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GEOTHERMAL ENERGY DEVELOPMENT STRATEGY IN REPUBLIC OF CROATIA DUE TO PROMOTION OF RENEWABLE ENERGY IN EUROPEAN UNION

STRATEGIJA RAZVITKA GEOTERMALNE ENERGIJE U REPUBLICI HRVATSKOJ SUKLADNO POTICAJNIM MJERAMA EUROPSKE UNIJE ZA KORIŠTENJE OBNOVLJIVIH IZVORA ENERGIJE

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Ključne riječi: geotermalna energija, strategija gospodarenja mineralnim sirovinama, obnovljivi izvori energije

Abstract

According to European Strategy for sustainable, competitive and secure energy, which guidelines are described in two documents: ‘’Green Paper: a European Strategy for Sustainable, Competitive and Secure Energy’’ and ‘’White Paper: Energy for the Future: Renewable Sources of Energy’’, it is predicted that share of renewable energy resources in total energy balance will raise from present 6% up to 15% until 2015. Croatia, as candidate country for EU admittance, with growing dependency upon imported energy because of continuous depletion of own energy resources, prior oil and gas, needs to follow EU strategic aims to achieve diversification of energy sources and implement and promote renewable energy resources.

This paper presents strategy of geothermal resources development in Republic of Croatia for the period of 2007-2030 in cascade and cogeneration principle of energy utilization. These projections of geothermal energy development are part of comprehensive Strategy of Mineral Resources Development which is made by Faculty of Mining, Geology and Petroleum Engineering for Ministry of Economy, Labour and Entrepreneurship.

Sažetak

Prema Europskoj strategiji za održivu, kompetitivnu i sigurnu energiju, a čije smjernice su opisane u dva dokumenta pod nazivom ‘’Green Paper: a European Strategy for Sustainable, Competitive and Secure Energy’’ i ‘’White Paper: Energy for the Future - Renewable Sources of Energy’’, predviđen je porast udjela obnovljivih izvora energije sa sadašnjih 6% u ukupnoj potrošnji energije na 15% u 2015. Hrvatska, kao zemlja kandidat za pridruženje EU, sa sve većim porastom uvoza svih oblika energenata treba slijediti EU trendove, postići diverzifikaciju energetskih izvora i snabdijevanja te promovirati obnovljive izvore energije u energetski sektor.

Pomoću sveobuhvatne statističke analize predstavljena je strategija gospodarenja geotermalnom energijom, za razdoblje 2007-2030, u kogeneracijskoj i kaskadnoj proizvodnji toplinske i električne energije. Projekcija je izrađena za potrebe Ministarstva gospodarstva, rada i poduzetništva Republike Hrvatske i to kao integralni dio dokumenta pod naslovom ‘’Strategija gospodarenja mineralnim sirovinama RH’’.

1. Introduction

Majority of geothermal sources in Croatia were discovered during hydrocarbons exploration and they are in fact negative oil and gas wells. Many of oil and gas aquifers should be taking into account through the evaluation of overall geothermal sources if such aquifers have favourable geothermal and hydrodynamic characteristics. Croatian geothermal resources with temperatures above 65 °C which could be energetically utilized are shown on picture. In addition, there are many geothermal springs with temperatures below this point which are currently utilized for Spa purposes.

There are two main sedimentary basin that covers entire area of Croatia. However, there are significant differences in geothermal potential for each of them. In the southern part of Croatia, Dinaridi basin has geothermal gradient of 0,018 °C/m with thermal flow of 29 mW/m^2 (Jelić, 1979) and in this area there can not be expected any significant geothermal potential. Regardless of that, there are some sites of that area which are used today, or could be, for balneology purposes, like in Istria region, town of Split, Dubrovnik and Sinj.

As opposed to Dinaridi, in Panon basin average geothermal gradients and thermal flow (G=0,049 °C/m i q=76 mW/m^2) are considerably higher than Europe mean values, with many discovered geothermal reservoirs (Fig1-1). These large variations in geothermal potentials of Dinaridi and Panon basin could be explained with Moho plate of discontinuity which is in Panon at approximately 28 km, as oppose to Dinaridi where is at 50 km.

