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Global Geothermal Power Market

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ABSTRACT

The heat stored within the continental earth crust, volcanic/magmatic areas and geopressured basins correspond to ca 10.500, 400 and 70 times the world total fossil fuel reserves respectively. Until recently, geothermal power plants were limited to hot water bearing subsurface formations of sufficient temperature and permeability, allowing commercially attractive flow rates from production wells. Such conditions are encountered at hydrothermal systems at the lithosphere plate boundaries, where the bulk of world power generation is located today.

Electricity generation from hydrothermal systems with wells down to 2-4 km is a mature technology, from enhanced geothermal systems (EGS) at 3-6 km depth is a new technology the feasibility of which was proven by the EU funded project at Soultz and from supercritical systems at 5-10 km depth will be a future technology. Depending on what production wells yield at the surface, geothermal power plant technology used is dry steam plants, flash plants and binary plants for wells yielding dry steam, two phase fluid and liquid water respectively. Binary plants can be combined with flash plants in cases of two phase fluids, in order to maximize electricity output.

Global installed geothermal power was 11,5 GWe in 2012, a figure expected to double by 2020, when considering all projects under development or announced, corresponding to 6,9 GWe flash, 2,9 GWe dry steam and 1,3 GWe binary respectively. Average plant capacity corresponds to 45 MWe dry steam, 30 MWe flash and 5 MWe binary and maximum one to 130 MWe flash. Six major turbine manufacturers control 95% of the market, and one of them 90% of binary market. Investment costs per MWe of new geothermal power plants amount at 2,3 – 3,6 million € for flash plants, 3,1 – 6,5 million € for binary and 6,2 – 11,6 million € for EGS. Total market size amounts at ca 7,2 billion € electricity value and 4,4 billion € annual investments in new field development projects.

Market barriers to geothermal deployment are lengthy permitting procedures, lack of regulations, high exploration risk and associated finance availability, and competent personnel availability. In USA, geothermal development is driven by federal and state incentives available to energy producers, manufacturers and utilities, which include renewable portfolio standards, tax exemptions, investment subsidies and access to grid. In EU and other developed countries the geothermal market is supported by feed in tariffs and premiums. Global geothermal market development is done by ambitious new market entering companies, most of which are either geothermal focused, or power utilities, or dedicated power producers, while a few of them come originate from the oil and gas industry or from the trade and investment sector.

1. INTRODUCTION: GLOBAL GEOTHERMAL RESOURCES

Geothermal Energy is the heat of the Earth. The heat content of the Earth crust has been estimated at 10.775.600 billion TOE, amount that corresponds to ca 10500 times the identified world total fossil fuel reserves, which amounted at 422 billion TOE coal, 234 billion TOE oil and 188 billion TOE natural gas at the end of 2011 according to BP (2012).

In areas of volcanism or magmatic intrusions of recent geological age, geothermal development is much more favourable due to the availability of high temperatures at shallow depths. The geothermal resources in such areas, which are located at the boundaries of lithosphere plates, are estimated as 327.360 billion TOE, or 400 times the world total fossil fuel reserves.

Other areas of interest for geothermal power development are the geopresurred basins, the geothermal potential of which is of the same order of magnitude with their natural gas content and has been estimated as 55.924 billion TOE, or 70 times the world total fossil fuel reserves.

2. TYPES OF GEOTHERMAL POWER PLANTS AND SYSTEMS

Geothermal exploitation technology requires drilling one or more production wells delivering subsurface hot fluids to the surface, which after feeding a geothermal power plant, are injected back to their origin formations through reinjection wells. In that case, e.g. when deep hot fluids are available, the geothermal resource is termed as a hydrothermal system. Almost all geothermal power plants today are located in such hydrothermal systems, which are encountered mainly at the boundaries of tectonic

plates and at geological hot spots, where hot magma is rising towards a thin earth crust. Location of geothermal power plants is shown in Figure 1.

