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Possibilities of electricity generation in the Republic of Croatia by means of geothermal energy

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ABSTRACT

In the Republic of Croatia there are some medium temperature geothermal sources by means of which it is possible to produce electricity. However, only recently concrete initiatives for the construction of geothermal power plants have been started. Consequently, the paper provides proposals of the possible cycles for the Republic of Croatia. On the example of the most prospective geothermal source in the Republic of Croatia detailed analysis for the proposed energy conversion cycles is performed: for Organic Rankine Cycle (ORC) and Kalina cycle. On the basis of analysis results both the most suitable cycle for selected and for other geothermal sources in the Republic of Croatia are proposed. It is ORC which in case of the most prospective geothermal source in the Republic of Croatia has better both the thermal efficiency (the First Law efficiency) and the exergetic efficiency (the Second Law efficiency): 14.1% vs. 10.6% and 52% vs. 44%. The ORC gives net power of 5270 kW with mass flow rate 80.13 kg/s, while the Kalina cycle gives net power of 3949 kW with mass flow rate 35.717 kg/s.

1. Introduction

Geothermal energy is a form of renewable energy contained in the solid Earth and its internal fluids. For the first time electricity was generated from geothermal steam at Larderello, Tuscany, Italy when Prince Piero Ginori Conti powered a 3/4-horsepower reciprocating engine to drive a small generator. By 1914, the first commercial 250 kW geothermal power plant was in continuous operation there [1].

During the last four decades, the utilisation of geothermal energy has increased significantly both for electricity generation and for direct use. Already today, geothermal energy is an important source of electricity in many countries. Today, electricity is produced from geothermal energy in 24 countries, worldwide, with a capacity of 8.9 GW [2].

Despite the fact that economic potential of geothermal energy utilization for power generation is usually significantly less than corresponding solar or wind potential, geothermal plants are regularly included in future energy systems development scenarios [3–5].

Geothermal power plants in operation at present are essentially of three types for high and medium temperature geothermal sources: dry steam, flash and binary [1].

The availability of geothermal energy in the Republic of Croatia from deep wells has been known already for about 40 years. This long period saw single attempts at starting the economic projects based on geothermal energy, but they used to be abandoned already in the preliminary phase, with the exception of building and spas heating. There are several reasons for such a condition, among others the most important one being: the policy of satisfying energy demands without renewable energy sources, except from the large hydro power plants, insufficiently developed awareness of the need for environmental protection, and lack of entrepreneurial initiative.

As early as 1998, the Energy Institute “Hrvoje Požar” prepared a Program of Geothermal Energy Usage in the Republic of Croatia, which shows that in the Republic of Croatia there are some medium temperature geothermal sources by means of which it is possible to produce electricity [6]. However, only recently concrete initiatives for the construction of geothermal power plants have been started.

The paper will provide the following:

- on the basis of experiences in the world, proposal of geothermal sources in Croatia suitable for electric power generation;
- proposal of the possible cycles for electricity generation;
- on the example of the most prospective geothermal source in Croatia detailed analysis for the proposed conversion cycles, and the selection of the most suitable plant;
- proposal of the energy conversion cycle for other geothermal sources in Croatia.

Comparison of the possible energy conversion cycles will be performed based on the results of their energy–exergy analysis. For

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Nomenclature

$\bar{c}$	average specific heat (J/kg K)
$\dot{E}$	exergy flow rate (J/kg)
e	specific exergy (J/kg)
$\dot{H}$	enthalpy flow rate (W)
h	specific enthalpy (J/kg)
$\dot{m}$	mass flow rate (kg/s)
p	pressure (Pa)
$\dot{Q}$	heat flow rate (W)
s	specific entropy (J/kg K)
T	temperature (K)
$\dot{W}$	work flow rate-power (W)
x	contents of ammonia–water mixture (−)

Greek symbols

ε	exergetic efficiency (−)
η	efficiency (−)

Subscripts

cf	cooling fluid
gf	geothermal fluid
in	input
is	isentropic state
KC-liq	liquid phase of the working fluid in Kalina cycle
KC-mix	ammonia–water mixture in Kalina cycle
KC-vap	vapour phase of the working fluid in Kalina cycle
net	net
ORC-wf	working fluid in ORC
out	output
p	pump
t	turbine
th	thermal

thermodynamic modeling and energy–exergy analysis the fundamentals from literature [1,7–17] are used.