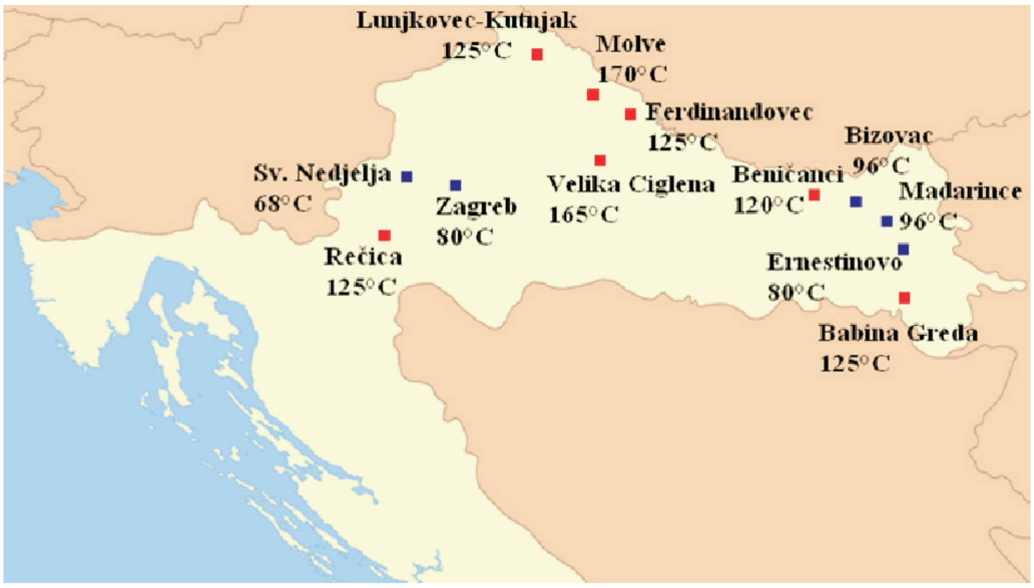

Figure 1-1 Geothermal resources of the Republic of Croatia with temperatures above 65°C

Slika 1-1. *Geotermalni resursi Republike Hrvatske temperatura viših od 65°C*

There are several positive anomalies in Panon which are measured during oil and gas drilling operations. Geothermal gradients at these locations are around 0,050 – 0,075 °C/m which is effect of spontaneous convection in reservoirs with relatively high vertical permeability.

Taking into account technological and economical criteria, reservoirs with temperatures of water above 65 °C are characterized as geothermal ones, although there are several reservoirs with temperatures below that threshold which are mainly used for balneological purposes (Topusko and Varaždin locations with 60°C)

2. Production and reserves of geothermal water in the Republic of Croatia

Besides numerous spas, geothermal water is used energetically only from Zagreb and Bizovac aquifer. Production and utilization of geothermal energy started from Bizovac reservoir, near town of Valpovo. With oil and gas exploration activities reservoir of geothermal water was discovered with water temperature of 98°C which resulted with Spa complex construction in the late 80's. After initial problems with eruptive production, project of reservoir pressure maintenance was developed and until today total of three wells were drilled, which are producing annually around 10 000 MWh of heat energy. However, production capabilities are three times higher regarding existing wells in surroundings which were negative during oil exploration. Energy is currently sold at 50% of energy value of natural gas price.

At the Zagreb geothermal field extensive geological and geophysical exploration activities were carried out to determine size of the geothermal aquifer. Utilization of geothermal energy begun in the 80's for swimming pools heating purposes in SRC Mladost. Until 1986 sixteen more wells were drilled with aim to heat locations at SRC Mladost and University hospital under construction at that time. SRC Mladost site is currently encircled technological process but with production capability far more than current energy utilization.

On University hospital location total of seven wells were drilled, from which three of them are negative. Remaining wells should be used for heating in any future projects at the site, like new arena planned for hand-ball championship. Currently only one well is used for heating purposes at the construction site (Golub et all, 2006). On following tables and Figure 2 produced quantities of geothermal water are shown for period of 1997-2005 in northern part of Croatia.

Table 2-1 Total production of geothermal water in Republic of Croatia for a period of 1997-2005

Tablica 2-1. *Proizvodnja geotermalne vode u RH za razdoblje od 1997.-2005. godine*

Production per year, in 10^3 m^3								
1997.	**1998.**	**1999.**	**2000.**	**2001.**	**2002.**	**2003.**	**2004.**	**2005.**
408,78	379,65	410,37	322,09	351,50	365,38	274,72	280,79	314,00

Table 2-2 Production of geothermal water in County of Osječko – baranjska for a period of 1997-2005

Tablica 2-2. *Proizvodnja geotermalne vode u Osječko - baranjskoj županiji za razdoblje od 1997-2005. godine*

Area	Location	Production per year, in 10^3 m^3								
		1997.	**1998.**	**1999.**	**2000.**	**2001.**	**2002.**	**2003.**	**2004.**	**2005.**
Valpovo	Bizovec	171,73	161,48	186,63	164,14	153,66	159,15	127,01	129,71	144,66

Table 2-3 Production of geothermal water in County of Zagreb for a period of 1997-2005

Tablica 2-3. *Proizvodnja geotermalne vode u Zagrebačkoj županiji za razdoblje od 1997-2005. godine*

