



GEOTHERMAL ENERGY: Status and Future in the Peri-Adriatic Area
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Prospects of geothermal energy exploitation in Croatia

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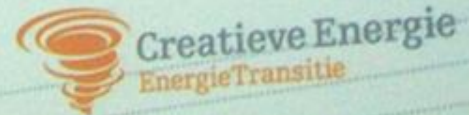
Geothermal energy and heat pumps - Ugly duckling of RES?

.....heat pumps are our secret weapon to reduce CO₂ emissions



I am small!
I am bashed!
Others are taller!

...but I am strong and you can trust me!



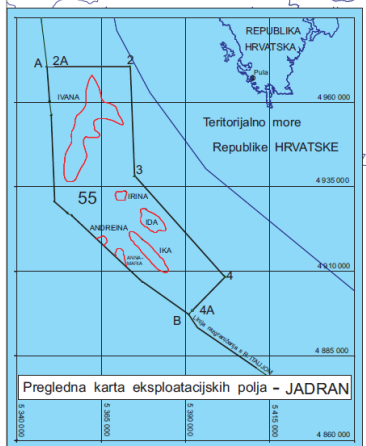


Deep geothermal energy closely tied to petroleum engineering

PREGLEDNA KARTA EKSPLOATACIJSKIH POLJA

5 150000

5 050000



- | | | |
|--------------------------|----------------------|---------------------------|
| 1 MIHOVLJAN | 20 ŠUMEČANI | 39 ĐELETOVCI |
| 2 LEGRAD | 21 BUNJANI | 40 ILAČA |
| 3 PETERANEC | 22 ŽUTICA | 41 ZEBANEC |
| 4 GOLA | 23 VEZIŠĆE | 42 VELIKI OTOK |
| 5 LEPAVINA | 24 OKOLI | 43 KUTNJAK - ĐELEKOVEC |
| 6 JAGNJEDOVAC | 25 STRUŽEC | 44 CVETKOVEC |
| 7 MOLVE | 26 MRAMOR BRDO | 45 MOSTI |
| 8 FERDINANDOVAC | 27 LIPOVLJANI | 46 GAKOVO |
| 9 KALINOVAC | 28 JAMARICA | 47 PEPELANA |
| 10 STARI GRADAC | 29 KOZARICA | 48 CABUNA |
| 11 ČEPELOVAC - HAMPOVICA | 30 KUČANCI - KAPELNA | 49 JANJA LIPA |
| 12 LETIČANI | 31 CRNAC | 50 BIZOVAC (geoter. vode) |
| 13 ŠANDROVAC | 32 BOKŠIĆ | 51 GALOVAC - PAVLJANI |
| 14 BILOGORA | 33 BENIČANCI | 52 VOLODER |
| 15 DUGO SELO | 34 KLOKOČEVCI | 53 OBRADOVCI |
| 16 LUPOGLAV | 35 OBOD | 54 GOJLO |
| 17 KLOŠTAR | 36 ŠTEVKOVICA | 55 SJEVERNI JADRAN |
| 18 JEŽEVO | 37 BIZOVAC | 56 ZAGREB (geoter. vode) |
| 19 IVANIĆ | 38 PRIVLAKA | 57 IVANIĆ (geoter. vode) |

