RENEWABLE ENERGY PROJECTS IN CROATIA: PRESENT SITUATION AND FUTURE ACTIVITIES

by

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Renewable energy sources should play an important role in the promotion of numerous Croatian energy goals. The development of a successful sector of renewables could in the long run contribute to energy efficiency improvement, diversification of production and supply safety, domestic production and lesser imports of energy sources and significant reduction of the environmental influences. Targets and strategy of the implementation for every renewable energy resource depends on the specifics of the particular one, with general trends in the European Union of renewable resource ratio increase in the energy balance.

Key words: *renewable energy sources, national energy programs, environment protection, energy policy*

Introduction

Within three year period (1995-1998), Ministry of Economy, Labour and Entrepreneurship as well as Ministry of Science, Education and Sports initiated numerous expert surveys in order to gather reliable platform for construction of energy sector development strategy of the Republic of Croatia [1]. Those basic data were essential in analyses and calculations as well as in precision regarding goal forecasting related to general social development. Regarding renewables, in 1997 the Government initiated an organized and systematic attention through the National Energy Programs. The programs that are especially important for renewable energy sources (RES) are:

– BIOEN – program for the use of energy from biomass and waste,
– SUNEN – program for the use of solar energy,
– ENWIND – program for the use of wind energy,
– GEOEN – program for the use of geothermal energy, and
– MAHE – program for construction of small hydro power plants.

The next milestone in Croatian energy reform was drafting of the Energy Strategy in 1998 which outlined basic natural expectations on one side (in the form of energy forecasts), and set guidelines for institutional reorganization on the other. This was followed by adoption of the Concept of Energy Sector Reform in the Parliament of Croatia in July 2000, which gave a green light for the institutional part of the Energy Strategy.

However, it simultaneously placed the update of quantitative energy forecasts for Croatia in state of pending until elaboration of next generation of strategic level documents regarding the energy industry development in Croatia (fig. 1).

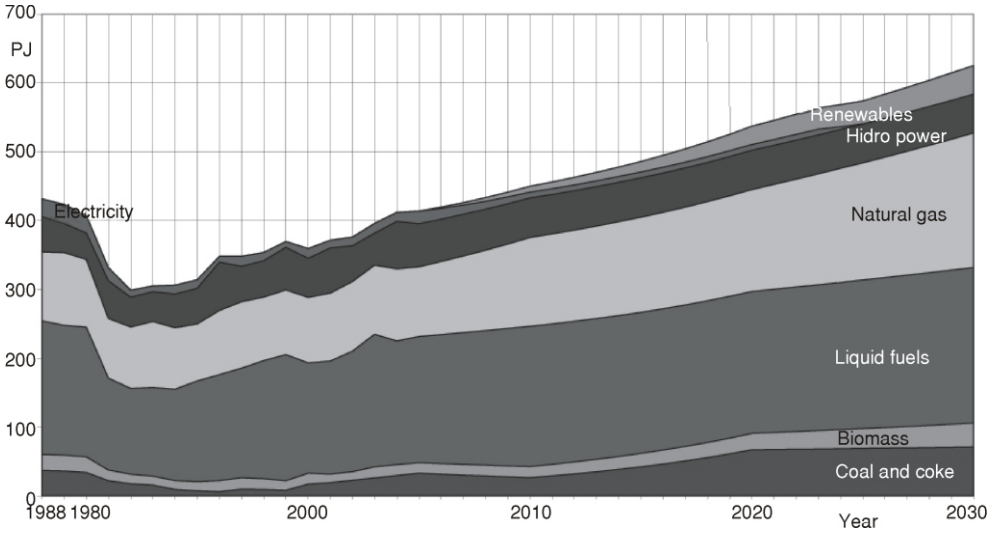

Figure 1. Total primary energy supply in Croatia [3]

Following the accepted concept of the energy reform, the basic legal frame in Croatia was prepared and, in July 2001, adopted through Energy Law, Law on Regulation and Energy Activities, Law on Electricity Market, Law on Gas Market, and the Law on Petroleum and Petroleum Products (Official Gazette 68/01 and 109/01). These laws define the basic organization and functioning of energy markets in Croatia. For an integral regulation of relationships in the energy markets, the implementation of the foreseen laws mean:

– establishment of new institutions (The Croatian Energy Regulatory Council, Fund of Environment Protection and Energy Efficiency),
– restructuring of energy entities (*e. g*. HEP and INA)*, and
– adoption of special laws (*e. g*. Law on Production, Distribution and Supply of Thermal Energy); and issuing a series of by-laws.

In 2002, Strategic planning office of the Republic of Croatia prepared a multi-volume strategic document, called H21 – Croatia in the 21st Century, for the Gov-

* HEP – Croatian electricity company – state company; INA – Croatian oil and gas company – state company with strategic partner (MOL – 25%)

ernment of Croatia (GoC) [2]. This document lays down development guidelines of the Republic of Croatia as a civil, economically strong, and democratic society.

It comprises a number of steps and measures in various fields, required for the realization of realistic and clearly defined goals, which should enable Croatia to become a full member of the European Union. One of the volumes was also Energy Sector Development Strategy which was adopted by the Croatian Parliament in March 2002. This release of the Strategy, prepared mainly by EIHP, strongly relies on the 1998 release, with some upgrades and amendments included. It is the last officially promoted strategic document that outlines vision of the Croatian Government regarding energy sector development.