Area	Location	Production per year, in 10^3 m^3								
		1997.	**1998.**	**1999.**	**2000.**	**2001.**	**2002.**	**2003.**	**2004.**	**2005.**
Zagreb	SRC Mladost/ KBNZ	237,04	218,17	223,74	157,95	197,84	206,23	147,71	151,08	169,34

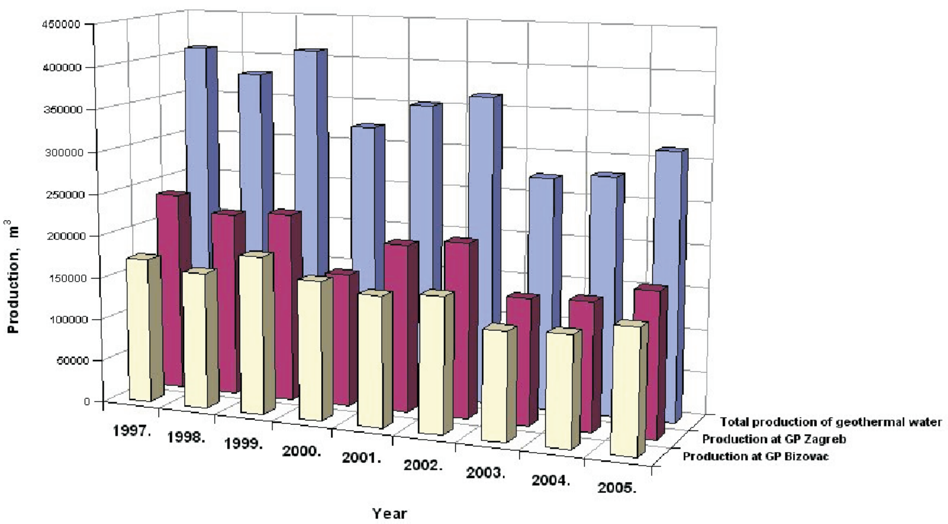

Figure 2 -1 Geothermal water production in Republic of Croatia for period of 1997-2005.

Slika 2-1. *Proizvodnja geotermalne vode u Republici Hrvatskoj po županijama za razdoblje 1997-2005.*

Total proved and balance reserves of geothermal water, for period of 1997-2005 are shown in following tables.

Table 2-4 Reserves of geothermal water in Republic of Croatia, l/s

Tablica 2-4. *Utvrđene eksploatacijske rezerve geotermalne vode u RH, u l/s*

Category	Year								
	1997.	**1998.**	**1999.**	**2000.**	**2001.**	**2002.**	**2003.**	2004.*	2005.
Proved reserves, l/s	83,356	83,356	83,356	83,356	83,356	83,356	83,356	137,356*	137,356
Total balance reserves, l/s	83,356	83,356	83,356	83,356	83,356	83,356	83,356	137,356*	137,356

*At the end of 2004., main reservoir engineering project was finished for Kutnjak-Lunjkovec geothermal reservoir.

Table 2-5 Reserves of geothermal water in County of Koprivničko – križevačka

Tablica 2-5. *Bilančne rezerve geotermalne vode Koprivničko – križevačke županije*

Area	Location	Category	Year								
			1997.	**1998.**	**1999.**	**2000.**	**2001.**	**2002.**	**2003.**	**2004.***	**2005.**
Legrad	Kutnjak	**Proved reserves, l/s**	0	0	0	0	0	0	0	54	54
		Total balance reserves, l/s	0	0	0	0	0	0	0	54	54

Table 2-6 Reserves of geothermal water in County of Osječko – baranjska

Tablica 2-6. *Bilančne rezerve geotermalne vode Osječko-baranjske županije*

Area	Location	Category	Year								
			1997.	**1998.**	**1999.**	**2000.**	**2001.**	**2002.**	**2003.**	**2004.**	**2005.**
Valpovo	Bizovec	**Proved reserves, l/s**	6,214	6,214	6,214	6,214	6,214	6,214	6,214	6,214	6,214
		Total balance reserves, l/s	6,214	6,214	6,214	6,214	6,214	6,214	6,214	6,214	6,214

Table 2- 7 Reserves of geothermal water in County of Zagreb

Tablica 2-7. *Bilančne rezerve geotermalne vode Zagrebačke županije*

Area	Location	Category	Year								
			1997.	**1998.**	**1999.**	**2000.**	**2001.**	**2002.**	**2003.**	**2004.**	**2005.**
Zagreb	SRC Mladost/ KBNZ	**Proved reserves, l/s**	77,14	77,14	77,14	77,14	77,14	77,14	77,14	77,14	77,14
		Total balance reserves, l/s	77,14	77,14	77,14	77,14	77,14	77,14	77,14	77,14	77,14

