

EFFICIENT LOW TEMPERATURE
GEOHERMAL BINARY POWER
LOW-BIN PROJECT - DG-TREN

IMPROVING EGS EXPLOITATION COSTS

by

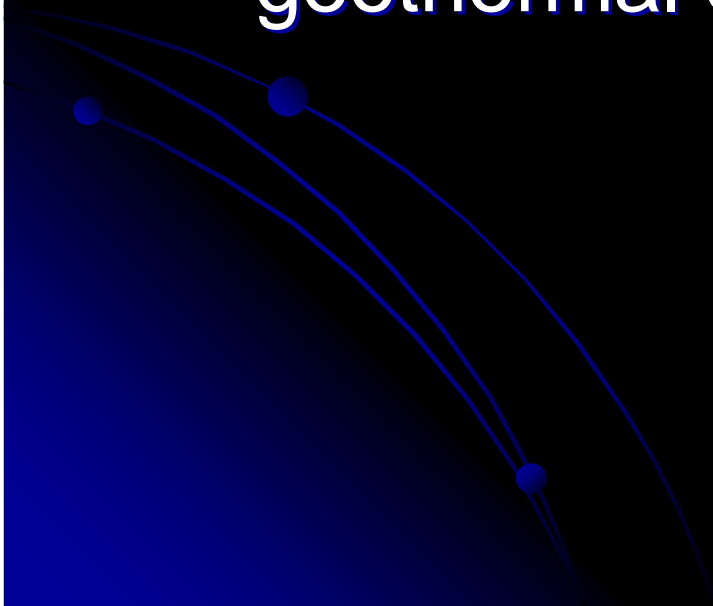
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Centre for Renewable Energy Sources

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LOW-BIN PROJECT AIMS IN IMPROVING

- Cost effectiveness
- Competitiveness
- Further market penetration of geothermal electricity generation



Widening market perspectives of Geothermal Rankine Cycle

- Power generation from low temperature geothermal resources with temperature threshold at 65°C (currently 90-100°C)
- Developing a CHP machine with heat recovery from the cooling circuit with total energy efficiency of 98-99% (currently 7-15%)

The LOW-BIN project involves:

- Theoretical research
- Laboratory experimentation
- 2 Pre-prototypes development
- Evaluation in terms of technology breakthrough achievement
- Evaluation in terms of energy efficiency
- Electricity generation costs and market potential
- Successful prototypes manufacturing and demonstration
- Monitoring, validation as well as technology dissemination and other innovation related activities

The LOW-BIN project consortium:

- CRES (Greece-Coordinator)
- TURBODEN (Italy)
- GFZ-Potsdam (Germany)
- GEOTEAM (Austria)
- University of Oradea (Romania)
- ESTSetubal (Portugal)
- Politecnico di Milano (Italy)
- BRGM (France)
- ISOR (Iceland)

LOW-BIN Budget distribution

Total budget : 3,935,713 €

EU Funding : 1,878,812 € (47,74%)

- R&D activities : 13.70%
- Demonstration : 74.50%
- Innovation related activities : 8.46%

Hydrothermal Resources of Europe: classification per temperature range for power generation

Area of geothermal interest	65-90 °C *		90-120 °C *		120-150 °C *		150-225 °C *		225-350 °C	
	MWth	MWe ¹	MWth	MWe	MWth	MWe ¹	MWth	MWe	MWth	MWe
Austria, Molasse	5 096	340	343	38						
Austria, Styrian	687	46	167	19	69	4				
Belgium - Hinut	71	5								
Belgium - Campine	196	13	176	20	19	1				
Bulgaria	177	12								
Czech - Bohemia	625	42								
Denmark - Gasum	930	62	338	34						

* including residual energy from higher temperature resources

* estimation based on data from the "Atlas of Geothermal Resources in Europe", 1st and 2nd editions, as well as on published data in the scientific literature and the Internet

* main assumptions: in 25 years (economic plant life) 25% of the heat stored in the hot water / steam producing horizons, present in depths less than 3km, is recovered.

¹ conversion efficiency according to the technology under development within the LOW-BIN project.

