2015 EMD Geothermal Energy Committee Annual Report

May 21, 2015

Mt Apo 1 and Mt Apo 2 geothermal power plants in the Philippines with a rated capacity of 54.24 MW each[1]

Paul Morgan, Chair

[1] http://www.interaksyon.com/business/96046/filinvest-unit-tops-bidding-for-mt--apo-geothermal-plants-output (Accessed 2015-5-21)

Introduction

Geothermal Energy contributes to the global energy economy through electrical power production, direct heat and cooling, and as a convenient thermal reservoir for heat pumps. Electrical power production is most commonly associated with geothermal energy but residential and commercial buildings account for more than one-third of the total energy consumption in the US and most of that energy is used for space heating and cooling and hot water. In many places geothermal resources can provide hot water and heating and cooling more efficiently than other energy resources, and ground-source heat pumps provide electrical energy savings of 75-80% or more for heating and cooling over the direct use of electricity for heating and cooling. The direct use of geothermal hot water for district heating systems is growing, especially in Europe, and there is a steady growth in the use of ground-source heat pumps in Europe and the US. The thermal energy output/savings of these systems is very large, but difficult to quantify in the U.S. because national data have not been compiled. In examples where geothermal water is cascaded from power generation to district heating the thermal energy recovered is typically several times larger than the electrical energy generated because the thermal energy can be recovered at a lower temperature and there are no losses in energy conversion. Direct-use and ground-source heat pumps remain underused geothermal resources. However, although they have global relevance, they have local application. This report focusses on the primary use of geothermal resources for power production and other transportable products.

One of the virtues of geothermal electrical power production with respect to wind or solar is that it provides base-load electricity providing power without the fluctuations of wind or the diurnal and seasonal cyclicity, and weather fluctuations of wind and solar. Most geothermal power plants have a capacity factor over 90%, equaling or exceeding the capacity factors of nuclear power plants because they very simple with no fuel or boilers. They typically have multiple turbines and wells so that maintenance of individual components can take place while the system is operating. Lower capacity factors are only common during development or expansion stages of operation, or if the internal load factors of the systems, such as well pumps, are not included in the capacity factor calculations (counting pumps integral to the system against the capacity factor of a geothermal system is equivalent to counting the mining, refining and disposal energy of uranium against the capacity factor of a nuclear power plant). Most power plants (coal, oil, nuclear) cannot be started quickly and there is a problem accommodating the fluctuating power delivery from wind and solar. To some extent this fluctuating power delivery may be accommodated by transferring solar and wind power from one part of a grid where it is being generated to another part of a grid where generation is lacking. However, this requires excess power capacity and flexibility in switching power around a grid that may not be available because of limitations in line capacities. The main current solution to pick up rapid shortfalls in power generation is gas-fired power plants; these plants can change their generating capacity relatively rapidly (hydro-electric power plants are also very flexible but opportunities to build new hydro-electric power plants are very limited). However, the rapid growth in wind and solar has required an almost one-to-one building of gas-fired power plants to back-up the fluctuating renewable resources.

Geothermal power plants have traditionally been run at or near full generating capacity because the plants were designed to operate most efficiently in that mode. However, within limits, the resource is not required to be withdrawn at the full capacity of the generating plant, and, with changes in design, plants can be constructed to provide power to the grid as needed up to the capacity of the system. Such a mode of operation lowers the efficiency of the geothermal power generation, but provide, an alternative solution to stand-by gas-fired power plants. Flexible geothermal operations have recently been demonstrated by several projects, including the Puna Geothermal Venture plant which generates 38 MW, and has contracted 16 MW of flexible capacity in Hawaii.[2] However, most growth in geothermal power production is for base load electricity, especially in countries where geothermal is primary growth in the nations' electricity system. Therefore, the report concentrates growth in base-load, geothermal electrical power production. Much of the information in this report is paraphrased from reports from the Geothermal Energy Association (Geo-Energy.Org), with special reference to the 2015 Annual U.S. & Global Geothermal Power Production Report[3]

