How to address the challanges of the climate preservation

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PRELIMINARY COMMUNICATION

This paper deals with the long term planning of the energy system of the Republic of Croatia. In addition to energy-technological-siting limitations, there is also an additional limitation deriving from the CO_2 emission mitigation target. In order to work out the ways to achieve the set targets, the analysis of the additional energy consumption scenarios was performed. The analysis considers the energy efficiency measures and new technologies for heating, hot water preparation, cooling and non-heat use of energy by households. On the basis of the conclusions, the guidelines for attaining the goals of the energy policy and climate preservation policies in Croatia are given.

Key words: security of supply, open market, role of the state

1. INTRODUCTION

The planning of energy system development was based on optimization and simulation models, where expenses (discounted value) or more accurately their minimization, were basic component of goal function while limitations derived from energy-technological-siting issues. The price of energy in western part of the world had real commercial value, while in the eastern part its price had more of a social value. Over last fifteen years, prices in the countries of former eastern block have been gradually reaching their real market level, while in the developed European countries, financial support was given to producers using renewable energy sources and to cogenerations to reduce CO_2 emission. In both cases we are talking about interventionism which affects energy market as well as the situation in the entire sector. Low energy prices had fatal consequences to the situation and development of energy sector and it will take many years for former socialist countries to recover. On the other hand, interventionism on the side of production from renewable energy sources and cogeneration actually supports construction and use of those plants, but creates two markets (supported and free) which, in the long run, is not possible.

In the times to come, climate preservation is imposed as a priority, which translated into necessary measures, means considerable reduction of CO_2 emission and other environmental impacts. To achieve this goal, beside already implemented restrictions arising from energy-technological-siting characteristics of a plant, dominant restriction is being introduces – cumulative rights and other restrictions related to technological characteristics of certain plants. This necessarily imposes the observation of longer time horizon (at least until 2050) and the use of complex optimization models, which may include numerous variables and limitations.

According to recent research, it is to be expected that this limitation should increase the price of energy service two to three times regarding the current situation if emissions are to be reduced by 50 percent. The question is; how to allocate these costs in state-energy company-buyer chain and at the same time the model should remain economically viable. In this paper we shall present the results on the example of household sector. Possibilities of applying energy efficiency measures have been analyzed by using MARKAL optimization linear model for long term planning of energy system where the entire energy system of the Republic of Croatia shall be monitored until 2050. MAED model was used for forecasting useful energy needs in all consumption sectors.

2. BASIC SIMULATION SETTINGS

Energy efficiency measures and use of renewable energy sources (for electricity generation and for room heating and DHW) have been modeled in energy system of the Republic of Croatia for the period from 2005 to 2050 by using MARKAL (MARKet ALlocation) optimization model. This model uses the technique of linear programming and least cost conditions in finding optimal solution. MARKAL model is used for presenting complex energy systems on national, regional or local planning level. This computer program has technical-economical data base on technologies, prices, given energy consumption and other parameters that define the given system.

Energy system model of the Republic of Croatia was especially used in the analysis of energy efficiency measures: insulation in households and service sector, use of new technologies for heating and DHW in households (biomass, heat pumps and solar collectors) and new technologies in traffic (compressed natural gas, hydrogen and hybrid drive). The production of electricity includes new power plants drive and certain new technologies (hydroelectric plants, nuclear power plants, coal powered and natural gas powered power plants candidates, solar power plants (concentrated solar radiation), wing power plants, geothermal power plants, biomass fuelled power plants, plants with integrated gasification combined cycle IGCC and coal and natural gas powered power plants with CO_2 carbon capture and storage (CCS). By 2015 there is a possibility of electricity export and after that the consumption is exclusively covered by production. Analyses were made with reference price scenario of primary energy forms, energy efficiency measures for households and services, especial discount rates for technologies and CO_2 emissions (special scenario with emission limitation).

National energy system is presented in detail according to energy balance structure of the Republic of Croatia such that in includes the following:

- Energy sources, i.e. domestic production and import of coal, crude oil, natural gas, hydropower, wood fuel, industrial waste, oil derivatives, municipal gas, electricity, steam and hot water, renewable sources (wind and solar energy) and compressed natural gas for transportation, hydrogen and bio-diesel
- Plants for energy transformation (existing plants and power plants candidates): hydropower plants, thermal power plants, district heating plants and boiler stations, industrial heating plants and boiler stations, oil refineries, ethane recovery plants and city gasworks
- Transportation and distribution of electricity and thermal energy, natural gas and crude oil
- All energy consumption sectors (households, services, industry, traffic, agriculture, construction, non-energy consumption).

Possible price forecast for certain energy products used in calculations is presented in Figure 1. The supposed price growth for each energy product is different due to market and exploitation reasons.

