Trends in Geothermal Applications 2016/17

Survey Report on Geothermal Utilisation and Development in IEA Geothermal Member Countries in 2016/17

with trends in geothermal power generation and heat use 2000 - 2017

IEA Geothermal

GEOTHERMAL TREND REPORT 2016/17

26 pages, with 16 tables and 12 figures

Authors:
Josef Weber, Betina Bendall, Lauren Boyd, Chris Bromley, Jonathan Busby, Margarita de Gregorio, María Guðmundsdóttir, Luis Carlos A. Gutiérrez-Negrín, Hiroyuki Kamenosono, Katharina Link, Jiri Muller, Takayuki Oishi, José M. Romo-Jones, Yoonho Song, Jeffrey Winick, Lothar Wissing, Kasumi Yasukawa

Corresponding Author: Dr. Josef Weber, Leibniz Institute for Applied Geophysics
Stilleweg 2, 30655 Hanover, Germany.
E-mail: josef.weber@leibniz-liag.de

IEA Geothermal

Publication of the IEA Geothermal, October 2019.
http://iea-gia.org

IEA Geothermal Secretariat: Brian Carey, GNS Science, Wairakei Research Centre,
Private Bag 2000, Taupo 3352, New Zealand.
E-mail: iea-giasec@gns.cri.nz

Picture Credits:
Front page image: J. Weber
Figure 1: J. Weber
Figure 2: J. Weber
Figure 3: Maps from The World Factbook, CIA (www.cia.gov, accessed April 2014)
Figure 4: C. Bromley
Figure 9: © State Authority for Mining, Energy and Geology, Lower Saxony, Germany (LBEG)
Figure 12: B. Ganz

Trends in Geothermal Applications 2016/17

IEA Geothermal

Survey Report on Geothermal Utilisation and Development

in IEA Geothermal Member Countries in 2016/17

with trends in geothermal power generation and heat use 2000 - 2017

Table of Contents

1 Introduction ... 3

1.1 About IEA Geothermal ... 3

1.2 Units and abbreviations ... 4

1.3 Glossary ... 5

1.4 Geothermal applications data: an overview ... 6

2 Geothermal power generation ... 7

2.1 Introduction ... 7

2.2 Trends 2000 - 2017: installed (2000 - 2009) and running (2010 - 2017) capacity ... 8

2.3 Trends 2000 - 2017: electricity production ... 10

3 Direct use of geothermal heat ... 12

3.1 Introduction ... 12

3.2 Centralised installations for direct heat uses ... 12

3.3 Geothermal heat pumps (GHP) ... 15

3.4 Trends in geothermal heat use 2000 - 2017 ... 17

4 CO_2 and fossil fuel savings ... 19

4.1 Fossil fuel savings by geothermal applications ... 19

4.2 CO_2 emission savings ... 19

5 References ... 22

Figures

Figure 1: Wairakei geothermal power station and aquaculture 3
Figure 2: The Champagne Pool at Wai-O-Tapu, New Zealand 5
Figure 3: Overview of geothermal power and heat utilisation in member countries and worldwide 2017 6
Figure 4: 140 MW_e Nga Awa Purua triple flash power station near Taupo, New Zealand 6
Figure 5: Installed and running electric capacities in member countries 2000 - 2017 9
Figure 6: Electric capacities in member countries, selected non-member countries and worldwide 2000 - 2017 10
Figure 7: Power generation in member countries, selected non-member countries and worldwide 2000 - 2017 11
Figure 8: Geothermal power generation in member countries 2000 - 2017 11
Figure 9: Principle of GSHP systems using borehole heat exchangers 15
Figure 10: Installed thermal capacity of geothermal heat uses in member countries and worldwide 2000 - 2017 18
Figure 11: Annual heat use in member countries and worldwide 2000 - 2017 18
Figure 12: Los Azufres geothermal power plant, Mexico 20

Tables

Table 1: Energy units, conversion factors and prefixes 4
Table 2: Participating countries (ISO 3166 country codes) 4
Table 3: Geothermal power generation in member countries and worldwide in 2017 7
Table 4: Running capacity in member countries by main activity producers and autoproducers 2017 8
Table 5: Gross power production in member countries by main activity producers and autoproducers 2017 8
Table 6: Installed and running electric capacities in member countries and worldwide 2000 - 2017 9
Table 7: Geothermal electricity produced in member countries and worldwide 2000 - 2017 10
Table 8: Direct use capacity of geothermal heat in member countries 2010 - 2017 12
Table 9: Direct use of geothermal heat in member countries 2010 - 2017 13
Table 10: Installed thermal capacity in member countries by main activity producers and autoproducers 2017 14
Table 11: Gross heat production in member countries by main activity producers and autoproducers 2017 14
Table 12: Geothermal heat pumps in member countries: installed capacity and annual heat use 16
Table 13: Geothermal heat use in member countries 2015 - 2017 17
Table 14: Fossil fuel savings by geothermal energy uses in member countries in 2017 19
Table 15: CO_2 savings for geothermal electricity in member countries in 2017 19
Table 16: CO_2 savings by geothermal heat uses in member countries in 2017 20

1 INTRODUCTION

1.1 About IEA Geothermal

The International Energy Agency (IEA) is an inter-governmental organisation which acts as an energy policy advisor to 30 member countries in their efforts to ensure reliable, affordable and clean energy for their citizens. Founded during the oil crisis of 1973-74, the IEA's initial role was to coordinate measures in times of oil supply emergencies. While this continues to be a key aspect of its work, the IEA has evolved and expanded. Today, the IEA's four main areas of focus are: energy security, economic development, environmental awareness, and engagement worldwide.