United States Geothermal Development 2014-2015

The overall geothermal generating nameplate capacity was about 3.5 GW with about 2.7 GW net capacity in 2014-2015. As discussed in the introduction, the difference in these two numbers is primarily in energy used to operate pumps used to produce and dispose of the geothermal fluids: the net capacity rather than the nameplate capacity should be used when calculating capacity factors for geothermal power plants. There was little significant growth in online geothermal generating capacity in the U.S market in 2014-2015 but there was about 1,250 MW of geothermal power under development with about 500 MW in limbo awaiting power-purchase agreements (PPAs). There was an increase in the number of states in which geothermal projects were under development (Figure 1). Expansion of geothermal in the U.S. market was limited by almost no growth in demand for new power, and uncertainties and unbalanced mechanisms for valuing new power in terms of tax credits and other financial incentives. The uncertain U.S. geothermal market resulted in consolidation and restructuring of a number of companies in the U.S. market. The U.S. geothermal industry will be closely watching the final result of the EPA Clean Power Plant rule and individual state actions that encourage clean power that supplies base load power and balances intermittent supplies of clean energy. The developing planned and installed geothermal capacities by state and number of developing projects by state are shown in Figures 2 and 3.

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[2] Geothermal Energy Association Issue Brief: Firm and Flexible Power Services Available from Geothermal Facilities, http://geo-energy.org/reports/2015/Firm%20and%20Flexible%20Power%20Services%20from%20Geothermal.pdf (Accessed 2015-5-21); Nordquist, J., T. Buckanan, & M. Kaleikini, 2013, Automatic generation control and ancillary services, GRC Transactions, v. 37. Operators in the Geysers field, located in northern California, operated in various modes in the past, including traditional base load, peaking, and load-following. However, flexible operations ceased in the early 1990s in response to low demand and lower costs of generation within the utility's system from hydro, coal and natural gas power plants.

[3] Geothermal Energy Association, 2015 Annual U.S. & Global Geothermal Power Production Report, February 2015, 21 pp. http://geo-energy.org/reports/2015/2015%20Annual%20US%20%20Global%20Geothermal%20Power%20Production%20Report%20Draft%20final.pdf (Accessed 2015-5-21).

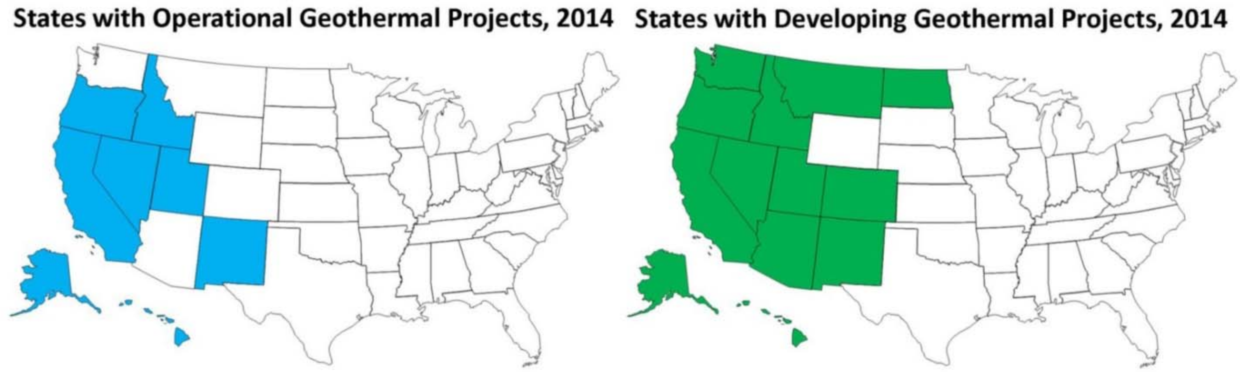

Figure 1. Left: States with operational geothermal generating projects shown in blue. Right: States with developing geothermal generating projects shown in green. Source: Geothermal Energy Association, Why Support geothermal Energy? Page 7, 8 pp. January 2015; http://geo-energy.org/pdf/FINALforWEB_WhySupportGeothermal.pdf (Accessed 2015-5-21).