All technologies for production, import, transformation and consumption of energy are characterized in technical parameters (process efficiency, connections between technology's input and output, relation between the forms of energy coming out of technology), capacity parameters (start of new technology drive, technology's life expectancy, maximal growth or maximal added technology capacity per period, value of the remaining installed power), cost parameters (investment costs, fixed and variable costs of the plant, maintenance costs, energy supply costs), availability parameters (forced plant's shutdowns, maintenance) and emission factors.

According to reference data, gradual price decrease is forecasted for all the considered technologies. Those parameters are very difficult to be forecasted with complete probability, however it is necessary to take them in consideration.

Household sector is additionally divided into the following consumption categories:

- family houses with central heating
- family houses with individual room heating
- apartments in buildings with central heating
- apartments in buildings with individual room heating

Along with household sector, the model also includes other consumption sectors:

- Services sector – consumption of useful energy for heating and domestic hot water (DHW), electricity consumption for non-heat use and cooling
- Industry sector – consumption of useful energy for direct and indirect heat, electricity consumption for non-heat use
- Traffic sector – energy consumption in passenger (city and intercity) and cargo traffic
- Agriculture and construction sector – electricity consumption, energy consumption for thermal needs and motor fuel consumption

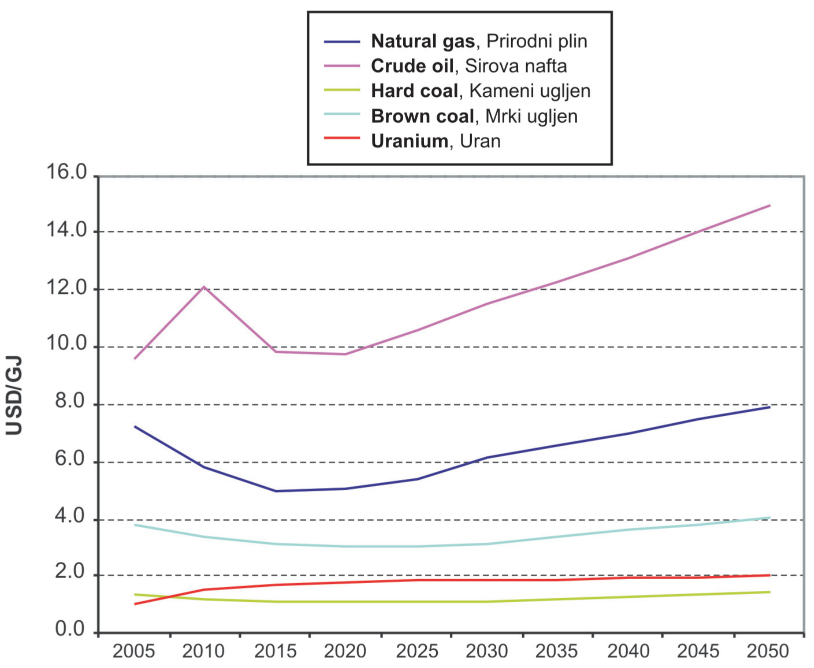

Fig. 1. Fuel Price Forecast
Sl. 1. Projekcija cijena goriva

3. SCENARIOS

Energy efficiency measures analysis in household sector was performed by setting the following scenarios:

- Reference scenario (RS)
- Scenario with special discount rates for technologies (DS)
- Scenario with limited CO_2 emission (ES)
- Scenario of incentive analysis (PS)

All scenarios were defined with the year 2000 as a base year, with five year period and planning period until 2050. Base year data were data from energy balance of the Republic of Croatia, data from technology bases for heating and DHW (investment costs, plant and maintenance costs, efficiency, power, plant duration) and final energy price. For the considered period until 2050, MAED model calculation results were used for final and useful energy consumption in