Area of geothermal interest	65-90 °C *		90-120 °C *		120-150 °C *		150-225 °C *		225-350 °C	
	MWth	MWe ¹	MWth	MWe	MWth	MWe ¹	MWth	MWe	MWth	MWe
France - Paris Basin	15 189	1 013	147	16	152	8				
France - Upper Rhine	2 926	195	2 321	250	408	23				
France - Aquitaine	4 590	306								
France - Rhone Graben	2 178	757	1 397	149	357	20				
France, Camarguaise	4 383	292	1 332	133						
France, Garrigues	2 184	146	446	50						
France, Guadeloupe	66	4	80	9	80	4	199	22	80	13
France, Martinique	33	2	40	4	40	2	100	11	40	7
France, La Reunion	33	2	40	4	40	2	100	11	40	7
Germany, N. German Basin	5 632	375	3 968	481						
Germany, Up. Rhine Graben	1 702	113	1 286	142	1 604	89				
Germany, Molasse	2 129	142	667	71						

Area of geothermal interest	65-90 °C *		90-120 °C *		120-150 °C *		150-225 °C *		225–350 °C	
	MWth	MWe ¹	MWth	MWe	MWth	MWe ¹	MWth	MWe	MWth	MWe
Greece, Milos	387	26	362	39	311	17	778	86	1557	259
Greece, Nisyros	26	2	31	3	26	1	60	7	120	20
Greece, Lesbos	151	10								
Greece, other	151	10								
N. Greece, Basins	3 964	264	4 756	423						
Hungary	39 342	2 623	27 512	2 476	1 815	101				
Iceland	7 612	507	9 135	1 015	9 135	507	22 836	2 537	30 449	5 075
Italy, Tuscany	5 765	384	6 919	769	6 919	384	17 296	1 922	34 593	5 765
Lithuania	1 744	116								
Netherlands	3 927	262	2 412	214						

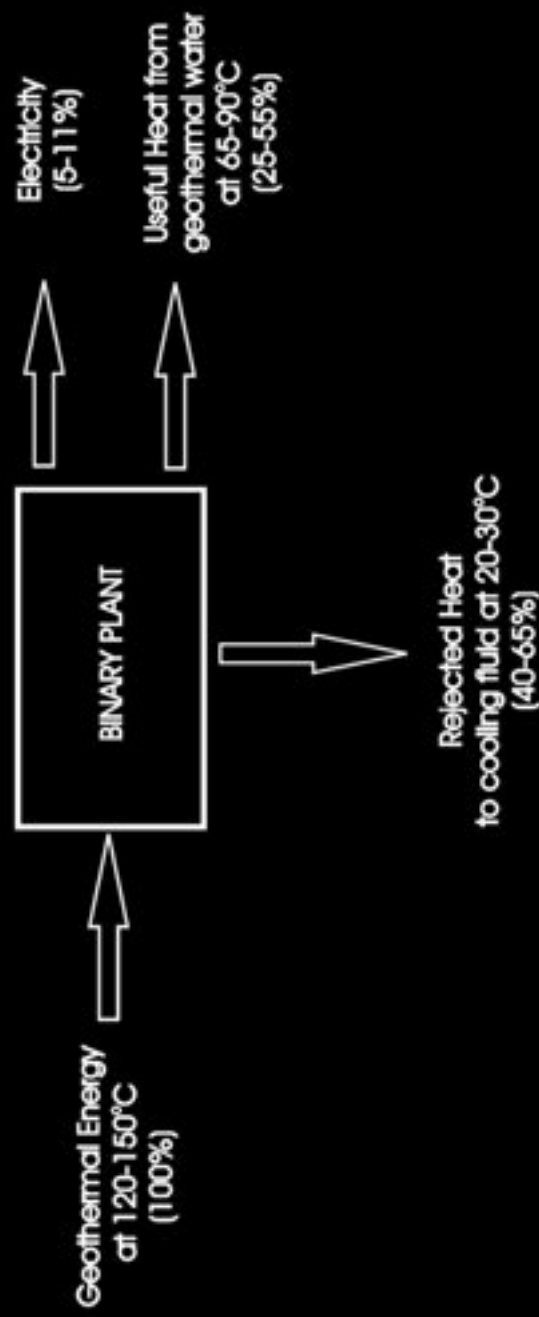
Area of geothermal interest	65-90 °C *		90-120 °C *		120-150 °C *		150-225 °C *		225-350 °C	
	MWth	MWe ¹	MWth	MWe	MWth	MWe ¹	MWth	MWe	MWth	MWe
Poland	3 486	232	972	86						
Portugal, Chaves	30	2								
Portugal, Azores	428	29	514	57	514	29	1 284	143		
Romania	11 895	793	828	77	106	6				
Russia, Caucasus	17 905	1 194	8 136	801	1 165	65				
Slovakia	545	36	179	16	0	0				
Slovenia	18	1								
Spain, Continental	118	8	9	1	19	1				
Spain, Canaria Islands	17	1	20	2	20	1	50	6	20	3
Switzerland	255	17	143	13						
United Kingdom	1 144	76	17	2						
TOTAL	147 736	10 462	75 421	7 503	22 819	1 268	42 703	4 745	66 897	11 150