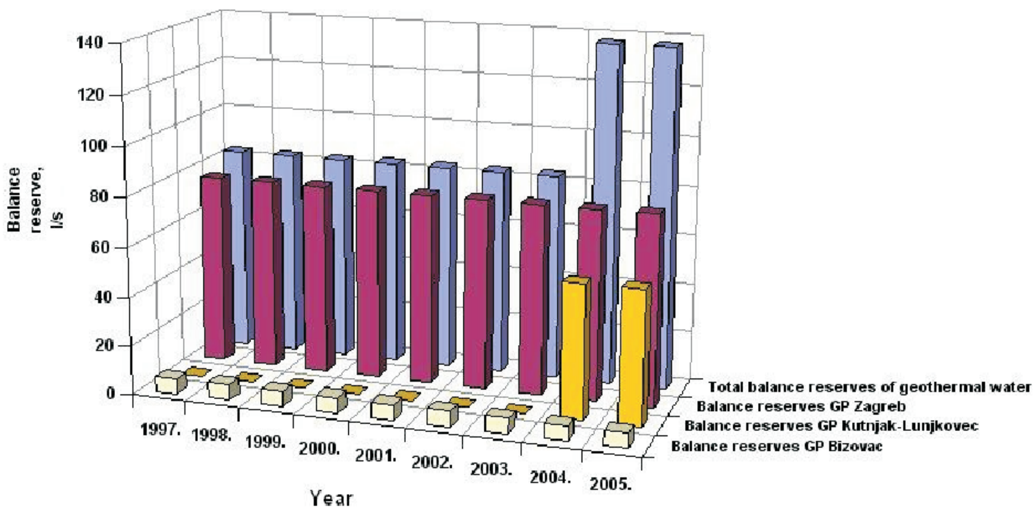

Figure 2-2 Total geothermal water balance reserves sorted by geothermal reservoirs

Slika 2-2. *Pregled ukupnih bilančnih rezervi geotermalne vode u Republici Hrvatskoj i podjela po županijama*

3. EU renewable energy strategy scenarios for geothermal energy according to world and EU trends

In last thirty years there is a mean increment in world geothermal energy production in rate of 11% per year. From Table 3-1 and Figure 3-1 it could be seen that installed electrical power is growing linearly, while direct consumption and installed heat power in last ten years is growing almost exponentially, prior to implementation of geothermal heat pumps.

Table 3-1 Installed geothermal electrical and heat power in the world (Bertani, 2005; Lund, 2005)

Tablica 3-1. *Pregled instaliranih električnih i toplinskih kapaciteta geotermalne energije u svijetu*

Year	Installed electrical power, MW	Number of countries	Installed heat power, MW	Number of countries
1970.	678	6	800	6
1975.	1 310	8	1 300	10
1980.	2 110	14	1 950	14
1985.	4 764	17	7 072	24
1990.	5 832	19	8 064	30
1995.	6 797	20	8 664	30
2000.	7 974	21	15 145	55
2005.	8 902	27	27 825	68

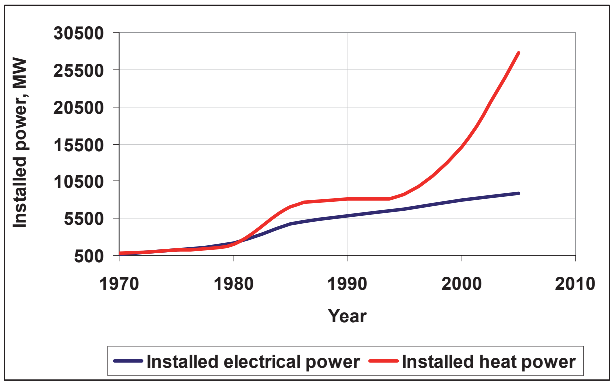

Figure 3-1 Installed geothermal electrical and heat power in the world

Slika 3-1. *Porast instaliranih električnih i toplinskih kapaciteta geotermalne energije u svijetu*

Renewable sources of energy are currently unevenly and insufficiently exploited in the European Union. Although many of them are abundantly available, and the real economic potential considerable, renewable sources of energy make a small contribution of less than 6% to the Union's overall gross inland energy consumption, which is predicted to grow steadily in the future. The EU's dependence on energy imports is already 50% and is expected to rise over the coming years if no action is taken, reaching 70% by 2020. Current trends show that considerable technological progress related to renewable energy technologies has been achieved over recent years.