In 2002, Croatian Parliament adopted laws on privatization of INA and HEP which was followed by Law on Fund for Environment Protection and Energy Efficiency (LoFEPEE), in 2003. LoFEPEE established a Fund for financing projects and programs in the field of protection and sustainable use of the environment, as well as for financing projects, measures and programs, including National Energy Programs, aiming to increase energy efficiency (EE) and use of RES. During 2004 and 2005, the Fund has been mostly increasing its revenues without major expenditures. Ministry of Economy, Labour and Entrepreneurship (MoELE), after intermission of elections in end 2003 and change of GoC, prepared proposal of energy laws amendments during 2004, which finally passed parliamentary procedure and become effective in December 2004. In 2005, Law on Production, Distribution and Supply of Thermal Energy entered parliamentary procedure, and was adopted in March 2005 (tab. 1).

Table 1. Pace of energy sector reform in Croatia

Year	Milestone
1994	PROHES project
1997	National Energy Programs
1998	Drafting of the Energy Strategy
2000	Concept of the Energy Sector Reform adopted in the Parliament
2001	"Package" of energy laws
2002	Croatia in the 21st Century: Energy Sector, Energy Sector Development Strategy of the Republic of Croatia
2002	HEP and INA privatization acts
2003	Establishment of the Fund for Environment Protection and Energy Efficiency
2003	Croatia signed MoU of the Regional Energy Market in the South East Europe
2004	Amendments on the energy laws
2005	Law on Production, Distribution and Supply of Thermal Energy

RES that have been used in Croatia for many years, and thus, recorded in annual energy reports, are hydro energy, fuel wood (biomass), and geothermal energy. Hydro energy is used exclusively for electricity generation, while fuel wood, as a traditional form of energy, is used in households for space and sanitary hot water heating and cooking. Geothermal energy is used mainly for recreational and balneological purposes *i. e.* heating of medical swimming pools. Other RES are still insignificant compared to hydro, biomass, and geothermal, but appearing on the horizon especially wind power with almost 6 MW_e installed on the island of Pag and 12 MW_e installed on location Trtar-Krtolin [3].

RES – Present status and future potential

General overview

One of the crucial actions that are expected to facilitate planning of the future role of RES in the Croatian energy mix is reliable assessment of renewables' resources. This would lead to designing of appropriate supporting mechanisms as part of a new legal framework. Since hydro, biomass, and geothermal resources are rather extensively studied in the past; these actions primarily refer to assessment of solar and wind energy potentials. The actions need to be launched in order to increase information on their resources such as measurement campaigns, resource modelling and assessments and mapping of their potential (tab. 2).

Table 2. Energy production and capacity of RES (in 2005) [3]

Resources	Installed heat capacity	Installed power capacity	Electricity production	Heat production
Solar	n. a.	48.84 kW	50.14 MWh	n. a.
Wind	0	5.95 MW	9.5 GWh	0
Biomass	512 MW	2 MW	10.9 GWh	14.767 PJ
SHPPs	0	26.7 MW	108.3 GWh	0
Geothermal	113.9 MW	0	0	547.33 TJ
Total	**625.9 MW**	**34.654 MW**	**128.7 GWh**	**15.314 PJ**

Croatian research priorities in renewable energy resources assessment are [4]:

– increased number of high-tower wind measurement stations, located in remote areas suitable for wind developments and a limited number of upper-air measurement stations,

– development and application of advanced wind resource modeling approaches and tools,
– a wider and denser network of solar radiation stations needs to be established,
– investigation of alternative methods to measure solar radiation components (*e. g.* multipyranometer array method),
– development of solar radiation utilization chart for solar thermal systems, and
– GIS based analyses and description of renewable energy sources and their spatial and temporal characteristics and compatibility.

RES development

Hydro energy [5]

Since its beginning in 1895, the hydroelectric power plant projects in Croatia reached their peak after the Second World War, when the significant utilization of the water potentials commenced. Sequence of construction of hydro power plants was based on their energy and economic value, *i. e.* on the benefit they provide to the power system. Apart from large-scale hydro power plants, there is also a number of small hydro power plants (SHPPs) in Croatia. Their expected annual generation is around 80 GWh. Their locations, installed capacities and first year of operation are given in tab. 3.

Table 3. Small HPPs in Croatia

Small hidropower plants	Installed capacity [MW]	Power production in 2005 [GWh]	Commissioned
Zeleni Vir	1.7	6.5	1922
Jaruga	5.6	33.16	1904
Ozalj 1	3.6	24.1	1908
Ozalj 2	2.2		1952
Zavrelje	1.5	4.8	1953
Krčić	0.44	0.9	1988
Čakovec	0.34	n. a.	1982
Dubrava	0.68	n. a.	1989
Duga Resa cotton mill	1.1	1.76	1937
”10. kolovoz” cement factory	1.2	n. a.	1913
Finvest 1	1.26	2.99	1995
Finvest 2	0.03		1997
Roški slap	1.7	8.61	1907

Biomass [6-8]

Next to hydro power, bioenergy is the most important renewable energy resource in Croatia, with its share of 4.6% in 1999 in total energy supply. However, in the past biomass had never taken an important place in the energy policy of the Republic of Croatia, as it has been utilized by rural population in a large scale for heating and cooking in all Croatian regions. Fuel wood, commercial and non-commercial cutting of woods amounted to 15% of primary energy consumption in 1970, and in 1990 that part, due to urbanisation and growth of the living standard was 5.3 percent, while biomass share in the 2001 total energy supply was 3.3%, mainly attributable to fuel wood utilization. In places where the gas grid will not reach it is expected to remain an important source of energy for heating purposes.