- EKSPLOATACIJSKA POLJA S KONCESIJOM
- EKSPLOATACIJSKO POLJE - VRAČENA KONCESIJA
- GEOTERMALNA POLJA

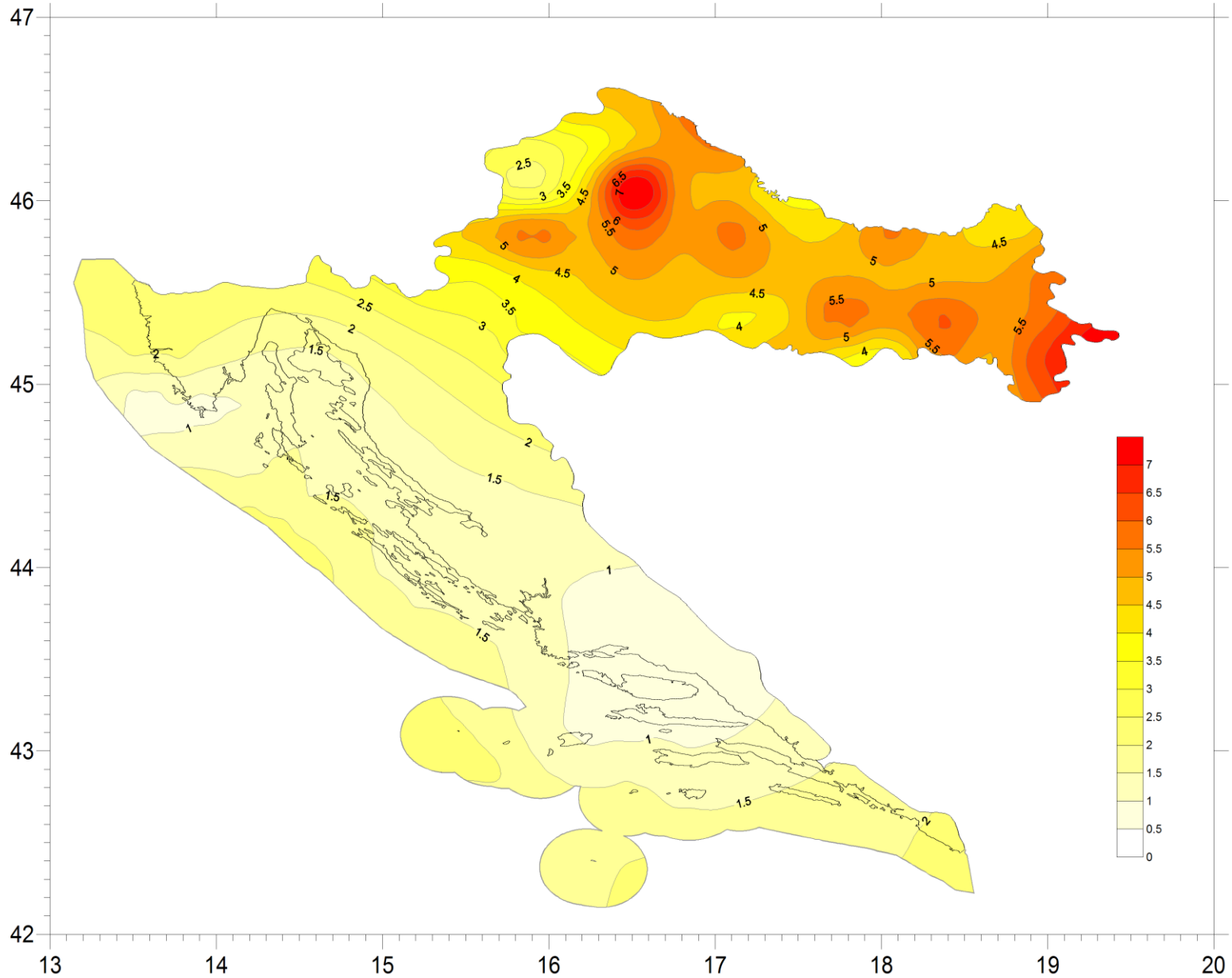
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Geothermal gradient - Croatia





Microlocations of Geothermal wells

Proven reserves





Balneology – most common geothermal energy utilization



1. Bizovačke toplice
2. Tuheljske toplice
3. Sutinske toplice
4. Jezerčica
5. Krapinske toplice
6. Topusko
7. Stubičke toplice
8. Istarske toplice
9. Varaždinske toplice
10. Daruvarske toplice
11. Šemničke toplice
12. Sveta Helena
13. Splitske toplice
14. Ivanić Grad