2. Geothermal potential of the Republic of Croatia

The Republic of Croatia has many centuries of tradition of geothermal energy usage from natural springs for medical purposes and bathing. Geothermal energy is the basis of the economic success of numerous spas in Croatia.

There are a total of 28 geothermal fields, out of which 18 are in usage. For the needs of space heating a total of 36.7 MW of heating power has been installed with annual usage of heating energy of 189.6 TJ/year. For bathing 77.3 MW of heating power is used, i.e. 492.1 TJ/year. Until now, geothermal energy was not used for the production of electricity [6].

Along with the research activities regarding oil and gas, Croatia has also developed the technique and technology for obtaining geothermal energy from deep geothermal layers. At the same time, abandoned oil wells could be considered for geothermal energy utilization [18].

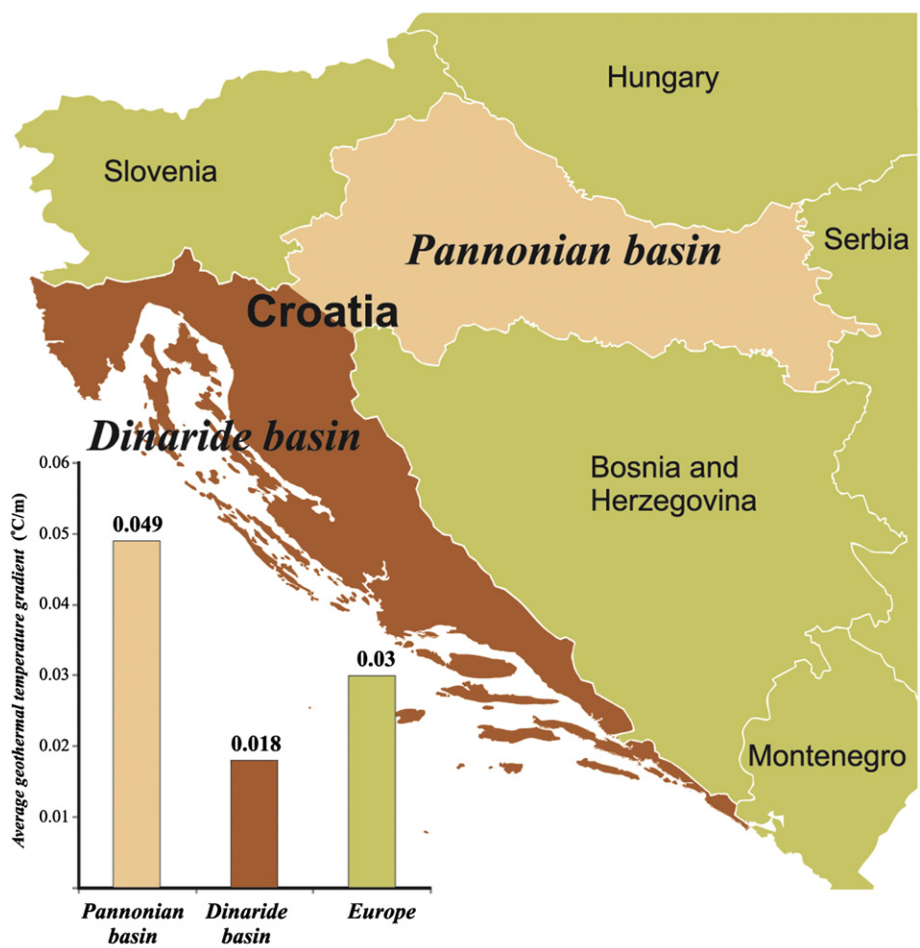

Fig. 1. The average geothermal temperature gradient in Croatia [3].