Figure 1. Geothermal power plants around the globe (yellow); the larger the cycle, the higher the installed plant capacity.

The geothermal plant at Soultz, proved that the exploitation of other parts of the earth crust, where deep hot formations do not naturally deliver the necessary amounts of fluids, is also technically feasible. In these geologic conditions, the hot rocks are artificially fractured by hydraulic fracturing, acidizing, propellants, etc., in order to engineer a man made reservoir, through which surface water is circulated serving as the heat transfer media. These are termed as enhanced geothermal systems (EGS). At present only a few EGS plants are in operation or under development around the globe, but future large scale exploitation of geothermal energy lies in this technology.

Depending on the temperature and permeability of the geothermal resource, production wells can deliver to the surface, either dry steam, or two phase mixture of steam and liquid water, or only liquid water.

Only a handful of dry steam resources are encountered around the globe. The most important are the geothermal fields of Larderello, Italy, Geysers, California, and Kamojang, Indonesia. In such fields, the steam from the production wells is directly conveyed to a steam turbine in order to generate electricity. This is termed as a dry steam plant.

In most cases, production wells deliver a mixture of steam and liquid water, which is flashed in order to separate the steam and the liquid (flash plant); the steam is conveyed to a turbine to generate electricity and the separated liquid can be further utilized for power generation or for its heat (cogeneration plant) and then reinjected to its origin reservoir. A flash plant is economically feasible if the production wells deliver more than 150°C.

In cases where resource temperature is lower than 150°C, production wells deliver liquid water with the aid of a submersible or line shaft pump, which feeds a binary power plant. In such a plant, the hot water delivers its heat to a closed loop of secondary fluid, which vaporizes, drives a turbine and condenses in a closed cycle (organic Rankine or Kalina).

In general, exploitation of hydrothermal resources down to 3-4 km depth is a mature commercial technology done by Binary plants for source temperature in the range 100-180°C, flash plants for source temperature higher than 180°C, and by dry steam plants at favourable locations.

EGS from 3-6 km depth is a new technology, while supercritical plants (T>350°C) from 5-10 km depth will be a future technology.

3. GLOBAL GEOTHERMAL POWER MARKET

The global geothermal power market amounts at 11,6 billion euro. It corresponds to 11.456 MWe of installed capacity with estimated annual sales of 71.997 GWhe, the value of which is 7,2 billion euro, plus annual growth of 1.588 MWe corresponding to 4,4 billion euro of investments.

The corresponding figures for the EU geothermal power market are 1,4 billion euro market size, comprising 941 MWe installed capacity generating annually 5982 GWhe of electricity, plus new additions of 70 MWe of geothermal power capacity annually.

Present and future forecast of installed capacity of geothermal power plants are presented in Tables 1 (world) and 2 (European Union). Future estimates are based on projects under development. At global level, market growth which was 3% during the past 20 years, is expected to exceed 10% in the next years, resulting in more than double installed geothermal capacity from 11,5 GW today to 24 GW by 2020.

At EU level, market growth patterns are expected to increase from 2% today to 6% during the next years, due to wider geothermal development, as EU member states try to reach their 2020 targets for 20% less greenhouse gas emissions, 20% renewable energy share and 20% more energy efficiency, resulting in installed capacity to increase from less than 1 GW today to 1,5 GW in 2020.

The different types of installed geothermal power plants today are presented in Figure 2. Average plant capacity is 5 MWe binary, 30 MWe flash and 45 MWe dry steam, with maximum at around 100-130 MWe.

Concerning geothermal power plants, the market is dominated by six major turbine manufacturers which control 95% of total installed capacity, as shown in table 3.