While 36% of the total land area makes forest, and with strong agriculture and wood industry, biomass has a great potential as a source of renewable energy in Croatia. The most important source of biomass for energy is wood from forestry and wood processing. At present, 1.8-1.9 million m^3 solid (12.1 PJ) of woody residues are available for energy production, about half of which originates from the wood processing industry. In comparison to other European countries and regions, Croatia ranks as a country with a significant share of timber-land in the total government-owned land (44%). This allows for a better utilization and share of wood biomass in the total energy balance (tab. 4).

Table 4. Energy potential of biomass in Croatia*

Source of biomass	Available biomass	Potential [PJ]
Biogas from manure	83 560 000.0 m^3	2.089
Pruning of trees (fruit)	197 504.3 t	0.691
Waste from fruit processing	3 625.0 t	0.027
Waste from agriculture (wheat, corn)	825 643.9 t	11.412
Wood residues	1 837 881.4 m^3	12.115
Round wood	825 054.9 m^3	7.425
Branches	458 043.9 m^3	2.004
Non-commercial cutting	344 937.0 m^3	3.296
Total technical potential		**39.059**

* Without municipal solid waste (MSW)

The most important oil crops in Croatia are sunflower, soybean, and rapeseed. In the structure of plant production they account for 10.2 percent of overall acreage in 1999. The most important raw material for biodiesel production worldwide is rapeseed

(82.82%), as well as sunflower (12.5%). As far as rapeseed requirements in Croatia are concerned, it can be stressed that very favourable soil and climate characteristics for rape are present in Pannonian agricultural region. The Government of the Republic of Croatia gave support to biodiesel production in year 2000, within the framework of the BIOEN Program and Ministry of Agriculture and Forestry has been appointed the head of the project. However, until now, there is only one biodiesel processing plant of 20,000 t capacity which is located in Ozalj (2006).

In the course of last few years Croatian scientists and engineers have undertaken much research and developed different technologies for energy production from biomass. In the area of briquetting significant results have been achieved and in some Croatian regions, briquettes are available on the market. Research have been conducted on briquetting (wood waste, saw dust, and maize stalks), biogas engine development and biomass fired boiler construction.

Estimation of total energy potential of municipal solid waste, based on energy potential from 4 main cities (Zagreb, Rijeka, Split, Osijek), is approximately 12.34 PJ for year 2011 (1.84 PJ gas and 10.50 municipal waste). Estimation of total technical potential for energy production (in 2011) is 6800 GWh of electricity and 870 GWh of thermal energy.

In Croatia, industrial bioenergy concepts vary from modest to very interesting, from an economical and environmental point of view. Nonetheless, a breakthrough in bioenergy utilization will have to be forced. Awareness and understanding of economical and environmental benefits of bioenergy will have to be raised.

Solar [4, 9]

The majority of solar collectors in Croatia were installed in 1980s during the period of increased social sensitivity toward solar energy, mostly all of domestic origin. During the last 15 years, there were two unfavourable courses of solar energy utilisation. Firstly, the total area of installed surfaces was modest and, secondly, rapid decline in cumulative surfaces as the collector systems installed in 1980s reached their functional lifetime. Today, total solar collector surfaces in Croatia can be estimated to not more than 15-20,000 square meters.

Photovoltaic systems applications include powering of road signals, telecommunication and radio diffusion systems, lighthouse and naval buoys, distance measurement systems, and similar applications. Only one grid-connected system is in operation, 7.4 kW system installed in Zagreb. However, the power it produces is delivered to the Croatian Power Utility (HEP d. d.) without any compensation as no regulation exists to regulate relations between independent power producer and utility power grid.

In Croatia, solar radiation measurement commenced in 1948 in Zagreb, and global solar radiation is measured since 1951 in Split. In 1983, eight radiometric stations were operational. However since 1989 almost all solar radiation measurements are discontinued, to be re-established only since 2003. Measurement of direct solar radiation in Zagreb, Split, Rijeka, and Osijek region are a priority. Based on the results of these measurements, and using hemispherical view shed solar radiation model based on digital ter-

rain model, a solar radiation atlas can be produced (it will be published for public use during year 2007) (fig. 2).