REPLICATION – MARKET IMPACT – ENVIRONMENTAL IMPACT

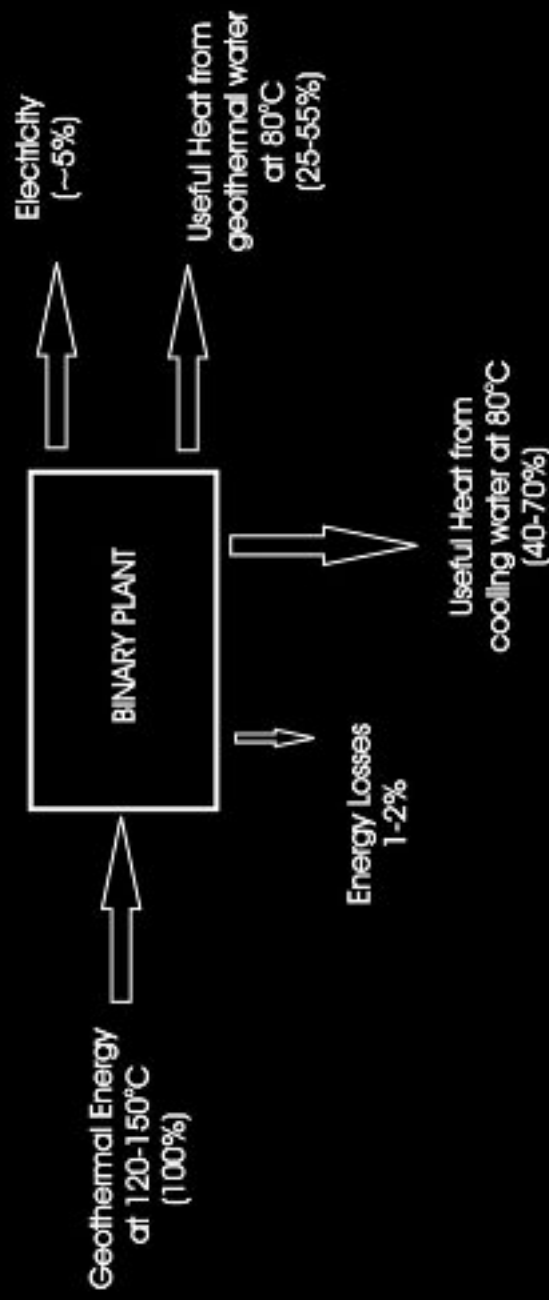
PROTOTYPE 1

YEAR	t	t+1	t+2	t+3	t+4	TOTAL
a) Annual Installation of new unit equivalents* of Prototype 1						
In unit equivalents	5	10	15	20	25	75
b) Accumulative Installed Electricity Capacity, in MWe						
In MWe installed	5	15	30	50	75	
c) Annual Accumulative Electricity Production **						
In MWhe	41.610	124.830	249.660	416.100	624.150	1.497.960
d) Annual Substitution of Conventional Fuel in TOE***						
In TOE	12.781	38.342	76.684	127.807	191.710	447.324
e) Annual avoidance/reduction of CO ₂ emissions in TCO ₂ , 1 TOE = 3,2 TCO ₂						
In TCO ₂	40.899	122.694	245.389	408.982	613.472	1.431.436
f) Annual estimated revenues at an indicative 1 Unit Equivalent price € 2.000.000						
In EURO	10.000.000	20.000.000	30.000.000	40.000.000	50.000.000	150.000.000
g) New jobs directly and/or indirectly created, 1 job per approx. € 1.000.000 revenue						
No. of Jobs	10	20	30	40	50	150

EXISTING PLANTS FOR GEOTHERMAL COGENERATION OF HEAT & POWER



LOW-BIN PLANT FOR GEOTHERMAL COGENERATION OF HEAT & POWER



PROTOTYPE 2

YEAR	t	t+1	t+2	t+3	t+4	TOTAL
a) Annual Installation of new unit equivalents* of Prototype 2						
In unit equivalents	4	8	12	16	20	60
b) Accumulative Installed Electricity Capacity, in MWe						
In MWe installed	4	12	24	40	60	
c) Accumulative Installed Thermal Energy capacity, in MWth						
In MWth installed**	32,5	97,2	194,4	324	486	
d) Annual Accumulative Electricity Production ***						
In MWhe	23.897	71.692	143.384	238.973	358.459	836.405
e) Annual Accumulative Thermal Energy Production ***						
In MWth	113.530	340.589	681.177	1.135.296	1.702.944	3.973.536
f) Total Annual Substitution of Conventional Fuel from Prototype 2 (electricity & heat), in TOE ****						