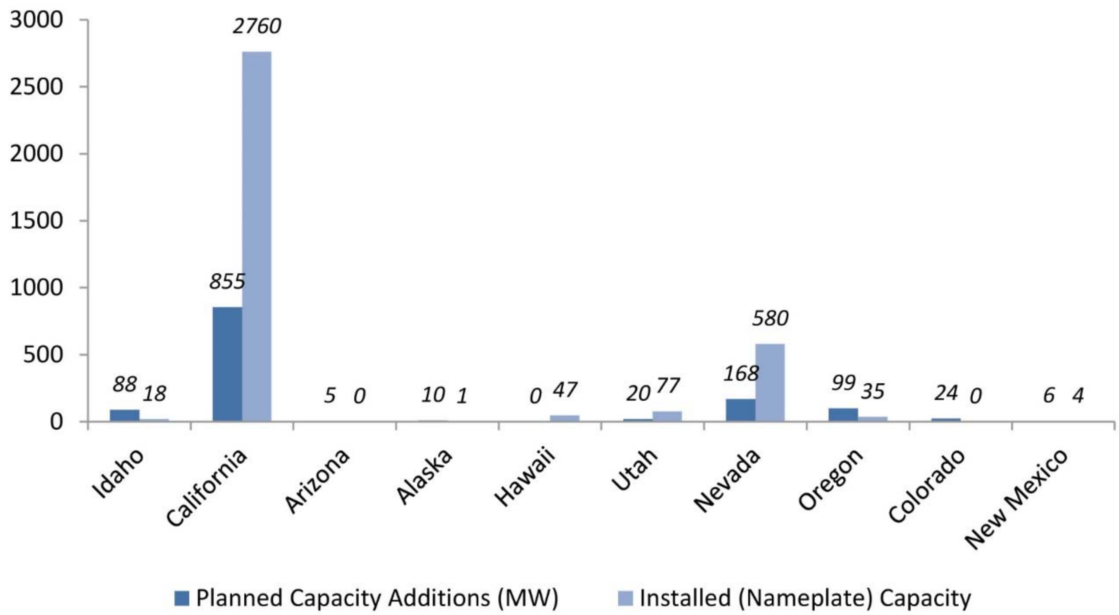

Figure 2. Planned capacity additions under development and installed nameplate capacities in the U.S. by state. Planned capacity additions are the estimated installed capacities of the power plants. Source: Geothermal Energy Association, 2015 Annual U.S. & Global Geothermal Power Production Report, Figure 7, 21 pp. February 2015; http://geo-energy.org/reports/2015/2015%20Annual%20US%20%20Global%20Geothermal%20Power%20Production%20Report%20Draft%20final.pdf (Accessed 2015-5-21).

U.S. Department of Energy Geothermal Programs

The U.S. Department of Energy is currently funding two programs associated with geothermal. The first program is a *play fairways exploration* program, following the *play fairways* concept in hydrocarbon exploration, to develop concepts of geothermal exploration models for different types of geothermal resources in type geological/tectonic/geothermal settings. The second program is to assist in developing technologies for mineral recovery from