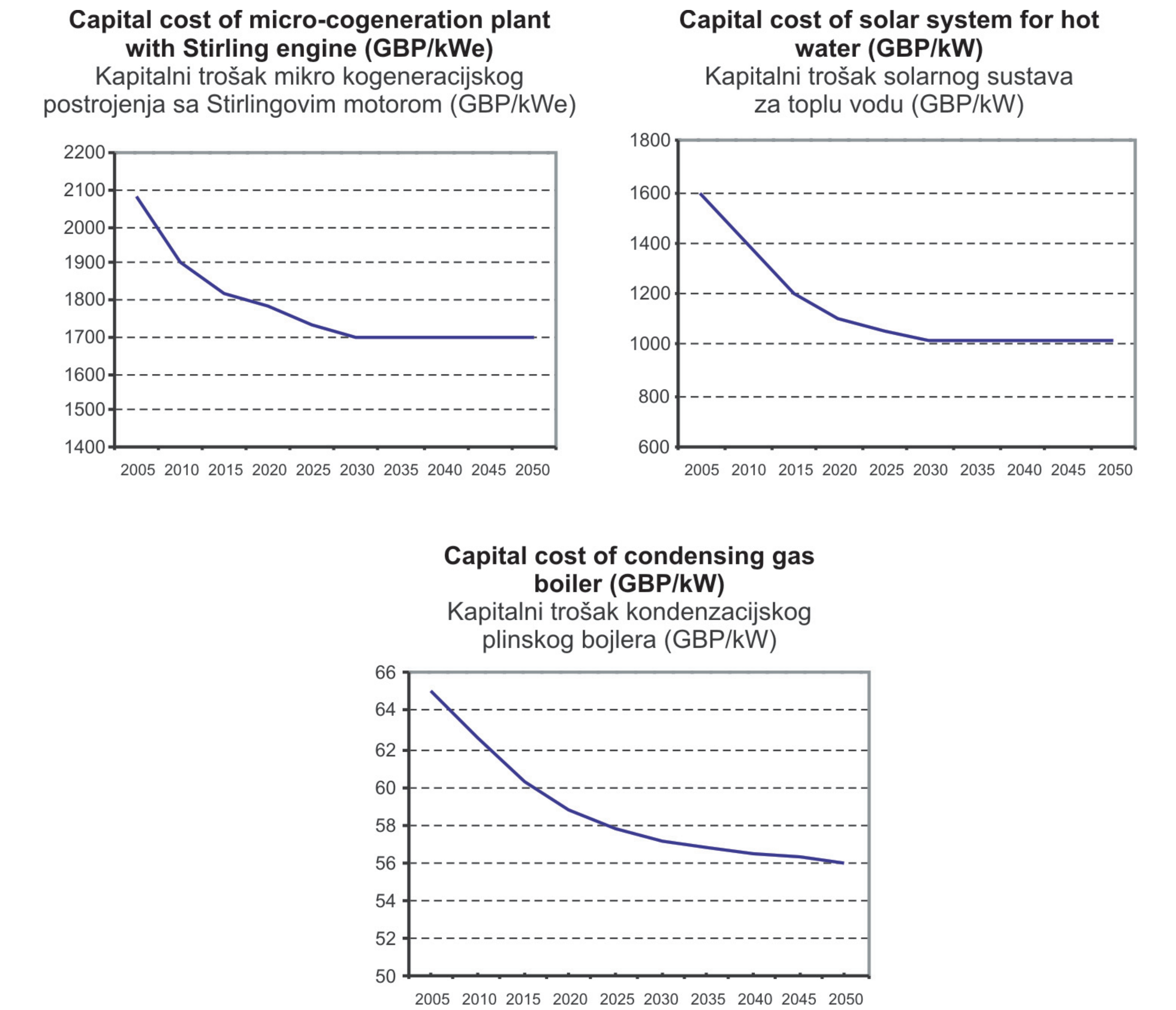

Fig. 2. Expected changes in the costs of certain technologies
Sl. 2. Očekivane promjene u troškovima nekih tehnologija

all consumption sectors (households, services, traffic, industry, agriculture and construction) together with final energy price forecasts according to energy forms.

Model MAED (***M****odel for* ***A****nalysis of* ***E****nergy* ***D****emand*) belongs to the group of end-use models and is based on MEDEE methodology (***M****odel for* ***E****nergy* ***D****emand* ***E****valuation*) i.e. mathematical-technical-economic model for long term forecast of final energy consumption. This method enables relatively simple consideration of all relevant energy consumption direction effects like growth and structure of domestic product, demographic growth, housing standard, population mobility, climate properties, changes in the efficiency of energy use, habits and customs, which based on development scenario of social-economic consumption directions, give the reflection (picture) of consumption.

This scenario has also a defined sub-scenario of entering into production power plants candidates and stopping the production of the existing plants in electro-energy sector (hydropower plants, thermal power plants, nuclear power plants) as well as plants for production of electricity and heat energy (micro cogeneration in households, district and industrial heating plants) and heat energy production plants (district and industrial boiler stations). Reference scenario includes a whole series of measures from energy efficiency in household sector, which are presented in Table 1.

4. ANALYSIS RESULTS

4.1 Reference Scenario (RS)

Reference scenario is based on reference prices of primary energy forms, with measures of energy efficiency in households and services sector without limitations on CO_2 emission.

