the new development platform possible; its realization is primarily an organisational-institutional and economic issue, and less an energy issue.
8. Setting of new development platform requires design of energy strategy by 2050, which will set the goals of greenhouse gas emissions reduction by minimum 50 percent against the reference year -1990.
9. It is necessary to design action plans on all government levels: national, regional and local, including all segments of society, particularly science and economy.
10. It is necessary to set up an institutional framework for the realization of the new development platform and all its measures and activities.



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