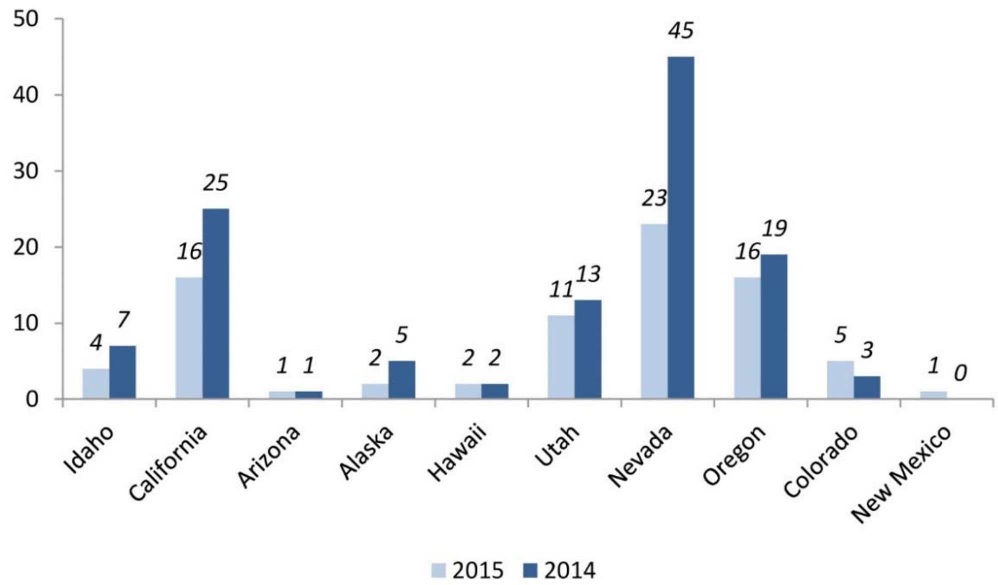

Figure 3. Number of U.S. developing geothermal generating projects by state. During the past few years demonstration and exploration projects have occurred in additional states such as Washington, Texas, North Dakota, Louisiana, Montana, Mississippi, and Wyoming. Source: Geothermal Energy Association, 2015 Annual U.S. & Global Geothermal Power Production Report, Figure 8, 21 pp. February 2015; http://geo-energy.org/reports/2015/2015%20Annual%20US%20%20Global%20Geothermal%20Power%20Production%20Report%20Draft%20final.pdf (Accessed 2015-5-21).

geothermal brines with a particular emphasis on rare earth, strategic, and other valuable minerals. Participants have been selected, but funding has not yet started for a third program, FORGE, the Frontier Observatory for Research in Geothermal Energy. The first two phases of this program are two select a site for the "observatory". The third phase is to develop a crystalline basement EGS system that will serve as a research test site for scientists and engineers.

The budget for the Department of Energy Geothermal Technologies Office increased by more than 20% from FY2014 to FY2015. The presidential budget requests a further 74.55% increase for FY2016 (Table 1). However, indications at the time of writing this report are that the Congressional Budget Committee will reduce the geothermal budget to something close to the FY2014 level rather than approve an increase. A more optimistic outlook at this time is level funding for FY2016.

International Geothermal Development

For the third consecutive year, the global power industry sustained a 5% growth rate. The world market reached 12.8 GW of geothermal power operational through 24 countries with primary growth in Turkey, Kenya, Indonesia, and the Philippines (Figures 4 and 5). There are also 11.5 to 12.3 GW of planned capacity additions in 80 countries and 630 projects as of the end of 2014. Fourteen of those 80 countries are expected to bring 2 GW of power online over the next 3-4 years based on current construction and the Geothermal Energy Association predicts that the global market will reach between 14.5 and 17.6 GW by 2020 (Figure 4).

Table 1. Enacted budgets from the Department of Energy for the Geothermal Technologies Office for FY2014 and FY2015 and the requested budget to FY2016. Source: U.S. Department of Energy, Geothermal Technologies Office, FY 2016 Budget At-a-Glance: http://energy.gov/sites/prod/files/2015/03/f20/fy16_gto_at-a-glance.pdf (Accessed 2015-5-21).