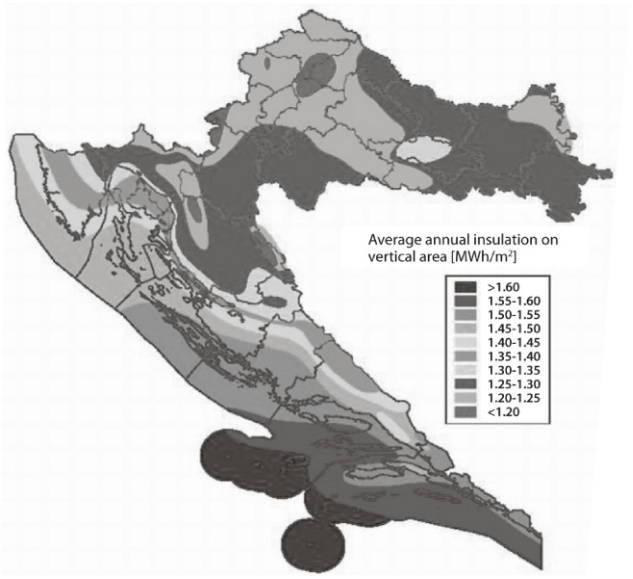

Figure 2. Solar atlas of Croatia [4]

Figure 3. Temperature gradient distribution

Energy production of solar thermal systems depends on the one hand on solar radiation as an energy source but, on the other hand the efficiency of a thermal system also depends on the ambient temperature: the lower the temperature the higher the thermal losses and thus lower the overall system efficiency. Investigation of these correlations is essential for solar thermal utilization.

Geothermal [10, 11]

Croatia has a centuries-long tradition of using geothermal water from natural springs for medical purposes. In the early 1970s along with oil and gas research and development, the appearance of geothermal water began to be observed. The calculations of temperature gradients based on the data obtained from exploration wells showed that the average gradient in the northern part of the country, belonging to the Panonian sedimentary basin, is considerably higher than the world average, while in the southern, Dinarides area its value is below that figure (0.049 °C/m and 0.018 °C/m, respectively, compared to 0.03 °C/m in Europe). The temperature gradient distribution in Croatia is shown in fig. 3.

Direct heat use is presently the only aspect of utilizing geothermal energy in Croatia. The majority of localities are spas, usually including hospitals and hotel capacities, equipped with swimming pools and other therapeutic and recreational facilities. Basic geothermal fields are indicated in fig. 4.

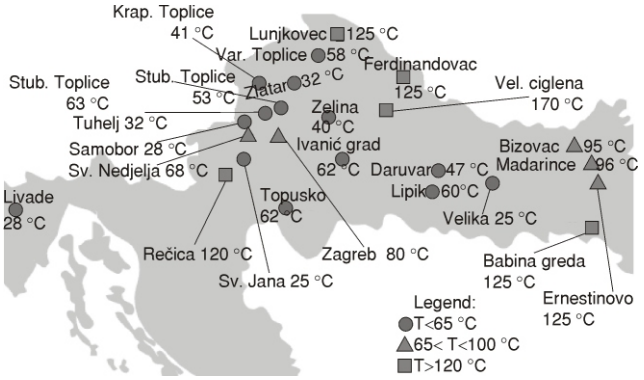

Figure 4. Geothermal potential in Croatia

Wind [12]

Although having a long tradition of using windmills on its islands, Croatia commissioned its first wind farm for electricity generation in February 2005. It's the Ravna I project on the island of Pag, consisting of 7 Vestas wind turbines of 850 kW each, totalling in 5.95 MW. The second was Trtar-Krtolin (May 2006) with 11.20 MW total power installed (tab. 5).

Table 5. Wind projects in Croatia (2005/2006)

Status	Project	Installed or planned power [MW]	Planned power production (estimated) [GWh]
Commissioned	Ravne I Trtar-Krtolin	5.95 11.20	12-15 25-30
Site permit or more	Stupišće Orlice Jasenice I	5.95 6.00 10.00	n. a. n. a. n. a.
Environmental impact study and assessment	Four projects are currently in the phase of environment impact assessment (EIA)		
Wind measurements	Wind measurements take place at additional 20 or more sites		

Croatia has substantial wind resource, notably on the Adriatic coast, where many areas have mean annual wind speeds in excess of 6 m/s. According to preliminary

analyses of wind potentials, it is expected that most of the wind farms in Croatia will operate between 2000 and 2400 full load hours. The total wind potential is still not known, since reliable wind atlas of Croatia is unavailable, and recent investors' measurements indicate that exploitative wind potentials exist in upland areas of Croatia, too, which adds significantly to approx. 1 TWh per year of preliminary estimated wind resource.

Beside Ravne I and Trtal-Krtolin projects, there are several wind projects currently in various stages of planning process. Wind developers started their activities in Croatia as late as 1996 and today there are around ten active investors developing more then 30 wind projects in total.

More specifically, Croatia has a promising wind potential, particularly in the coastal region, but large regions are either completely unexplored or poorly evaluated. Locations of existing meteorological stations are more or less impropriate for wind resource assessment and existing data can only partially be used for regional/national wind resource estimates because of low density and low quality of the data. Because of rather complex terrain, available data is insufficient, which makes wind resource assessment and micro location analysis for future wind projects difficult and overall cost analysis uncertain.

Moreover, specific wind climate and characteristics can be expected in coastal parts of Croatia that calls for development of new wind modelling approaches and strategies [4]. Namely, recent research has shown that application of common wind flow modelling tools does not result in a reliable wind resource prediction in complex terrain. Namely, the atmospheric processes leading to the formation of strong sustained downslope winds like Bora (very present in Croatia) are dominated by the mesoscale effect induced by the mountains and thermal structure of the atmospheric boundary layer. Such atmospheric situations should be modelled by models that take into account the mesoscale dynamics of strong downslope winds.