Table 1. List of energy efficiency measures in household sector

Measure	Use
Insulation[1] (family houses with central heating)	heating
Insulation (family houses with individual room heating)	heating
Insulation (buildings with central heating)	heating
Insulation (buildings with individual room heating)	heating
Dishwashers	non-heat use
Washers	non-heat use
Driers	non-heat use
Other	non-heat use
Refrigerators	non-heat use
Freezers	non-heat use
Refrigerators with freezer	non-heat use
Big freezers	non-heat use
Stand by power	non-heat use
Low energy houses	heating
Condensing gas boiler (houses)	heating/DHW
Condensing gas boiler (apartments)	heating/DHW
Heat pumps (electricity)	heating/cooling/DHW
Heat pumps (natural gas)	heating/cooling/DHW
IC engines (micro cogeneration) powered by natural gas	heating/DHW and power production
IC engines (micro cogeneration) powered by LPG	heating/DHW and power production
IC engines (micro cogeneration) powered by light heating oil	heating/DHW and power production
IC engines (micro cogeneration) powered by bio-diesel	heating/DHW and power production
Hydrogen fuel cells (micro cogeneration)	heating/DHW and power production
Natural gas fuel cells (micro cogeneration)	heating/DHW and power production
Stirling engine (micro cogeneration) powered by natural gas	heating/DHW and power production
Efficient lighting – halogen	lighting
Efficient lighting - CFL[2]	lighting
Efficient lighting - LED[3]	lighting
Thermostatic radiator valve (TRV)	heating
Room thermostats	heating
Individual heat consumption meter (radiator)	heating
Solar collectors (solar/electric)	DHW
Solar collectors (solar/pellets)	heating/DHW
Solar collectors (solar/pellets)	heating/DHW
Photovoltaic systems (houses)	power generation
Area heating and DHW on pellets (small cogeneration)	heating/DHW
Boilers with pellets	heating/DHW

[1] Total insulation of outer walls, ceiling and windows
[2] Compact Fluorescent Light
[3] Light Emitting Diode

Figure 3 shows final energy consumption in households until 2050 according to types of energy. Considering the optimization results of reference scenario, among all possible measures of energy efficiency in households, the introduction of the following ones is cost efficient:

Family houses with central heating and DHW

- Insulation
- Thermostatic radiator valve
- Room thermostat
- Condensing gas boilers
- Solar collectors for heating and DHW
- Pellet boilers
- Micro-cogeneration systems (Stirling engine)
- Heat pumps for heating and cooling (natural gas)

Family houses with individual room heating and DHW

- Insulation
- Heat pumps for heating and cooling (electricity)
- Heat pumps for heating and cooling (geothermal energy)
- Heat pumps for heating and cooing (natural gas)

Apartments with central heating and DHW

- Insulation
- Thermostatic radiator valves
- Room thermostat
- Individual heat consumption meters (electronic dividers)
- Condensing gas boilers
- Micro-cogeneration systems (IC internal combustion engines powered by natural gas and light heating oil)

Apartments with individual room heating and DHW

- Insulation
- Heat pumps for heating and cooling (electricity)

The highest energy saving potential is in household insulation; its share being 4.5 percent regarding the total final energy in households (year 2015), 22.7 percent (year 2030) and 41.6 percent (year 2050). The highest insulation potential, i.e. possible energy saving for heating and DHW are in houses and flats with central heating which are the households with highest income and big consumption of energy for heating.

As the results of this calculation were obtained by mathematical analysis (model) in which equal consumption conditions and possibilities for all energy forms were supposed, we need to point out that some of the results shall not relate to actual consumption. One of the examples is natural gas consumption in 2010, which shall be lower that presented in Figure 3 as all the consumers in the Republic of Croatia shall not have access to distribution network (Dalmatia).

4.2 Scenario with special discount rates for technologies (ds)

MARKAL optimization model in calculations with the lowest total system consumption uses entry data on discount rate size, which can be set for all technologies in a system (as it was the case in reference scenario) or for