Costs are rapidly dropping and many renewables, under the right conditions, have reached or are approaching economic viability. A comprehensive strategy for renewables has become essential for a number of reasons. Without a coherent and transparent strategy and an ambitious overall objective for renewables implementation, these sources of energy will not make major contribution in the Community energy balance. A policy for the promotion of renewables requires initiatives encompassing a wide range of policies: energy, environment, employment, taxation, competition, research, technological development and demonstration, agriculture, regional and external relations policies. A central aim of a strategy for renewable energy will be to ensure that the need to promote these energy sources is recognised in new policy initiatives, as well as in full implementation of existing policies. In the Green Paper on Renewables the Commission sought views on the setting of an indicative objective of 12-15% for the contribution by renewable sources of energy to the European Union's gross inland energy consumption by 2010.

The technical potential, however, is much larger. Geothermal energy accounts for only a very small part of total renewable energy production in the European Union. Although power production is already viable from high-temperature dry steam, the risks associated with exploitation still present a disincentive to investment.

Table 3-2 European Strategy Plan regarding promotion and implementation of renewable sources (Commission of the European Communities, 2006)

Tablica 3-2. *Pretpostavljeni scenarij udjela obnovljivih izvora energije po sektorima u EU, u 2010*

Energy source	**Installed power in 1995**	**Projections for 2010**
Wind	2,5 GW_e	40 GW_e
Hydropower	92 GW_e	105 GW_e
-large scale	(82 GW_e)	(91 GW_e)
-small scale	(9,5 GW_e)	(14 GW_e)
PV cells	0,03 GW_p	3 GW_p
Biomass	44,8 Mtoe	135 Mtoe
Geothermal		
-electrical power	0,5 GW_e	1,0 GW_e
-heat power (+heat pumps)	1,3 GW_t	5,0 GW_t
Solar thermal collectors	6,5 million m^2	100 million m^2
Passive solar		35 Mtoe
Other		1 GW

4. Strategy of geothermal energy production in Republic of Croatia

Until EU admittance, Croatia needs to fulfil renewable energy obligation and increase renewable energy share in energy balance of 10%. This value is based on Energy Sector Development Strategy of the Republic of Croatia, National Environmental Action Plan, as well as macroeconomic and demographic indicators. In energy sector it is required that:

- expected growth in energy consumption will not lead to further growth in emissions of greenhouse gases which favours further geothermal energy development and utilization
- consumers needs to be stimulated to change consumption habits and to preserve energy which points out to energy-nonintensive activity with further development of renewable sources

In the Strategy of mineral resources management of the Republic of Croatia, principle of sustainable development means three mutual conjunct variables of ecological, economical and social principles which need to involve local communities and resources. For example, to meet ecological requirements only intervention in environment that provides extensive eco-system conservation is allowed, which is favourable for geothermal energy utilization. Regarding that, it is necessary, according to engineering practise, to do following actions:

- estimate potential geothermal areas as well as wellsprings,
- drill shallow exploration wells to evaluate potential of deep geothermal reservoirs
- test reservoir parameters with injection wells production method to determine movement of subcooled zone and temperature dynamics
- evaluate utilization possibility from geothermal aquifers at the oil and gas reservoirs (Beničanci, Molve, Kalinovac, Stari Gradac).

4.1. Prospects of geothermal energy in Croatia through two specific subscenarios

In Energy Sector Development Strategy of the Republic of Croatia three possible scenarios of development are elaborate which also deflect on geothermal energy utilization. For Croatia, S2 scenario is the most probable one, which includes introduction of new technologies and active government measures after EU admittance. According to same scenario, geothermal share in renewable energy would be around 5%. Production of electricity in cascade principle of geothermal resources utilization would have linear growth with 5 to 10% increment per year after 2010. Production of electricity becomes economically unjustifiable if heat energy is not utilized, taking into account internal consumption of power plant and power needed for injection of fluid back into the reservoir. Utilization of heat energy from cascade principle, as well as from other geothermal reservoirs with temperatures below 100 °C and oil&gas aquifers would increase exponentially according to world trends, especially from heat pumps implementation. It could be expected that INA Oil Co., as exclusive concessionaire of thermal resources, would not expand capacity regarding existing infrastructure of around seventy geothermal wells and around thirty wells from oil&gas aquifers which can be easily transformed into geothermal ones taking into account existing infrastructure.

As part of the Scenario S2, two sub-scenarios could be expected:

- *Subscenario A* – exploitation of existing geothermal resources until 2015,
- *Subscenario B* – production increment with additional investments (drilling, reservoir engineering, hot dry rock technology development, geothermal heat pumps) until 2030.

For Subscenario A two variants could be realized as well:

- Variant A1 – phase of test production with termolift effect, solely in form of heat energy utilization, which would generate certain financial assets necessary for further reservoir engineering and confirmation of reserves. This period should be realised until 2010. and subsequently production of electricity and heat in cascade principle of utilization.
- Variant A2 – period between 2010. and 2015. with commercialization in cascade principle of electrical and heat energy production, with significant implementation of geothermal heat pumps and active government measures.