Specific technological research areas for RES

Heating and CHP [4, 6-11]

Solar water heaters are one of the most cost effective renewable energy solutions on the market today. However, application in Croatia have been rather limited due to relative higher prices caused by low sales volumes, poor image in the public as an unreliable and breakdown susceptible technology, low availability of qualified installers and a rather low energy prices of electricity and fuels making this renewable option unattractive. Solar water heaters are on the market for more than 30 years and are considered as mature and reliable technology. Still, the improvements to the components are made – more efficient absorbers, solar glass, and pumps. This technology has the greatest potential in coastal region of Croatia where it will replace electric heaters and reduce electricity demand as the electric grid is already bearing the burden of rapid increase in air-conditioning and general demand for power.

In the field of solar cooling, no experience has been gained in Croatian research institutions. The concept however has a great potential in applications in service sectors, especially tourism.

Solar crop drying is used very rarely in Croatian agriculture. The concept can provide drying for a wide variety of crops, relatively is low-cost, simple and adaptable, and requires little or no maintenance. Solar crop drying has a potential to protect agriculture from volatile prices of fossil fuels, simultaneously reducing pollutant and greenhouse gas emissions. Solar dried food can be publicized as a special "green processed food", similar to the organic food labels.

Small scale combustion of biomass is by far the most extensive application of bioenergy in Croatia. In areas where the gas grid does not reach, and where there is no district heating system, fuelwood is the main source of primary energy used for heating purposes. Large scale production of bioenergy takes place in the industry exclusively. Many companies in the wood industry have a substantial heat demand, in specific sawmills and furniture factories. Most of them produce their own heat, quite often from fossil fuelled boiler systems but some also from their wood resources.

Combustion is a commercial technology with traditional fuels such as wood residues and MSW (municipal solid waste) and several successful applications can be identified. Biomass for heating and combined heat and power (CHP) research priorities:

– new applications have to be developed for the more complex feedstocks such as straw, grasses, and mixtures of several different fuels,
– grate systems as a preferred type of combustor due to their reliability and industrial experience especially for small to medium size applications (0.5-5 MW_e) should be further upgraded,
– fluidized bed combustors, which have been proven very successful due to the relative easy scale up and their capacity to operate with a variety of fuels so long as the bed sintering (due to the high ash content of some of the biomass fuels) can be effectively controlled, should be more developed especially in range 3-20 MW_e. Furthermore, development should be focused on the incineration of refuse derived fuel in fluidized bed systems. There is nevertheless need for long term operation of fluidized bed systems in order to prove their reliability,
– future technical development should focus on using more difficult feedstocks and multi-fuel operation, and
– the industry should follow the advances on materials made by the coal boiler technology in using supercritical steam conditions in view of increasing the conversion efficiency to electricity. CHP applications offer the best economic viability due to the sale of heat to district heating networks or industrial users.

After almost 15 years of continuous promotion of biofuels benefits along ongoing rapid development of biofuels industry in almost every European country, first amounts of biofuels are to be produced in Croatia, finally. The first produced biofuel will be biodiesel from modest capacity, but new and exciting large scale biodiesel and bioethanol projects are already under development.

In 2003, the Subcommittee for biofuels was formed within the Technical department 28 of the Governmental Office for Standardization and Metrology, which defined

the Croatian norms for biodiesel. This practically means acceptance of the EU norm EN 14214. The Subcommittee also made a decision to allow the mixing of 5% of biodiesel in the standard mineral diesel fuel without special marking. In 2002, the Croatian Government has, based on the proposal of the Ministry of Environmental Protection and Physical Planning, adopted the Regulation on Quality Standards for Liquid Oil Fuels, which was last amended in August 2005. In 2005, the same Ministry prepared the Regulation on Biofuels Quality which regulates all issues regarding the biofuels quality but also gives some indicative targets for national biofuels consumption in line with the Directive 2003/30/EC.

Recent studies within BIOEN program identified the following R&D needs:

- the top priority is to reduce the production cost of biofuels,
- integration of installations to produce biodiesel with the aim of achieving self-supply in agricultural concerns,
- studies into reforming vegetable oil extraction for the production of biodiesel, and
- a clear identification of the niche markets is needed to show which would benefit most from the use of biodiesel.

Regarding biodiesel the following R&D technology priorities are identified:

- intensify R&D effort on multi-component biodiesel production,
- optimizing the use of biodiesel by substantial modifications to engines,
- optimizing the use of biofuels by substantial modifications to engines,
- research into new plant varieties to optimise the biodiesel production process,
- implementing schemes with vehicles running on ethanol; local, regional, and national authorities and vehicle manufacturers should be involved,
- experiments and research into new materials and lubricants to reduce the maintenance costs resulting from the use of biofuels, and
- research into the optimal gasification process to transform biomass into methanol.

Electricity production [4, 5, 11]

Wind farm sites in Croatia are mainly positioned remotely from consume, especially after Ministry of Environment Protection, Spatial Planning and Construction prohibited construction of wind farms in the coastal area. The evacuation of electricity from wind farms thus might be technically demanding or even impossible because of the poor capacity of the grid in some areas to transfer large amounts of energy. This could significantly limit the technical wind resource and increase costs. Therefore, it is crucial to execute strategic studies and research on grid integration of wind farms and smart grid control and management at this very early phase, since results would influence planned solutions for grid development and extension.