In TOE	19.545	58.635	117.270	195.450	293.175	684.075
g) Annual avoidance/reduction of CO ₂ emissions in TCO ₂ , 1 TOE = 3,2 TCO ₂						
In TCO₂	62.544	187.632	375.264	625.440	938.160	2.189.040
h) Annual estimated revenues at an indicative 1 Unit Equivalent price € 1.500.000						
In EURO	6.000.000	12.000.000	18.000.000	24.000.000	30.000.000	90.000.000
i) New jobs directly and/or indirectly created, 1 job per approx. € 1.000.000 revenue						
No. of Jobs	6	12	18	24	30	90

Energy and Financial Performance

	LOW TEMPERATURE GEOTHERMAL BINARY POWER PLANT	GEOTHERMAL BINARY HEAT & POWER COGENERATION PLANT
Nominal Size	200 kW(e)	200 kW(e)
Geothermal Energy Use	3.333 kW(th)	1.667 kW(th)
Power Generation		
only electricity mode:	200 kW(e)	200 kW(e)
Cogeneration mode:	n.a.	67
Energy Conversion Efficiency		
Power generation only:	6%	12%
Cogeneration:	n.a.	75%
Overall Energy Efficiency		
Power generation only:	6%	12%
Cogeneration:	n.a.	99%
Load Factors		
Power generation only:	95%	55%
Cogeneration:	0%	40%
Maintenance:	<u>5%</u>	<u>5%</u>
Total:	100%	100%

<i>Continued from previous table</i>	LOW TEMPERATURE GEOTHERMAL BINARY POWER PLANT	GEOTHERMAL BINARY HEAT & POWER COGENERATION PLANT	
Useful Energy Delivered	Electricity: Heat:	1.664.400 kW(e) n.a.	1.197.200 kW(e) 5.550.336 kW(th)
Capital costs		400.000 €	300.000 €
Annual operation & maintenance costs		50.000 €	45.000 €
Life cycle costs <i>(for 25 years with 5% cost-of-money)</i>		0,017 €/ kWh(e)	0,021 €/ kWh(e)
Price of RES-electricity		0,078 €/ kWh(e)	0,078 €/ kWh(e)
Annual Revenues		129.823 €	93.382 € *
Annual Profits		79.823 €	48.382 € *
Payback, years		5,0 years	6,2 years
Annual Return on Investment		20%	16%

() from electricity only – heat sales have not been not included*