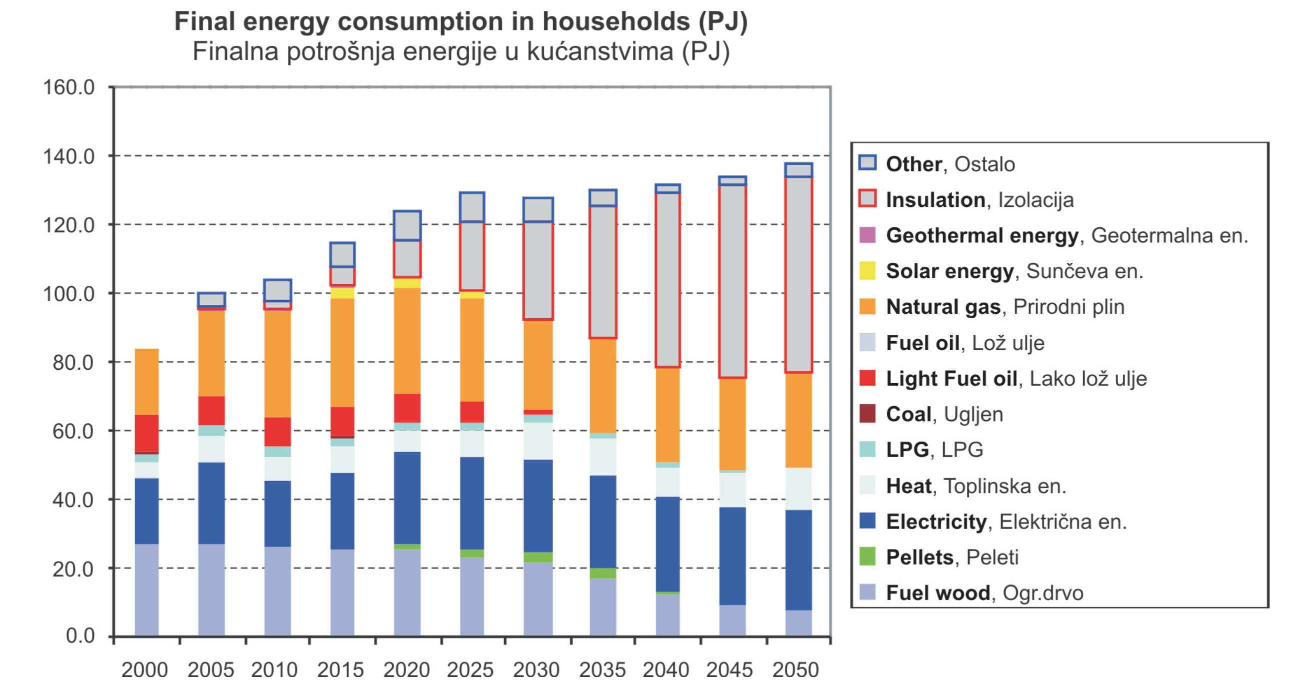

Fig. 3. Final energy consumption in households according to reference scenario (RS)
Sl. 3. Finalna potrošnja energije u kućanstvima u referentnom scenariju (RS)

certain technologies, minimal expected hurdle rate values can be given. The use of these additional rates is justified by the fact that in MARKAL model the rates model consumers' behavior; or more likely they model non commercial parameters that define consumers' behavior, like special characteristics of certain product or service, market and administrative hurdles, lack of marketing etc.

Reference studies indicate that the expected minimal rate of return on energy efficient technologies is mostly at least 10 percentage points more than expected rates of return on investments in conventional technologies or market interest rates on loans and savings (as minimally acceptable reference rates of return at the principles level, i.e. as a measure of investment opportunity cost, per se).

The stated phenomenon, which is in contradiction with neo-classic economic theory and taken in consideration market specifics of energy efficient technologies (which are thus modeled in MARKAL), can be explained through the following theses:

- Price, or initial investment, of energy efficient technologies is so high that investor/consumer requires such type of investment to have a high rate of return, taking in consideration risk premium, at the shortest time possible, so the investor/consumer can get inventive to "overcome the hurdle" of high initial investment. Behavioral economy indicates a phenomenon of time money preference which makes each individual prefer the money he owns today rather than money that he could generate through future period, by which in case of investment he prefers an investment with shorter period of return and higher discounted net current value.
- Buyer/investor is behaving rationally regarding high price of energy efficient technologies and expects a high rate of their return considering the irreversible nature of such investments. However, it is almost impossible for the investor to use these technologies for some other purpose. Besides, these technologies are developing intensively and their development makes technology efficiency grow while the price drops (like computers and generally micro-electronics). Thus the rational investor expects to return such investment in a short time, because the technology development which causes price drop and consequently the drop of utilization limit can distort the investment's feasibility
- At the time when energy price in most countries is (artificially and unrealistically) low, the buyer/investor needs big "incentive" (in the form of short return derived from high rates of expected return) to invest in energy efficient technology
- This is a case of classic issue of market malfunction, co called principal-agent problem, which comes to lack of information on the benefits/shortages of expensive technologies in combination with the above mentioned, artificially low energy prices, distorting the real relationship of average and marginal price of investment options.