(Dollars in Thousands)	FY 2014 Enacted	FY 2015 Enacted	FY 2016 Request
Enhanced Geothermal Systems (EGS)	27,084	32,100	45,000
Hydrothermal	10,285	12,500	36,500
Low Temperature and Coproduced	4,708	6,000	9,000
Systems Analysis	3,698	3,900	5,000
NREL Sitewide	0	500	500
Total, Geothermal Technologies	**45,775**	**55,000**	**96,000**

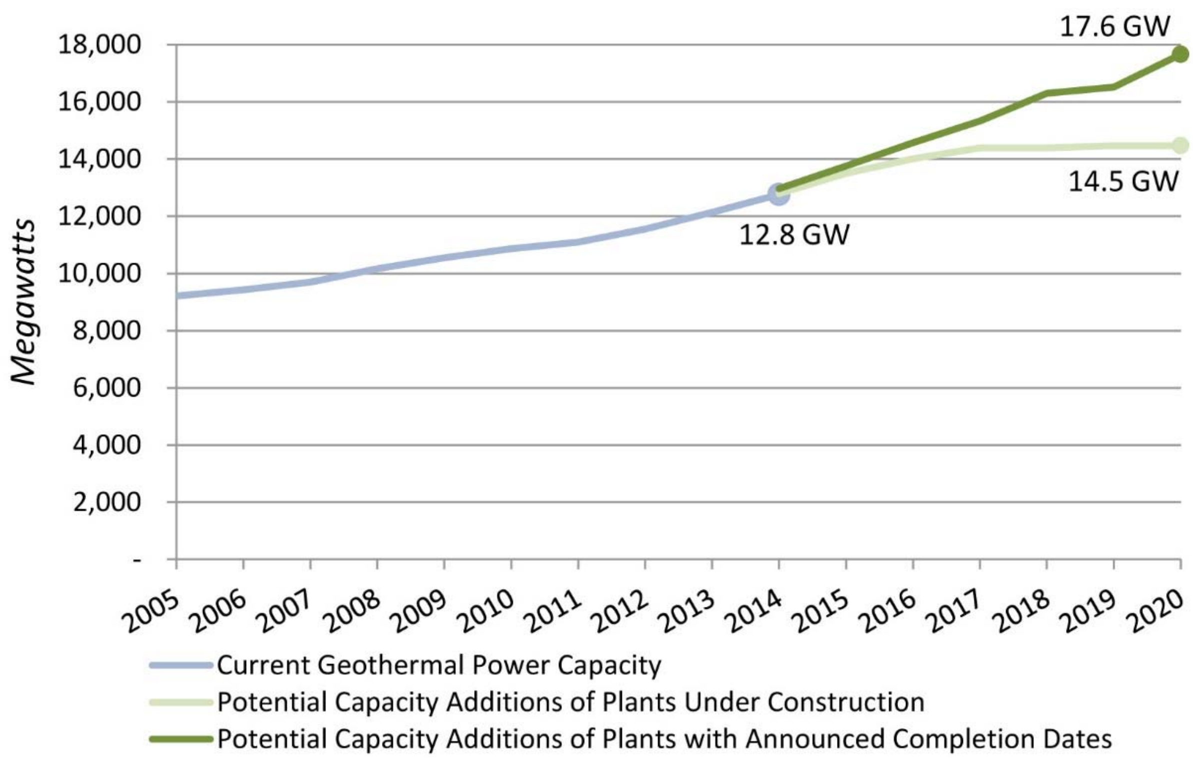

Figure 4. Growth in total international geothermal power nameplate capacity. Planned capacity additions, pilot plants, and utility-scale geothermal plants built in the first half of the 20th century and then decommissioned are not included in the above time series. Source: Geothermal Energy Association, 2015 Annual U.S. & Global Geothermal Power Production Report, Figure 1, 21 pp. February 2015; http://geo-energy.org/reports/2015/2015%20Annual%20US%20%20Global%20Geothermal%20Power%20Production%20Report%20Draft%20final.pdf (Accessed 2015-5-21).