In Croatia there are few potential localities for electricity production via binary Clausius Rankine process. According to GEOEN, which is part of National energy program, with complete reservoir engineering potential installed power is around 40 MW. This value is calculated through Carnot reversible process (first law efficiency) as limes with the maximum possible thermodynamic efficiency. Regarding utilization factor, which is a direct measure of the efficiency of reservoir utilization, and thermodynamic efficiency which is just partial element, installed power of geothermal source should be expressed through Bošnjaković exergy or theoretical maximum amount of work that can be obtained from the system at a prescribed state when operating with a reservoir at the constant pressure and temperature and sink conditions as final state. Therefore, potential power should be multiplied with utilization factor efficiency (second law efficiency). Regarding required ecological standards, entirely produced geothermal fluid must be injected back into the reservoir.

4.2. Electrical and heat power utilization in cascade and cogeneration principle at the reservoirs with temperatures above 100°C and according to S2 Subscenario A

Total theoretical power for five potential localities, on which electricity could be produced in cascade principle of utilization, is calculated for situation in 2006 and given in Table 4-1. However, taking into account variant A2, production start-up could begin after EU admittance in 2010.

Table 4-1 Possible installed electrical and heat power on localities with temperatures of geothermal water above 100°C with cascade and cogeneration principle of production, situation in 2006 for Subscenario A

Tablica 4-1. *Lokaliteti s temperaturama geotermalne vode iznad 100° za kaskadni način korištenja, stanje 2006. godina, podscenarij A*

Location	Wellhead temperature (°C)	Installed electrical power (1) (MW)		Installed heat power (2) cascade principle from 80°C till 35°C, (MW)		Installed heat power (3) cascade principle from 35°C till 11,6°C, (MW)	
		Till 80 °C, Actual	Do 80°C, Possible	Actual	Possible	Actual	Possible
Babina Greda	125	1,18	1,18	18,45	18,45	9,59	9,59
Ferdinandovac	125	0,59	1,18	9,22	18,45	4,80	9,59
Lunjkovec-Kutnjak	140	1,11	2,22	9,78	19,56	5,08	10,17
Reèica	120	0,46	0,92	9,22	18,45	9,59	19,18
Velika Ciglena	170	5,4	10,8	21,22	42,43	11,03	22,07
Total		**8,74**	**16,3**	**67,89**	**117,34**	**40,09**	**70,6**

(1) Exergy power without internal consumption

(2) Balance heat power without efficiency of heat exchanger effect

(3) Non-balance heat power without efficiency of heat exchanger effect calculated till Panonj sink conditions

4.3. Potential of direct consumption of heat according to Subscenario A, Variant A1 on all geothermal reservoirs with temperatures above 65°C for period 2005-2010

Situation of all significant geothermal resources in Croatia for utilization in direct consumption of heat and potential installed heat power is shown in Table 4-2, regarding lower temperature margin for greenhouses of 50°C and balneology with 25°C.

Table 4-2 Potential installed heat power and produced heat energy of all geothermal resources for direct consumption of heat in subscenario A, Variant A1, for period 2005-2010

Tablica 4-2. *Potencijalna toplinska snaga svih geotermalnih ležišta za direktnu potrošnju, prema podscenariju A, varijanta A1, za period od 2005-2010.*

	Location	T (°C)	Installed heat power (MW)				Thermal energy (TJ/year) (1)			
			Till 50°C		Till 25°C		Till 50°C		Till 25°C	
			Actual	Possible	Actual	Possible	Actual	Possible	Actual	Possible
Medium temperature geothermal resources	Babina Greda	125	31,38	31,38	41,84	41,84	494,63	494,63	659,50	659,50
	Ferdinandovec	125	15,69	31,38	20,92	41,84	247,31	494,63	329,75	659,50
	Lunjkovec-Kutnjak	140	19,56	39,11	25,00	50,00	314,58	629,16	803,93	1607,86
	Rečica	120	14,64	29,29	19,87	39,75	230,83	461,65	313,26	626,53
	Velika Ciglena	170	58,07	174,21	70,17	210,51	910,11	2730,33	1106,03	3318,09
	Total medium temperature geothermal resources		139,34	305,37	177,80	383,94	2197,46	4810,40	3212,47	6871,75
Low temperature geothermal resources	Bizovac TG	96	0,58	0,58	0,89	0,89	9,10	9,10	14,05	14,05
	Bizovac PP	90	3,85	46,19	6,26	75,06	60,67	728,09	98,60	1183,14
	Ernestinovo	80	2,89	5,77	5,29	10,59	45,51	91,01	83,43	166,85
	Ivanić Grad	60	-	-	0,43	0,43	-	-	13,85	13,85
	Madarince	96	1,92	1,92	2,97	2,97	30,34	30,34	46,82	46,82
	Sveta Nedjelja	68	3,39	6,78	8,10	16,19	53,42	106,84	127,61	255,23
	Zagreb (Mladost RC)	80	6,28	6,28	11,51	11,51	98,93	98,93	181,36	181,36
	Zagreb (University hospital)	80	6,90	6,90	12,66	12,66	108,82	108,82	199,50	199,50
	Total low temperature geothermal resources		25,81	74,42	48,1	129,86	406,78	1173,12	751,37	2060,81
	Total		**165,15**	**379,79**	**225,90**	**513,80**	**2604,24**	**5983,52**	**3963,84**	**8932,56**