Instaled capacity – balenology + direct heating

| Locality | Type ¹ | Maximum Utilization | | | | | Capacity ³ (MWt) | Annual Utilization | | |
|---------------------------------------|-------------------|---------------------|------------------|--------|-------------------------------|--------|--------------------------------|---------------------|--------------------------------|---------------------------------|
| | | Flow Rate (kg/s) | Temperature (°C) | | Enthalpy ² (kJ/kg) | | | Ave. Flow (kg/s) | Energy ⁴ (TJ/yr) | Capacity Factor ⁵ |
| | | | Inlet | Outlet | Inlet | Outlet | | | | |
| Bizovac (Termia RC) | HB | 6.0 | 85.0 | 30.0 | | | 1.38 | 5.01 | 36.35 | 0.83 |
| Bošnjaci (Greenhouse) | G | 20.0 | 65.0 | 30.0 | | | 2.93 | 12.00 | 55.40 | 0.60 |
| Daruvar (Daruvar Spa) | B | 21.0 | 42.6 | 27.6 | | | 1.32 | 5.44 | 10.76 | 0.26 |
| Ivanić Grad (Naftalan) | B | 3.0 | 60.0 | 30.0 | | | 0.38 | 0.02 | 0.08 | 0.01 |
| Jezerčica (Jezerčica Spa) | B | 10.0 | 38.4 | 23.4 | | | 0.63 | 2.50 | 4.95 | 0.25 |
| Krapinske Toplice (Krapina Spa) | HB | 81.6 | 40.7 | 26.0 | | | 5.02 | 20.40 | 39.55 | 0.25 |
| Krapinske Toplice (Greenhouse) | G | 10.0 | 45.0 | 30.0 | | | 0.63 | 7.00 | 13.85 | 0.70 |
| Lešće (Liesce Spa) | B | 6.2 | 30.7 | 15.7 | | | 0.39 | 1.55 | 3.07 | 0.25 |
| Lipik (Lipik Spa) | HB | 23.0 | 58.7 | 43.7 | | | 1.44 | 5.75 | 11.38 | 0.25 |
| Livade (Istria Spa) | B | 2.0 | 28.0 | 13.0 | | | 0.13 | 0.50 | 0.99 | 0.25 |
| Samobor (Šmidhen SRC) | B | 19.7 | 29.2 | 14.2 | | | 1.24 | 4.93 | 9.75 | 0.25 |
| Stubičke Toplice (Stubica Spa) | HB | 95.0 | 53.4 | 38.4 | | | 5.96 | 23.75 | 46.99 | 0.25 |
| Sveta Jana (Sveta Jana) | B | 53.0 | 26.0 | 11.0 | | | 3.33 | 13.25 | 26.22 | 0.25 |
| Sveta Nedjelja (Greenhouse) | G | 25.0 | 63.0 | 25.0 | | | 3.97 | 20.00 | 100.24 | 0.80 |
| Topusko (Topusko Spa) | HB | 151.0 | 66.6 | 51.6 | | | 9.48 | 37.75 | 74.69 | 0.25 |
| Tuhelj (Tuhelj Spa) | B | 85.0 | 32.9 | 17.0 | | | 5.65 | 21.25 | 44.57 | 0.25 |
| Varaždinske Toplice (Varaždin Spa) | HB | 95.0 | 57.6 | 42.0 | | | 6.20 | 23.75 | 48.87 | 0.25 |
| Velika (Toplice RC) | B | 35.0 | 25.0 | 10.0 | | | 2.20 | 8.75 | 17.31 | 0.25 |
| Zagreb (Mladost SC) | HB | 12.0 | 80.0 | 30.0 | | | 2.51 | 5.15 | 33.96 | 0.43 |
| Zagreb (Univ. Hospital) | H | 65.0 | 80.0 | 30.0 | | | 13.60 | 1.11 | 7.32 | 0.02 |
| Zagreb Ludko (INA) | H | 2.0 | 50.0 | 30.0 | | | 0.17 | 0.49 | 1.29 | 0.24 |
| Zelina (Zelina RC) | B | 30.0 | 40.0 | 25.0 | | | 1.88 | 7.50 | 14.84 | 0.25 |
| Zlatar (Sutinske Spa) | B | 80.0 | 33.8 | 18.8 | | | 5.62 | 20.00 | 33.57 | 0.25 |
| TOTAL | | 930.5 | | | | | 75.44 | 247.85 | 641.99 | 0.27 |