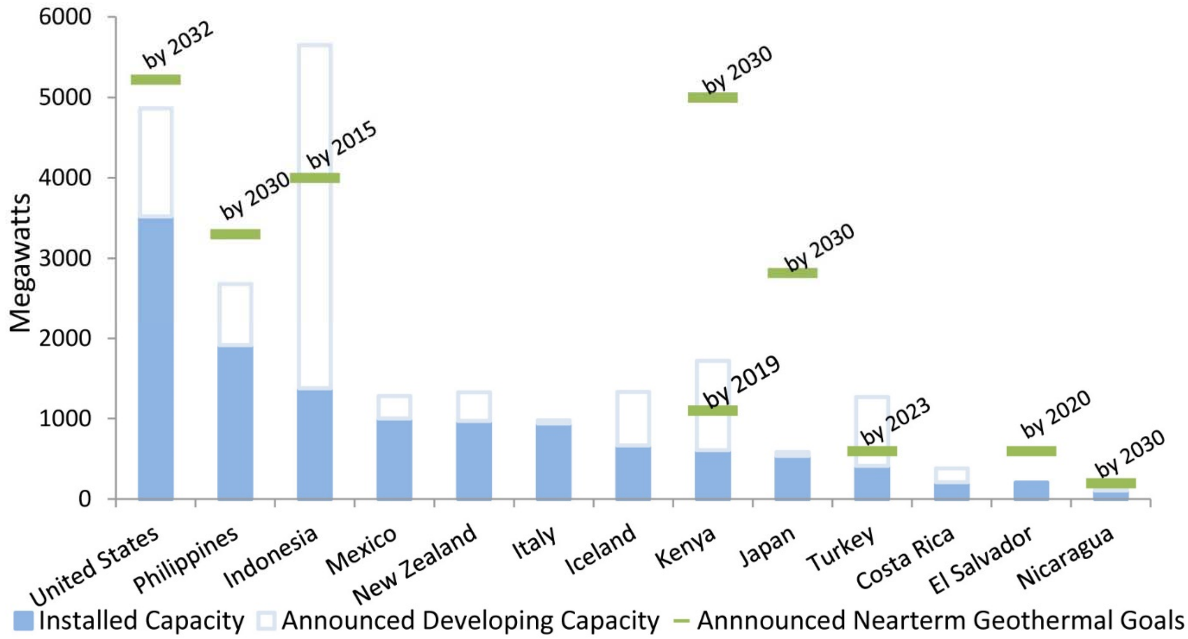

Figure 5. Major international geothermal markets, installed capacity, announced developing capacity, and announced near term geothermal goals which include government and private sector development goals. Mexico has set a general renewable energy goal of 35% from renewables by 2024; however, this goal is not geothermal specific. The U.S. goal is the Imperial Irrigation District's objective of building out geothermal capacity at the Salton Sea Resource Area by 2032. Estimates rounded to nearest 5 MW and "net capacity" was used when nameplate capacity was not available. Source: same as Figure 4, but this is Figure 2 from the report.

Two factors are spurring the growth in the international geothermal market both in terms of the installed capacity and in the number of participating countries. The first factor is that geothermal energy is a cost-competitive green renewable energy source and part of the solution toward lowering the emissions that contribute to global climate change. This factor allows the World Bank's Energy Sector management Assistance Program (ESMAP) to mobilize funds through the Clean Technology Fund toward scaling up geothermal energy. The second factor is that geothermal energy is a domestic resource that is available in many countries that are lacking in other energy resources: high-grade geothermal resources are generally concentrated on active plate boundaries that lack mature sedimentary basins rich in fossil fuels. The World Bank and other multi-lateral organizations focused on early-risk mitigation has funded a number of programs to initiate development in a number of geothermal-rich/fossil-fuel poor nations where surface exploration has been completed but additional financing is needed to confirm the commercial viability of the geothermal resources. ESMAP estimates that as many as 40 countries could meet a large proportion of their electricity demand through geothermal power[4]. Some of this development is illustrated in Figures 6 and 7.

[4] The World Bank, Geothermal Energy: Expansion Well Underway in Developing Countries, Feature Story, December 3, 2014, http://www.worldbank.org/en/news/feature/2014/12/03/geothermal-energy-expansion-well-underway-in-developing-countries (Accessed 2015-5-21).