Such special rates can be applied to new technologies in all consumption sectors (households, service sector etc.) as well as to new technologies for electricity generation like wind power plants, micro-cogenerations, photovoltaic systems and similar. The amounts of these rates are higher than standard discount rate (8%) which is defined for the entire energy system. For the purpose of this

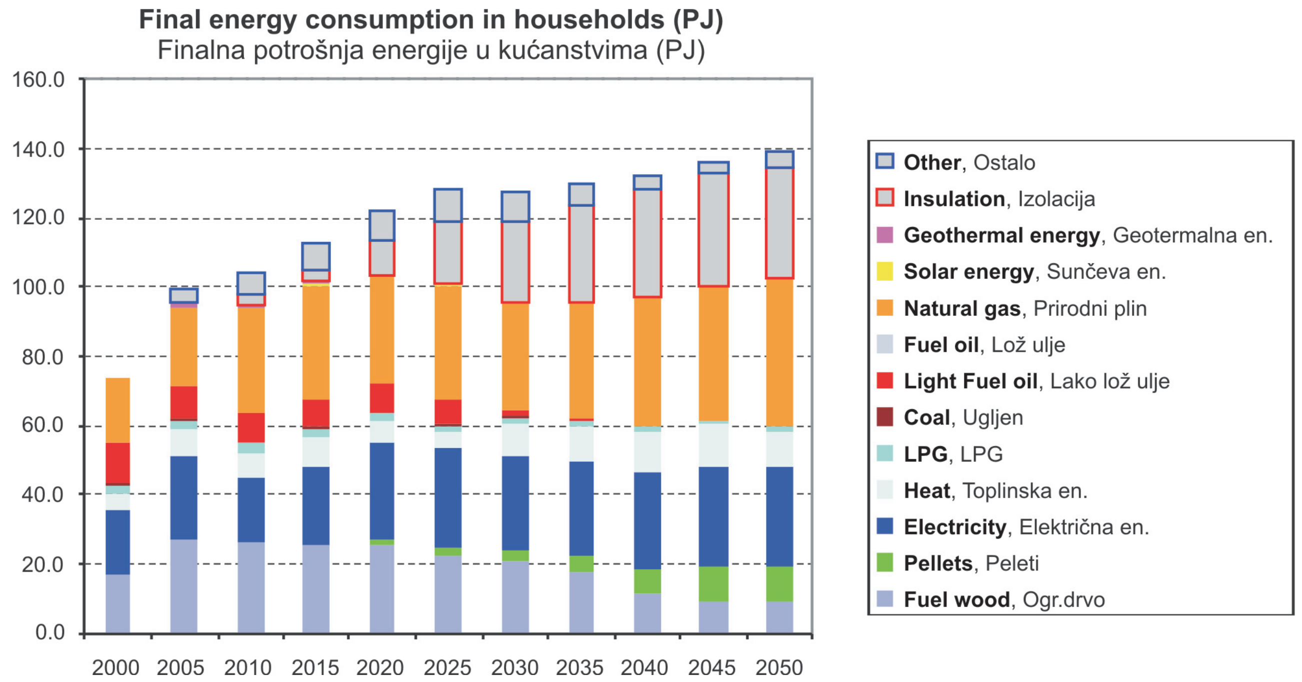

Fig. 4 Final energy consumption in households within special rates scenario (DS)
Sl. 4. Finalna potrošnja energije u kućanstvima u scenariju s posebnim stopama (DS)

analysis, the values of minimally acceptable return rates for technologies were used:

- Insulations in households and service sector - 15%
- Heat pumps (geothermal energy) for heating and DHW in houses with central heating and DHW - 15%
- Micro-cogeneration systems in houses and apartments for generation of electricity and heat energy - 25%
- Heat consumption meters in apartments with central heating - 15%
- Photovoltaic systems in houses for electricity generation - 25%
- Solar collectors in services sector and households for heating and DHW and for DHW - 15%.

Total insulation potential in relation to other forms of energy final consumption in households within special discount rates scenario (DS) is presented in Figure 4. Total insulation potential in households regarding total final energy is 3.4 percent (year 2015), 18.0 percent (year 2030) and 21.6 percent (year 2050), which is lower than in reference scenario.

Unlike reference scenario (RS), houses with central heating and apartments with individual room heating have highest insulation potentials, i.e. possible energy savings for heating and DHW within the scenario with special discount rates for technologies (DS).

4.3 Scenario with limited CO_2 emission (es)

Scenario with limited CO_2 emission (ES) supposes the same values of minimally acceptable return rates for technologies as in DS scenario, with additional condition that CO_2 emission in 2020 amounts to 12 percent of CO_2 emission from 2005; this share grows up to the amount of 50 percent in 2050 (this restriction was set according to the recommendations of Directive 2009/29/EC)[4].

Figure 5 shows average values of insulation share in overall consumption of final energy for heating and DHW in households according to all scenarios. Applying minimally acceptable return rates for technologies in DS scenario resulted in insulation potential decrease in households, while placing restrictions on CO_2 emission (with special discount rates for technologies) in ES scenario resulted in insulation potential increase.