(1) Capacity factor β = 0,5

4.4. Production of heat according to Subscenario A, Variant A2, in cascade principle of utilization after electricity generation for period 2010-2015.

On medium temperature geothermal reservoirs suitable for electricity production, utilization is only economically justifiable with cascade principle. In Table 4-3 are given values of possible heat energy production after production of electricity on medium temperature geothermal resources for lower temperature margin of 50°C (agriculture and industry) and margin of 25°C (balneology + industry and agriculture). Inlet temperature of 80°C is predicted for all reservoirs after electricity generation.

Table 4-3 Possible installed heat power and yearly thermal energy consumption in cascade principle of utilization for medium temperature geothermal resources

Tablica 4-3. *Potencijalna toplinska snaga i godišnja potrošnja energije u kaskadnom korištenju za srednje temperaturna geotermalna ležišta nakon proizvodnje električne energije*

	Location	t (°C)	Possible Installed heat power in cascade principle of utilization after electricity production, (MW)				Thermal energy consumption with cascade principle of utilization after electricity production, (TJ/year) [1]			
			Till 50°C		Till 25°C		Till 50°C		Till 25°C	
			Actual	**Possible**	**Actual**	**Possible**	**Actual**	**Possible**	**Actual**	**Possible**
Medium temperature geothermal resources	Babina Greda	80	12,30	18,45	22,55	22,55	197,85	197,85	362,73	362,73
	Ferdinandovec	80	6,15	12,30	11,28	22,55	98,93	197,85	181,36	362,73
	Lunjkovec-Kutnjak	80	6,52	13,04	11,95	23,90	104,86	209,72	192,24	384,49
	Rečica	80	6,15	12,30	11,28	22,55	98,93	197,85	181,36	362,73
	Velika Ciglena	80	14,15	42,44	25,93	77,80	227,53	682,58	417,13	1251,40
	Total medium temperature geothermal resources		45,26	98,52	82,98	169,35	728,09	1485,85	1334,83	2724,06

(1) Capacity factor β = 0,5

4.5. Dynamics of future geothermal resources utilization in Croatia for production of electricity according to Subscenario B

Future progress of geothermal resource utilization with electricity production could be viewed through scenarios of Energy Sector Development Strategy of the Republic of Croatia. Through all three scenarios project start-up with cascade principle should be till 2010 and admittance of Croatia in EU, with linear increment in yearly production of 10%. This growth is justifiable through renewable energy share of 10% obligation.

Table 4-4 Projections of increment dynamics in electricity production until 2030 according to own research

Tablica 4-4. *Projekcije buduće proizvodnje električne energije iz geotermalnih ležišta RH za razdoblje do 2030. godine*

Year	Installed electrical power, MW_e	Electrical energy production, TJ/ year [1]
2005.	0,0	0
2010.	8,7	247
2011.	9,6	271
2012.	10,6	301
2013.	11,6	329
2014.	12,8	363
2015.	14,8	420
2020.	16,3	463
2025	16,3	463
2030.	16,3	463

(1) Capacity factor β = 0,9

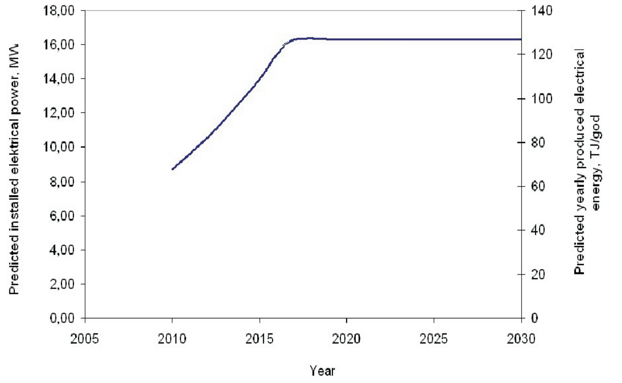

Figure 4-1 Predicted electrical power installed on medium temperature geothermal resources until 2030.