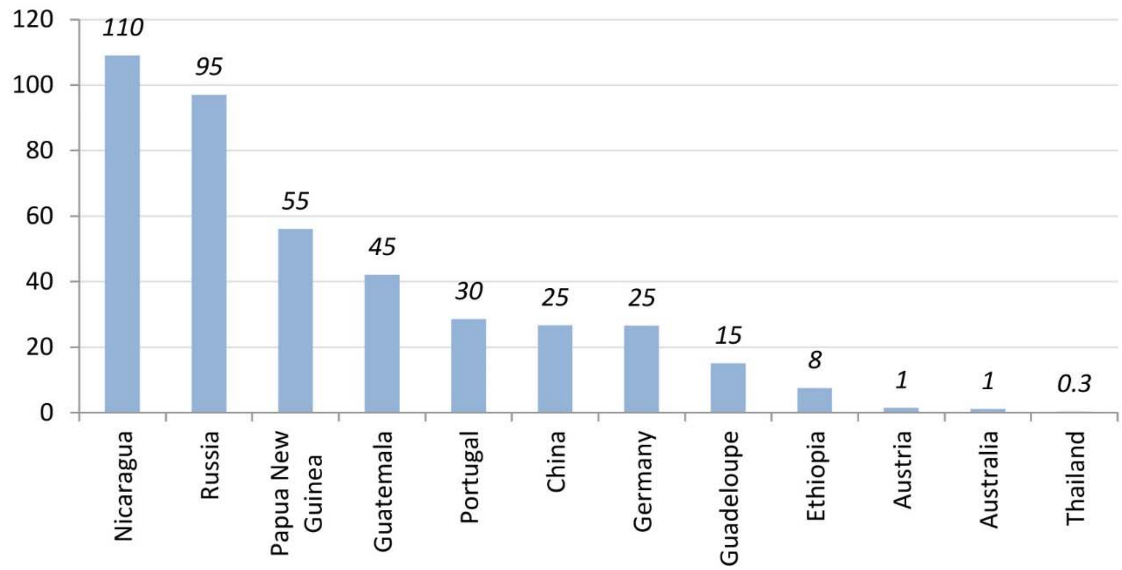

Figure 6. Totals of developing nameplate capacities in MW in developing markets. Estimates are rounded to the nearest 5 MW and "net capacity" is used when nameplate capacity was not available. Source: same as Figure 4, but this is Figure 4 from the report.