Instaled capacity – by sector

| Use | Installed Capacity ¹⁾ (MWt) | Annual Energy Use ²⁾ (TJ/yr = 10 ¹² J/yr) | Capacity Factor ³⁾ |
|--|---|--|-------------------------------|
| Individual Space Heating ⁴⁾ | 31,99 | 291,79 | 0,29 |
| District Heating ⁴⁾ | 13,77 | 8,61 | 0,02 |
| Air Conditioning (Cooling) | | | |
| Greenhouse Heating | 7,53 | 169,49 | 0,71 |
| Fish Farming | | | |
| Animal Farming | | | |
| Agricultural Drying ⁵⁾ | | | |
| Industrial Process Heat ⁶⁾ | | | |
| Snow Melting | | | |
| Bathing and Swimming ⁷⁾ | 22,15 | 172,1 | 0,25 |
| Other Uses (specify) | | | |
| Subtotal | 75,44 | 641,99 | 0,27 |
| Geothermal Heat Pumps | 4,50 | 42,50 | 0,30 |
| TOTAL | 79,94 | 684,49 | 0,27 |



Geothermal field Zagreb

Startup of the production 1987.

Two locations – SRC Mladost & Clinical hospital Blato

Proven reserves cumulative 77 l/s with 80°C

Used for balneology and direct heating





Geothermal field Bizovac

Startup of the production 1974.

Two locations – Slavonka-1 & Bizovac-4

Proven reserves Slavonka-1 -> 3,1 l/s with 75°C

Proven reserves Bizovac-4 -> 3,0 l/s with 95°C

Used for balneology and direct heating





Geothermal field Kutnjak-Lunjkovec

Discovered 1968. (production KT-1 and Lunj-1 injection well)

Proven reserves Kutnjak-1 -> 54 l/s with 140°C

Wells revitalized 2006. with hydrodinamical testing of the reservoir

Planned 2 MW electricity production – waiting on investment





Geothermal field Draškovec

Discovered 1972. geothermal water rich with methane (GWR 5 m³ / m³)

Revitalised in last few years.

Tested eruptive flow 3,1 l/s with 110°C (10 l/s with submersible pump)

Financed by EC trough NER300 programme

Planned 6MW of electricity production (gas turbine fired by methane plus AORC)



AORC is planned in next phase along with direct heating.

Complete geological model of reservoir needs to be done plus drilling additional 7 production wells