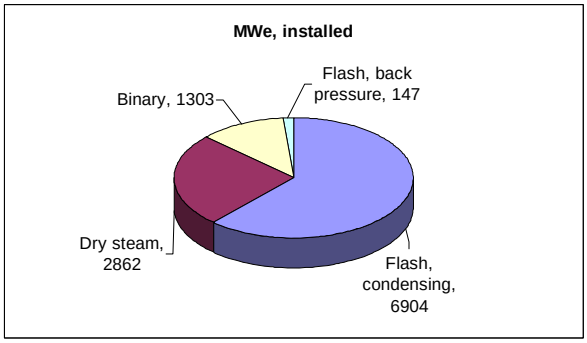

Figure 2. Types of geothermal power plants

Table 1: Installed and forecasted capacity (MWe) of geothermal power plants at global level.

Country	2012	2015	2020
USA	3.187	4.136	5.442
Philippines	1.972	2.112	3.447
Indonesia	1.335	2.325	3.453
Mexico	990	1.208	1.208
EU	941	1.113	1.499
New Zealand	750	1.350	1.599
Iceland	675	890	1.285
Japan	537	568	1.807
Kenya	205	402	560
El Salvador	204	287	290
Costa Rica	201	201	201
Nicaragua	124	209	240
Turkey	115	206	1.232
Russia	82	190	194
Papua NG	56	75	75
Guatemala	52	120	141
China	24	60	84
Ethiopia	7	45	70
Australia	1	43	70
Chilli		40	160
Honduras		35	35
Nevis		35	35
Argentina		30	300
Canada		20	493
Thailand		1	1
Bolivia		0	100
Iran		0	50
Peru		0	40
Armenia		0	25
Tanzania		0	20
Norway		0	5
Switzerland		0	3
World total	11.456	15.701	24.162

Table 2: Installed and forecasted capacity (MWe) of geothermal power plants in EU.

Country	2012	2015	2020
Italy	883	923	1.019
Portugal	29	39	60
France	16	41	42
Germany	12	92	184
other	1	18	194
EU total	941	1113	1499

Table 3: Geothermal power plant manufacturers with their corresponding installed capacity

Manufacturer	Flash MWe	Binary MWe	total MWe
Mitsubishi	2.729		2.882
Toshiba	2.721	25	2.746
Fuji	2.315		2.423
Ormat		1.234	1.234
Ansaldo	1.556		1.556
General Electric	532		532
Alstom	155		155
Assoc. Elec. Ind.	90		90
Kaluga	72	10	82
British Thomson Hou.	82		82
Mafi Trench		72	72
Qingdao Jieneng	62		62
UTC Turboden (MHI)		19	19
Kawasaki	15		15
Westinghouse	14		14
Elliot	12		12
Harbin	11		11
Enex		11	11
Turbine air system		8	8
Parsons	5		5
Makrotek	5		5
Siemens		4	4
other		3	3

4. ELECTRICITY GENERATION COSTS

The investment costs of geothermal power plants depend on the depth, temperature and chemistry of the resource, as well as the delivery flow rates of the wells. The dry steam, flash and binary plants in operation today exploit the most favourable resources usually from 2-3 km depth, going down to 4-5 km for EGS plants. Investment (capital) costs of recent projects in different parts of the globe are listed in Table 4, while the corresponding levelized electricity generation in Table 5. Investment costs include exploration, field development and power plant.

In order to estimate the electricity generation costs presented in Table 5, typical operation costs of 0,011-0,020 €/kWh were assumed, an investment discount factor of 8% for 20 years, as well load factors relevant to the installed country: 90% for USA, Portugal and Germany, 80% for Iceland and world average and 70% for Italy, Turkey and EU average.

Main market barriers hindering geothermal deployment are lengthy permitting procedures, lack of regulations, high risk in finding & identifying geothermal resources and associated finance availability, as well as know how and competent personnel to few companies only.

In USA, geothermal development is driven by federal and state incentives available to energy producers, manufacturers and utilities. They include renewable portfolio standards, tax exemptions, investment subsidies and access to grid.