Slika 4-1. *Predviđena instalirana električna snaga na srednje temperaturnim geotermalnim ležištima uz prikaz pretpostavljene godišnje potrošnje energije za razdoblje do 2030. godine*

4.6. Dynamics of future geothermal resources utilization in Croatia for production of heat energy according to Subscenario B

Geothermal potential for heat energy utilization only is approximately 500 MW (with assumption that the medium temperature wells will be utilized for electricity generation and heat energy in cascade principle). Current heat capacities in balneology sector are around 80 MW, while capacities of low temperature wells are around 130 MW, calculating till lower temperature margin of 25°C.

On medium temperature geothermal wells potential of heat utilization after electricity generation is 170 MW.

With completion of oil and gas on some reservoirs with suitable flow and thermal characteristics of the surrounding aquifers (such are Beničanci, Molve, Kalinovac, Stari Gradac), production of geothermal water could be established with minimum investments in infrastructure. Installed heat power on this reservoirs could be high as 120 MW. In near future, implementation of geothermal heat pumps could be expected in government and business buildings, as well as in the households. Due to fact that geothermal gradients in Panon are above Europe mean values, and that heat pumps are one of the most efficient heating and cooling technologies, significant potential exists.

Table 4-5 Projection of geothermal reservoirs installed heat power and produced thermal energy of until 2030 according to own research

Tablica 4-5. *Projekcija instalirane toplinske snage geotermalnih izvora uz godišnju potrošnju energije za RH za razdoblje do 2030. godine*

Year	**Installed heat power for direct consumption, MW**	**Produced thermal energy, TJ/year [(1)]**
2005.	120	1890
2006.	125	1970
2007.	130	2050
2008.	136	2150
2009.	142	2240
2010.	155	2440
2011.	165	2600
2012.	175	2760
2013.	186	2930
2014.	197	3110
2015.	209	3300
2020.	280	4420
2025.	375	5910
2030.	500	7890

[(1)]Capacity factor $\beta = 0,5$

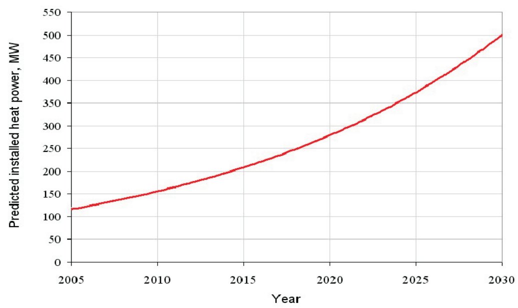

Figure 4-2 Projected installed heat power on geothermal reservoirs until 2030

Slika 4-2. *Predviđena instalirana toplinska snaga iskorištavanjem geotermalnih potencijala RH za razdoblje do 2030. godine*

5. Renewable energy share in energy consumption in Republic of Croatia

The commitments for Croatia admittance in EU are not possible to be accomplished without the environment preservation according to the sustainability development principles. In Croatia there are no mechanisms of economical adjustment to cleaner production and decrement of energy consumption per unit product. Regarding this problem it is necessary to significantly improve management of natural energy mineral resources with "on the source" method. This aspect removes causes of problem and only the consequences are solved ("end of pipe" view). Entrance in the EU means unconditional acceptance of measures and standards which in the segment of renewable sources means increment of their share in total energy balance up to 10%. This will initiate remarkable social, technological and administrative measures. Interests and needs of the local communities have the priority in Croatia, as well as encouragement of the economical activities at the local level and in the segment of mining and energetic with active measures of the state.

6. Conclusion

Hydrocarbons and geothermal energy yields around 2/3 of primary energy in Republic of Croatia and remaining share is imported. Regarding political circumstances in Europe and in the world, further increment of energy import dependence seems to be insecure path. Therefore, domestic energy sources as for example geothermal energy, till today inadequately estimated, needs to have priority.

These activities will achieve the necessary basis for the commercial part of utilization and necessary economy growth with GDP increment. Regional plan for each county with geothermal potential, either from geothermal reservoirs or hydrocarbon aquifers, will be initiated according to simulation methods of production and available heat energy. With permanent disposal of CO2 additional amounts of energy from mineral sources could be provided as well as decrement of dependence upon energy import. Analysis of the market and annual level of utilization of present geothermal capacities, regarding consumers (quantity and form of consumption), should be initiated. Moreover, it is essential to determine possible organizational form of business activities, ownership and other rights, economy and profitability, NPV, IRR and examine regulation and legislative measures. Regarding S2 scenario of Croatia strategy of energetic development and EU conditions concerning renewable energy consumption increase, results from these program/projects would stimulate the production of geothermal energy and get Croatia closer to EU standards.

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