Geothermal field Bošnjaci

Discovered 2010. – first private investment

Proven reserves 20 l/s with 65°C

Greenhouse heating – indication of further development -> heat pumps

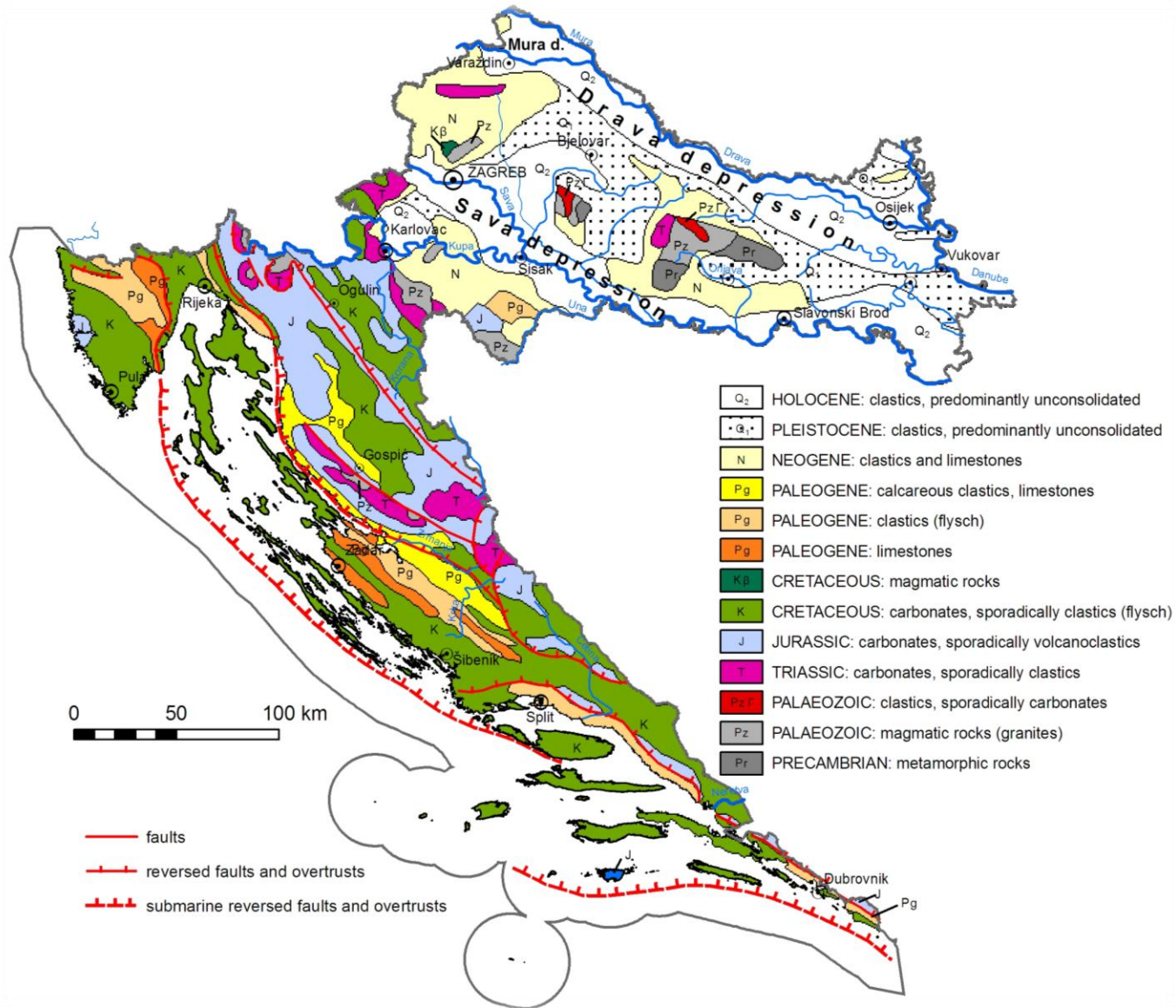




Shallow geothermal resources via heat pumps

| | 2008 g. | 2009 g. | 2010 g. | 2011 g. | 2012 g. | 2013 g. | Σ |
|---------------------------------|---------|---------|---------|---------|---------|---------|------|
| Borehole heat exchangers | 18 | 48 | 40 | 20 | 32 | 26 | 184 |
| Investors | 3 | 11 | 7 | 5 | 10 | 7 | 43 |
| Average no. of BHE per investor | 6,00 | 4,36 | 5,71 | 4,00 | 3,20 | 3,71 | 4,28 |
| Groundwater wells | 7 | 4 | 5 | 4 | 9 | 10 | 38 |

Shallow geothermal resources - Geological map - Croatia



Hydrogeological map of Croatia





Borehole heat exchangers– 1U or 2U mostly 100m





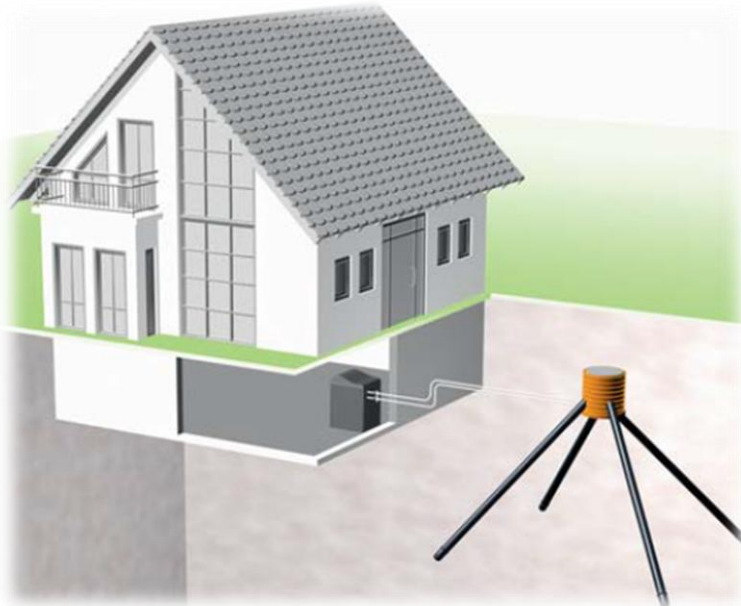
Koaxial heat exchangers – up to 40m



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Energy baskets and spirals





Energetske košare i spirale – do 5m – Opuzen





Energy piles up to 10m





Thermal response test - TRT





Thank you for your attention!