Croatian grid operator might settle technical requirements in a way that wind farms would be obliged to output planning. If so, wind forecasting will become increasingly important to maximize wind farms revenues. Due to specific wind regime in Croatia, accurate wind forecasting requires new and advanced methods and models need to be developed.

Croatia also has a need for developing national standards and certification procedures in the field of wind energy in order to avoid uneven practices and ensure that minimum quality standards and safety requirements are met. Transposition and updating of relevant international standards into national requires time and experts involvement in the process. In addition, proper implementation of certification procedures is connected with testing facilities, at least for small-scale applications, and therefore such institutional capacity needs to be established in Croatia (tab. 6).

Table 6. Croatian potential, present share and prospects for the utilization of RES for heat and electricity [4]

Type of RES	Potential	Present share	Prospects
Heat			
Biomass	Significant	Good	Good
Solar	Significant	Poor	Good
Geothermal	Significant	Poor	Poor
Electricity			
Wind	Significant	Poor	Good/Excellent*
Biomass CHP	Significant	Poor	Excellent
Geothermal CHP	Limited	Poor	Poor
Small hydro	Significant	Poor	Good
Solar PV	Significant	Poor	Poor
Transport			
Biofuels	Limited	Poor	Good

* Depending of local transmission grid capacity

The following specific research wind technology areas can be recognized in Croatia:

– strategic studies regarding transmission and distribution system capabilities for integration of wind power into Croatian electric system, including grid management with different levels of intermittent generation,
– wind forecasting and prediction at system operator level,
– research on capacity credits of wind energy in Croatia (max. penetration of wind power plant regarding present (and future) production from existing conventional PP and transmission grid capacity),
– technology development and design research with special features for specific wind regime in Croatia,
– standardization in the field of wind energy, especially safety requirements,

– research of interaction between wind energy and energy market in general, particularly with regard of the intermittency of wind farm output and its consequences on the wind energy value, and
– database on wind characteristics and wind turbine operation in complex terrain.

Environment and RES

Croatia has made significant improvement regarding environmental issues assessments although the process of enforcement of those deliverables goes at a slow pace. The Environmental Protection Act (Official Bulletin 82/94, 128/99) stipulates that the Croatian Government submits the State of the Environment Report to the Croatian Parliament every four years. In 2002, National Environmental Strategy (Official Bulletin 46/02) was prepared under the co-ordination of the Strategic Planning Office of the Republic of Croatia through the Croatia in 21st Century process. Parallel to that, National Environmental Action Plan (NEAP) (Official Bulletin 46/02) was prepared in co-operation between the Ministry of Environmental Protection and Physical Planning and the World Bank through the Project on Environmental Policy Development and Regulatory Capacity Building. In the process of NEAP preparation Priority Action Plan (PAP) was prepared, containing projects presented at the Donors conference in Zagreb, 2001.

In March 1999, Croatia signed the Kyoto protocol of the United Nations General Climate Change Conventions (UNFCC). After it is ratified by the Croatian Parliament, the Croatian obligation will be to maintain CO_2 emission at the 1990 level until the end of the century. According to Kyoto protocol, Croatia should have reduced CO_2 emissions to 95% of the highest emission year in the 1985-90 period (some 4.8 t per capita).

This represented an extremely serious responsibility. In 1990, Croatia had almost the lowest emission of CO_2 per capita in Europe, half the west European average. Finally, in late 2005, at the first meeting of the Parties to the Kyoto protocol in Montreal in conjunction with the 11th session of the Conference of the Parties to the Climate Change Convention in Montréal, after four years of negotiations, certain flexibility was awarded to Croatia in respect to the higher starting base for reduction of GHG. In return, Croatia seriously committed to consider renewable energy sources utilization.

Kyoto protocol entails, among others, definition and enforcement of strategies and measures for climate change mitigation, data base for LULUCF (*Land-use, land-use change, and forestry*) sector carbon storage until December 31st, 2006, as well as establishment of national system for calculation of GHG emissions until 2007 together with emission register. Those tasks could be perceived as priorities for Croatia regarding research and development in measurement and evaluation issues.

The Croatian Government established the Croatian Environment Agency (CEA) in June 2002 (Official Bulletin 75/02). The Agency is envisaged as a focal point for collecting and integration of the environmental data on a national level, their processing, maintaining the environmental database, environmental monitoring and reporting not only regarding Kyoto protocol but also regarding other national and international environmental issues.

The Agency should provide state of soil, sea, inland water, air, biodiversity, and waste reports as well as indicators for monitoring of changes and realisation of objectives by sector policies or strategies, according to European Environment Agency (EEA) framework. So far, CEA delivered several publications such as: Corine Land Cover 2000 Data Base (2004), Agro-environmental Indicators (2005), Biodiversity Indicators (2005), Land-registry of Risky and Potentially Risky Installations in Croatia (based on Convention on Cross-border Effects of Industrial Accidents (Official Bulletin 7/99), Intervention Plan for Environmental Protection (Official Bulletin 82/99, 86/99, 12/01), and Sveso II directive 96/82/EC, 2003/105/EC).