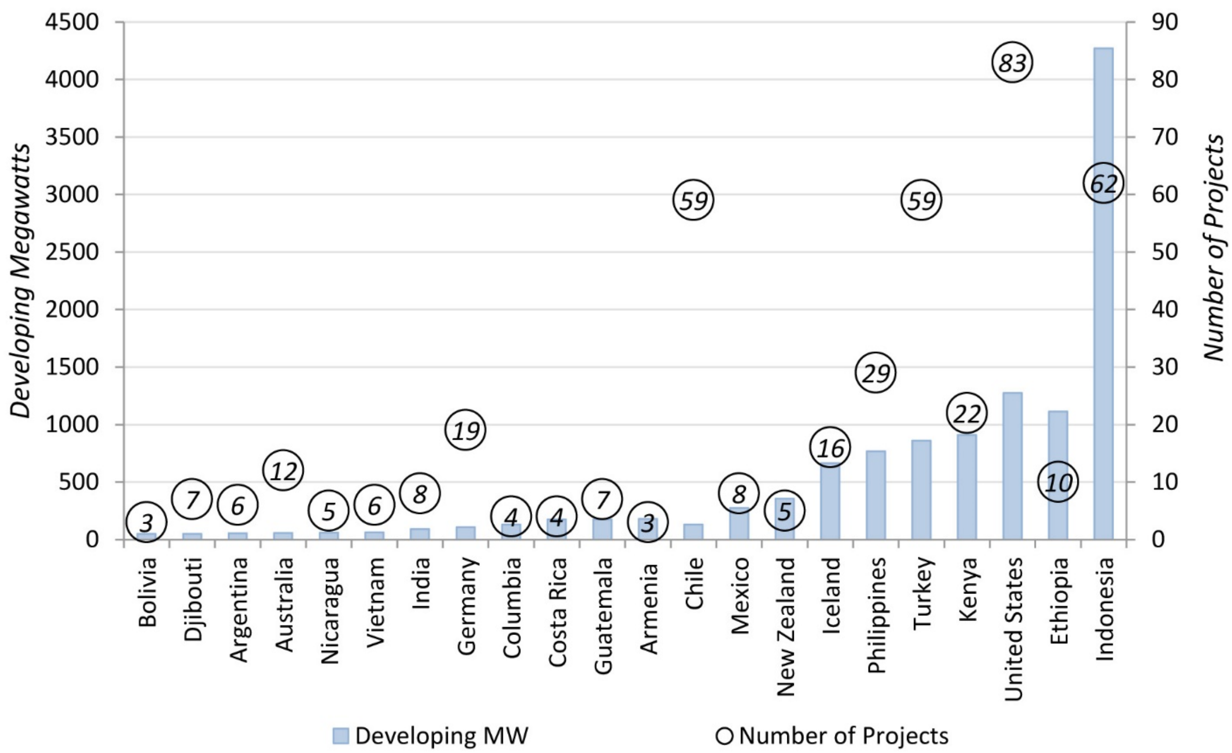

Figure 7. Totals of developing capacity and numbers of projects by country or territory. The large amount of developing capacity for Indonesia could be the result of a backlog of projects stalled by prolonged power-purchase agreements, delayed permits related to the use of conservation or protected areas and resistance from local communities. Source: same as Figure 4, but this is Figure 5 from the report.

Concluding Remarks

The international geothermal energy market is enjoying steady sustained growth and that growth is expected to continue. The growth is based primarily on countries with the domestic availability of high-grade geothermal resources but a lack of other fuel resources from which to generate electricity. In other countries growth in the use of geothermal resources is more erratic and more dependent on baseline energy prices, reliability of supply of fossil-fuel resources (short- and long-term), and government policies and incentives. For example, in most of Europe, geothermal resources are low grade, but energy prices are high, and there are incentives, either through individual countries or through European Economic Community grants to develop alternative energy resources. Germany currently receives most of its natural gas supplies from Russia and would like to reduce its dependence on this source. It has an aggressive program to use alternative energy sources. It has installed about 27 MW_e geothermal electricity generating capacity but about 150 MW_t thermal geothermal district heating capacity using resources with insufficient temperature to generate electricity[5].

The U.S. continues to lead the world in installed geothermal generating capacity and annual geothermal electricity production. However, growth was stalled in 2015 and despite pressure for increased green generating capacity in the U.S., there are few incentives from the federal and state governments for geothermal development and many regulations that slow development. Programs pursued by the Department of Energy DOE Geothermal Technology Office look far into future, perhaps too far into the future. Most of the funds from this office in past years have been used for studies of Enhanced Geothermal Systems (EGS): the feasibility of this technology was demonstrated at Fenton Hill, New Mexico, by scientists at the Los Alamos National Laboratories in the 1970s and 80s, but it was far from economic. Experiments in the U.S. and around the world during the past 30 years have made little improvement on the economics. There have been great improvements in geothermal power-plant technologies, however, that allow electricity to be generated with lower temperature resources than was possible in the 1980s. Thirty years ago sedimentary basins were not fertile grounds for generating electricity. Today the low hanging fruit for a new horizon for geothermal resources is sedimentary basins as electricity can be generated at temperatures in the high-end of the oil and gas window. This horizon is the perfect interface for AAPG and geothermal as it is the backyard for oil and gas drilling.

[5] Agemar, T., J. Webar, and R. Schulz, 2014, Deep geothermal energy production in Germany, Energies, 2014, 7, 4397-4416. (www.mdpi.com/journal/energies)