Results of all the analyzed scenarios are of mathematical nature, i.e. optimization according to principle of the lowest cost of a system. According to calculation results a final conclusion can be made: to fulfill the condition of reducing CO_2 by 47% in 2050 (in relation to 2005), from 2040 there shall be no more fossil fuel consumption in households. This consumption should be substituted by pure technologies on pellets, heat pumps on electricity drive (electricity generated from clean technologies like wind power plants, nuclear, solar and gas power plants with carbon capture technology) and micro-cogeneration. The additional contribution to natural gas consumption reduction in households and the main cause for such reduction would be improved insulation

[4] Directive 2009/29/EC of the European Parliament and of the Council dated April 23, 2009 amending Directive 2003/87/EC so as to improve and extend the greenhouse gas emission allowance trading scheme of the Community.

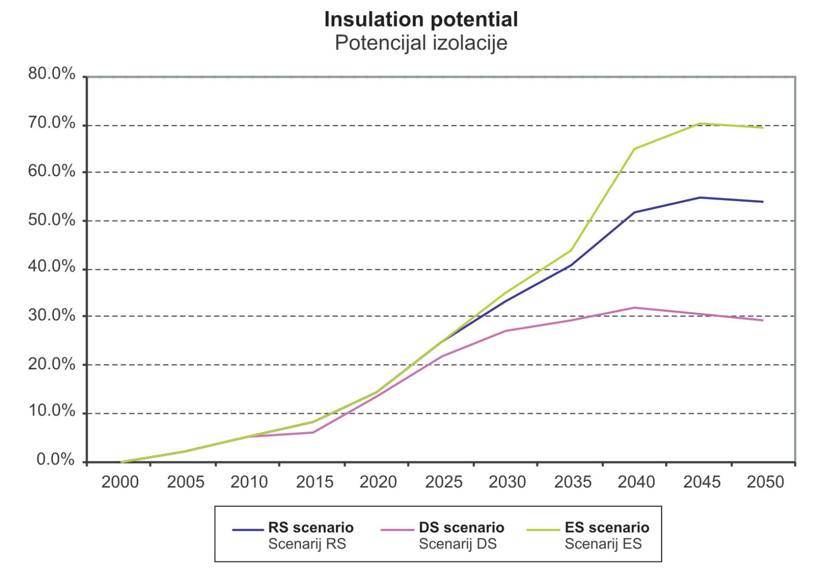

Fig. 5 Insulation potential in households in RS, DS and ES scenarios
Sl. 5. Potencijali izolacije u kućanstvima u scenarijima RS, DS i ES

in all types of households and heating, which directly shows that investment in better insulation of buildings is the most cost effective measure of all energy efficiency measures, reducing the consumption of useful energy for heating and cooling.

4.4 Incentive Analysis Scenario (Ps)

Analysis of necessary incentives, i.e. subventions on technology investment cost, was made for all insulation and solar collectors in households. Investment cost is reduced from 10 to 70 percent for selected technologies (measures), while the optimization result (technology share in total final consumption of defined energy demand) was compared to the share acquired in limited CO_2 emission (ES) scenario.

The share of insulation in total final energy for heating according to types of households and heating, considering the size of incentive for insulation investment cost, depends on the type of household, its income and energy consumption. Wealthier households that consume more energy (households with central and individual room heating) have higher energy savings potential by introducing insulation and the needed amount of incentive for them is 30 percent by 2020 and 70 percent from 2020 until 2050. The apartments with central heating require smaller incentive amounting from 10 to 20 percent by 2015, while the apartments with individual room heating shall need incentive of 50 percent in 2020 and around 70 percent in the period from 2030 to 2040.

Analysis results showed that, even with big incentive of 70 percent to the investment cost for solar collectors for heating and DHW in houses with central heating, collectors' share is still considerably lower from the results from CO_2 restricted emission scenario (ES). This fact can be explained in two ways. The first one is that ES scenario results are mathematical. The second one is in accordance with expert evaluation and the fact that results from scenario with incentives (PS) are real, i.e. the incentive of 70 percent in the period from 2015 to 2020 is sufficient to reach the market share for solar collectors of 15 percent in houses with central heating category (for the incentive of 30 percent that share would be around 10%). Optimization results of incentives scenario (PS) for solar collectors for DHW in houses with individual room heating, real market share for collectors with incentive of 70 percent in the period from 2020 to 2025 would be 12 percent and in the period from 2030 to 2040 around 45 percent.

5. COMMENTS OF RESULTS

Results of the described scenarios were acquired by applying MARKAL optimization model and can be interpreted as mathematical analysis results. This especially applies to the scenario with restricted CO_2 emission (ES) where a big change in final energy consumption structure occurs, with the emphasis on fossil fuel consumption end from 2030 (the biggest part of consumption consists of electricity and energy savings due to insulation).