Research priorities:

– giving monetary value to the environmental costs of energy production in respect to human health (Statistical value of life), biodiversity and nature (Hedonic prices) as well as total natural resource degradation (Willingness to pay *vs*. Willingness to accept). In that sense, there will be enough data to contrast conventional energy sources *vs*. RES utilisation not only by unit cost of energy (kWh) but also by its effect on the society as a whole,
– research and estimation of the external costs of different energy forms use in Croatia, and
– environmental impact issues related to renewable energy sources.

Legislation

The Croatian energy legislation ("package" of energy laws) [12-21], adopted in 2001, although generally affirmative regarding the use of renewable energy sources, after four years of application has not been completed in its implementation aspect, *i. e*. at the level of secondary regulation. Some vital issues for RES, like incentives or even institutional arrangements, have been left inadequately regulated or even undefined. Such environment for renewable energy sources is not in accordance with the European framework adopted and it is far from an average state of development of national legislation concerning the use of renewable energy sources within the EU.

In Croatia the legal treatment of RES and cogeneration started only a few years ago. Due to the generally high production costs of energy from RES and cogeneration, and due to the existence of the so called incremental costs, the legislator envisaged introduction of financial support to RES and cogeneration. At the same time, supply companies are obliged by law to use certain portion of renewables and cogeneration in the energy mix they are selling. This portion (or share) of RES is not yet defined (September 2005), but the law obliges the Government of Croatia to define this share by the *Decree on minimum share of RES and Cogeneration*. The role of an intermediary between renewable producers and supply companies is given to a recently established independent market operator. According to [13-20], the market operator is responsible for contracting with renewable generators on one hand, and remunerating them at price determined by the law, and with suppliers on the other hand, ensuring that they fulfil their legal obligation. Additionally, the market operator, which is under the control of the Croatian Energy

Regulatory Agency, will also be responsible for "accounting, collection and distribution of financial assets coming from special fees for promotion of RES and cogeneration". In this way the incremental cost of renewables and co-generation will be passed on final consumers in the most efficient way. The foreseen support scheme is intended to be operational only for the quantity of renewables and cogeneration prescribed by the Croatian Government. The law prescribes that the Government will determine the minimum share of RES and cogeneration, but not the pace of implementation. The draft *Decree on minimum share of RES* proposed a linear annual increase of RES generation starting from 2006 by approx. 150 MW per year until 2010. As regards heat, the Law on Production, Distribution and Supply of Heat regulates in a systematic and comprehensive manner all activities related to production, distribution and supply of heat, including the rights and obligations of energy subjects (heat producers), the rights and obligations of customers, the measures to provide financial means for building up of plants and facilities for production, distribution and supply of heat, and others. The Law specifically envisages the stimulation of RES utilization for heat production by introducing two new sub-laws which will define incentive measures as well as the targeted quota of RES in heat production, by the Tariff system which will regulate both electricity and heat generation from RES.

Except the regulated tariffs for RES and cogeneration (fixed price or feed-in) and minimum share obligation, there is another strong instrument for promotion of RES in Croatia. It is the Fund for Environment Protection and Energy Efficiency, established by a special law in 2003. The aim of the Fund is to ensure additional financial sources for projects and programs in the field of protection, sustainable use and improvement of the environment. Furthermore, the Fund takes part in financing projects, programs, and measures (including National Energy Programs) aiming to increase energy efficiency and use of renewable energy sources. The Fund is an extra budgetary fund with characteristics of a legal entity and public authorities defined by the law. Public authorities of the Fund are in its capability to adopt administrative acts referring to introduction of fees and special fees, definition of the conditions that have to be fulfilled by the Fund beneficiaries as well as definition of conditions and criteria for selection of projects and programs, to be financed from the Fund. The Fund should act as the main source of investment subsidies for off-grid and individual thermal applications in the field of RES in Croatia.

The legal document Effect Decree on Management and Protection of Coastal Region (Official Gazette No. 128/04) results in the situation that construction of wind farms in the coastal region is not allowed.

Education and public acceptance

The importance of public education, knowledge, and opinion about a particular topic cannot be overemphasized. Education is an effective means of achieving energy sustainability, since children and young adults, the decision makers of the future, are more receptive to new concepts and new behaviours, and can introduce new habits at home and latter during their professional career. Looking at the subject of RES and en-

ergy efficiency (EE) and especially biomass and bioenergy, the lack of public awareness of the various benefits (environmental, social, economic) and the consequent lack of acceptance of their use is constantly pointed out as one of the major barriers. Raising this awareness is, however, a complex problem which cannot be solved in one step.

Having that in mind, as the cornerstone for designing and starting education activities in Croatia, an extensive public opinion survey which included more then 2000 households was undertaken in 2003 by the Energy Institute Hrvoje Požar. The results of the survey indicate a low level of knowledge and information among the Croatian population regarding RES and EE, but also general energy issues and the environment. The general conclusion was that in order to overcome the barriers to a greater utilisation of RES and EE, but also for a complete and transparent public involvement in the decision making process in the energy sector, it would be necessary to devote a considerably increased attention to public education than before [22].