Table 4: Investment in million €/MWe of recent geothermal power plant projects

	Flash	Binary	EGS
USA	2,7	3,1	6,2
Indonesia, N.Zealand, Philippines	2,3		
EU – Germany		4,5 6,5	11,6
Chile	3,6		
Turkey	2,75		

Table 5: Levelized electricity generation costs in c€/kWhe in recent geothermal power plant projects

	Flash	Binary	EGS
USA	5,5	6,0	10,0
Indonesia, N.Zealand, Philippines	4,4		
EU – Germany		9,5 10,4	21,3
Chile	7,2		
Turkey	6,6		

Table 6: Available feed-in tariff and feed-in premium support schemes

country	**€/kWh**
Japan: >15MW - <15MW	0,2692 - 0,4077
Switzerland: >20MW - <5 MW	0,1890 - 0,3330
Germany: hydrothermal - EGS	0,2500 - 0,3000
France - continental - overseas	 0,2000 - 0,2800 0,1300 - 0,1600
Slovakia	0,1905
Czech Republic - feed-in tariff - feed-in premium	 0,1810 0,1420
Italy: feed-in premium	0,0800 - 0,1300
Croatia	0,1590
Slovenia - feed-in tariff - feed-in premium	 0,1524 0,1036
UK: feed-in tariff equiv. 2 ROCs per MWh	0,1422
Indonesia	0,0833 - 0,1308
Greece	0,1220
Romania: feed-in tariff equiv. 2 green cert. per MWh	0,0540 - 0,1100
Hungary	0,0390 - 0,1070
Turkey	0,08 - 0,10
Belgium: green certificates (min)	0,0900
Portugal: Azores only	0,0884
Austria	0,0743
Estonia: feed-in premium	0,0537
Spain - feed-in tariff - feed-in premium	 0,0765 0,0427

In EU, geothermal development is supported by feed in tariffs, with the tendency to be replaced by feed in premiums. Following the successful example of Germany, Japan, Indonesia and Turkey have recently introduced aggressive feed in tariff schemes, in order to stimulate large scale geothermal power development in their territory. A summary of available feed in tariffs and premiums is presented in Table 6.

In developing countries support sources to geothermal projects are carbon credits and loans from World Bank ($336 million in 2012, $1710 million overall), Japan International Co-operation Agency, French Development Agency, European Investment Bank ($256 million), German development bank KfW, African Development Bank ($129 million), Asian development bank ($557 million), Interamerican development bank ($416 million) as well as national development banks .

Global geothermal market development is done by ambitious new-coming companies, the most important of which correspond to ~65% of total power plant capacity under development worldwide and are presented in Table 7.

Table 7: Companies investing in new geothermal power projects

Company	Location	installed MWe	new projects MWe
Gradient resources	USA	0	1025
Pertamina	Indonesia	642	875
Oski Energy	USA	0,8	655
Ram Power	USA,global	40	610
Enel	Italy,global	955	505
Contact Energy	N. Zealand	336	490
Landvirksjun	Iceland	63	480
CallEnergy	USA	329	470
Calpine	USA	1309	420
Idatherm	USA	0	400
Ormat	USA,global	777	350
US Geothermal	USA	54	350
Itochu	Japan, Indonesia	0	330
EDC	Philippines	756	305
KenGen	Kenya	150	280
Altera	USA,global	198	280
Zorlu	Turkey	15	185
Terra-Gen	USA	392	180
		Total:	8190

5. CONCLUSIONS

Despite that geothermal resources exceed by many orders of magnitude fossil fuel reserves, geothermal power corresponds to a niche market of about 11 billion Euros, with plants located mainly around the

world's volcanic zones, where economics are more favourable.

Market growth is expected to accelerate in next years, and installed capacity is expected to double by 2020, aided by new market entrants, new technologies adopted, as well as by favourable feed-in tariffs and premiums in developed world and by international development funds in developing countries.

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