Analysis results of scenario with minimally acceptable rates of return for technologies (DS) showed that application of these rates which represent all market, administrative and other obstacles which appear during introduction of a new technology to the market, affect insulation level in households and services as well as the use of other energy efficiency measures. Application of minimally acceptable rates of return for technologies in RS scenario should be taken as a textbook example as for the Republic of Croatia there are no special analysis that would present real values of this parameter.

Analysis of incentives scenario (PS) shows which incentives need to be provided for implementing insulations and use of solar collectors in households. These results approximately relate to the expected results acquired by experience analysis.

The unique result of all the analyses is that the increase of energy efficiency is the first priority of strategy and energy policy of each country, during the whole process from generation, transformation, transport/transmission, distribution and consumption by end-user. Strategic goal is to generate, transform, transport, distribute and spend less energy for the same efficiency and quality of service. Energy efficiency increase is a measure imposed by itself, economically justifiable and further price increase shall only strengthen its importance. Priorities are where big savings can be achieved, primarily in construction of buildings and also in other processes with potentials for energy consumption reduction.

6. CONCLUSIONS

Radical reductions of CO_2 and other greenhouse gas emissions considerably change relations in energy sector. To reach greenhouse gas emission reduction goal, there is a need for energy efficiency increase, but energy consumption structure changes as greenhouse gas emission can not be reduced equally in all parts of generation, transformation and consumption. Technologies using fossil fuels and producing CO_2 and other greenhouse gases are gradually being abandoned in households while being replaced by technologies without emission. The use of fossil fuels is concentrated to the places where their capture and storage are possible, and those are big plants for production of power and heat energy. The increase in electricity consumption shall be considerable (production from so called clean technologies), which shall substitute other energy forms for end users. These results show that the given restriction on CO_2 emission in the amount of 50 percent in 2050 related to 2005, considering the size, development level and economic power of the Republic of Croatia and necessary investments in new technologies, are high scope for Croatian energy system and consequently for the entire economy of the Republic of Croatia. For the developing countries, like Croatia, it is important that the response on climate preservation obligation is right and sustainable in the long run and that obligations of each country are equal for all the inhabitants.

Protection of climate in the CO_2 and other greenhouse gases emission reduction project is a project that can be realized and has to be based on international agreement and responsibility of all the countries. The project can be realized with the real price of energy which includes the cost of environmental protection. The additional presumption is considerably higher directing of financial means and synergy effect in scientific research and technological development. Finally, as the third presumption, these processes should begin as soon as possible.

Choice of technology in reaching the set goals of supply safety with CO_2 emission reduction shall depend on prices and it is difficult to forecast what shall be happening with certain technologies and what period of time shall be needed for a certain technology to change from unreachably expensive one to the widely available one. Certainly, implementation dynamics depends on energy price change as well as on the market development. Over the past 10 years we have witnessed that the prices of certain technologies have dropped even several times.

Energy consumption reduction in building construction beside its energy and environmental dimension, has also a business dimension. Between 7 – 10 billions kuna need to be invested annually in reconstruction of civil and office buildings that were built between 1945 and 1990 with the goal to repair current state over the next 20 years due to bad insulation in buildings.

The increased use of renewable sources directly by energy buyers in current situation of technological development and price relations requires financial aid up to 70 percent. Basically, it can be considered that by including the environmental costs, mainly CO_2 emission reduction cost instead of financial help, financial competition of technologies shall be evaluated according to realistic energy prices.

To reach the goals set for climate preservation and obligation for reducing CO_2 and other greenhouse gases emission, it is necessary to have a long term vision of all the processes and obligations at least until 2050, so the long term and short term goals and measures can be defined. Energy sector development strategies for the period until 2050, favorably even longer, need to be made for Croatia as well as for all EU countries.

It is necessary to set the total frame for acquiring targeted energy policy and climate preservation policy in Croatia, which includes legal framework, financial means, rational procedures and appropriate education at all levels for the following priorities:

1. The basic principle of future energy policy should be that in all energy processes from generation, transformation, transport/transfer, distribution and finally consumption by the end user of energy: less energy should be used with the same effect and the same quality of service in generation, transformation, transport, distribution and consumption
2. Increase of energy efficiency in building construction
3. Increase of energy efficiency in all technological processes
4. Support the introduction of unique cost protection evaluation, mainly CO_2 emissions
5. Stop stimulating the use of all technologies and energy solutions that increase the level of CO_2 emissions and stimulate all energy and technological solutions which are sustainable in the long run from climate preservation point of view
6. Create all the necessary conditions needed for continuous increase of sustainable energy sources use
7. Continuous incentive for technological development to increase energy efficiency, use of renewable energy sources and advanced technologies for the use of nuclear energy.

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