Based on the conclusions of the survey, in 2004 the Energy Institute, with the support of the Ministry of Economy, Labor and Entrepreneurship, started a comprehensive education program. The important components of the first phase of the program include didactical materials for elementary schools, a teaching program and workbook for high schools teachers and pupils, University programs, and an Internet web site.

The first education materials that were completed during 2004 include: the comic booklet Blackout! What now?, printed in colour on 20 pages, which should explain to children in a popular and appealing way the basics about energy, renewable energy sources, the importance of rational energy utilization, and the impact of energy production on the environment, and the educational board based game Energy and Environment in which in order to progress through the playing field the players must correctly answer several a/b/c and yes/no type of questions related to renewable energy sources and energy efficiency. Both the booklet and the cardboard game were published in large numbers (51.000 and 30.000, respectively) and distributed free to most elementary schools as well as through periodicals and magazines in order to reach a wide audience. The future activities planned to take place within the educational program in 2006 include the following:

– setting up a comprehensive exhibition on RES and EE in the Technical Museum in Zagreb, which during 2004 had more then 100,000 visitors of which approximately one quarter were elementary school pupils. The Technical Museum and the Energy Institute are jointly developing the concept of the exhibition, which will include working models of various RES technologies, interactive touch-screen boards, a reading and teaching cabinet, and other,
– the inclusion of subjects and themes related to RES and EE within the educational computer game Učilica (Learner in Croatian), developed last year as a comprehensive supplement learning material for elementary schools. The game is endorsed by the Ministry of science, education and sport and the Department of public schools of the Republic of Croatia, and
– performing the second public survey on knowledge, attitudes and opinion, and setting this up as a traditional two-year activity in order establish a feedback link for

evaluating the effectiveness of the various educational activities performed within the program.

Conclusions

Research and development of RES in Croatia should be aimed on two crucial objectives; to support optimal penetration of renewables as energy sources for heat and electric production and its markets, and to increase understanding and knowledge about possibilities of various RES options (fig. 5). However, current funding available for research in the field of RES is rather limited and insufficient to cover R&D of one of the discussed RES let alone all country needs. Therefore, balanced R&D program in Croatia would consider the following priorities and areas.

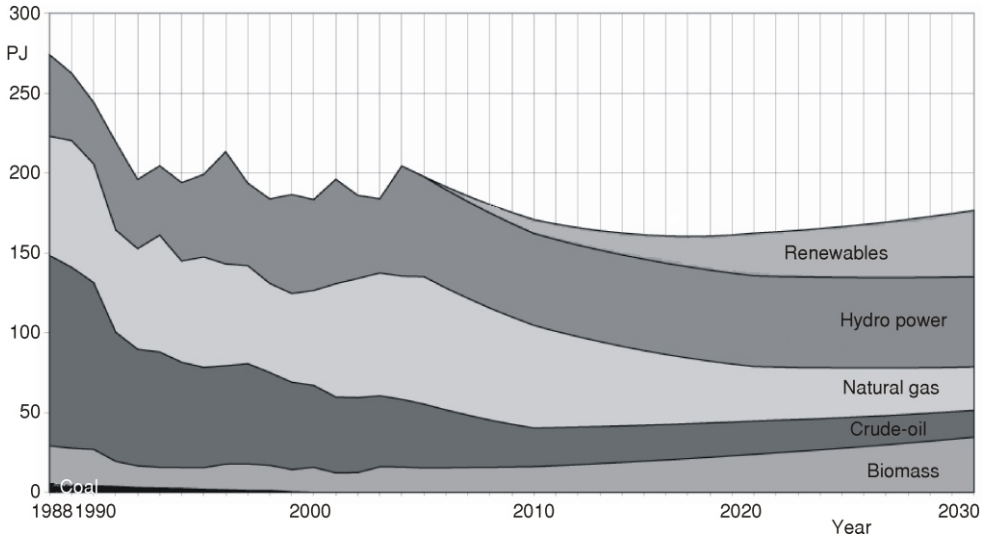

Figure 5. Primary energy production [3]

Capacity building of RES research infrastructure

- testing facilities for various RES technologies (solar collectors, small-scale wind turbines, hybrid systems, *etc*.),
- measurement stations networks, and
- RES labs and education centers.

Research activities to demonstrate possibilities and increase RES value

- database of renewable resources characterization in spatial and time domain,

- reliable RES resource assessment and mapping,
- building of national standards and certification capacities,
- improving reliability of RES technologies, and
- environmental impact analyses of the energy sector, including external costs of generation.

Economic, policy, and administrative aspects of RES utilization in Croatia

- cost-benefit analyses of renewable energy sources at micro- and macro-economic level,
- environmental cost-benefit analyses of RES with assessing their externalities in socio-economic and environmental aspects,
- cost-effective support and promotion of RES,
- database on foreign practices, best options, and experiences in administrative issues related to RES,
- research and analyses in the field of spatial planning and policy, and
- continuous monitoring of RES implementation.

Technology-related research areas for RES best options in Croatia, addressing specific problems associated with different RES technologies, and socioeconomic research and education

The actions in the aforementioned research priority areas will build capacity, develop grounds for elaboration of Croatian renewable energy strategy, create sound legislative framework, activate entrepreneurship in the energy sector and, as a final consequence, improve the state of the environment in Croatia.

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