To promote international scientific collaboration and to foster research, development and deployment of particular technologies, the IEA created a legal contract, the Implementing Agreement, and a system of standard rules and regulations. The Geothermal Implementing Agreement (GIA), or IEA Geothermal, provides an important framework for wide-ranging international cooperation in geothermal R&D. The GIA went into effect for an initial period of five years in 1997 and is now in its fifth term of operation. Efforts concentrate on encouraging, supporting and advancing the sustainable development and use of geothermal energy worldwide, both for power generation and direct use applications (Fig. 1).

The management of the organisation is conducted by an Executive Committee with one representative from each country and each sponsor member, while the management of the various major activities (Working Groups, WG) is the responsibility of the Operating Agents and their WG Leaders. In 2019, the IEA Geothermal has 16 members: 13 country members - Australia, France, Germany, Iceland, Italy, Japan, Mexico, New Zealand, Norway, Korea, Switzerland, the United Kingdom, and the United States; the European Union, and two sponsors: the Spanish Geothermal Technology Platform (GEOPLAT) and ORMAT Technologies, Inc.

The IEA Geothermal's activities cover a diverse range of research areas, or Tasks, which are organised in five Working Groups (as at 2019): WG 1 - Environmental Impacts of Geothermal Development, WG 8 - Direct Use of Geothermal Energy, WG 12 - Deep Roots of Volcanic Geothermal Systems, and WG 13 - Emerging Geothermal Technolgies. A geothermal data and information activity is organised in WG 10 - Data Collection and Information, which all country members are required to participate in.

The main objective of WG 10 is to collect essential data on geothermal energy uses, trends and developments in member countries and to publish these data in an annual report, the Geothermal Trend Report. This report provides a brief overview of data such as installed/running capacities and electricity generation and heat use. Individual reports from each country, which are based on a standardised questionnaire, provide the basis for the data collection presented here. To illustrate trends and a comparison with geothermal uses worldwide, additional data sources, such as the publications associated with the World Geothermal Congress, are also evaluated.

This report "Trends in Geothermal Applications" presents the seventh annual collection of standardised data from 14 countries (13 country members & one sponsor) and extends the information provided in the more general Annual Reports. Future trend reports will supply substantial information on geothermal applications and help to illustrate trends in geothermal energy use on an international scale.

For further information please visit the website of the IEA Geothermal: http://iea-gia.org.

Figure 1: Wairakei geothermal power station and aquaculture

1.2 Units and abbreviations

Units of Energy and Capacity

Energy produced (electricity, heat): **watt-hour** [Wh]; **joule** [J]

Capacity (electric, thermal): **watt** [W_e], [W_t]

Table 1: Energy units, conversion factors and prefixes

1 megawatt-hour [MWh]	1,000 kilowatt-hours [kWh]
1 gigawatt-hour [GWh]	1 million kilowatt-hours [kWh]
1 terawatt-hour [TWh]	1 billion kilowatt-hours [kWh]
1 gigawatt-hour [GWh]	3.6 terajoule [TJ]
1 terawatt-hour [TWh]	3.6 petajoule [PJ]
1 terajoule [TJ]	0.2778 gigawatt-hours [GWh]
1 petajoule [PJ]	0.2778 terawatt-hours [TWh]

Kilo- (k)	10^3
Mega- (M)	10^6
Giga- (G)	10^9
Tera- (T)	10^{12}
Peta- (P)	10^{15}
Exa- (E)	10^{18}

Country codes

Table 2: Participating countries (ISO 3166 country codes)

Country	**Country code**
Australia	AUS
France	FRA
Germany	DEU
Iceland	ISL
Italy	ITA
Japan	JPN
Mexico	MEX
Republic of Korea	KOR
New Zealand	NZL
Norway	NOR
Spain	ESP
Switzerland	CHE
United Kingdom	GBR
United States of America	USA

Abbreviations

BHE Borehole Heat Exchanger
CAGR Compound Annual Growth Rate
COP Coefficient of Performance
GIA Geothermal Implementing Agreement
GSHP/GHP Ground Source Heat Pump/Geothermal Heat Pump
IEA International Energy Agency
na (data) not available
R&D Research and Development
SPF Seasonal Performance Factor
WG Working Group

1.3 Glossary

Autoproducers generate electricity and/or heat wholly or partly for their own use as an activity which supports their primary activity. An example is a thermal spa using geothermal water from their own well, while also selling a smaller amount to a neighbour (Ketilsson et al., 2015).

Capacity factor: Indication of the amount of use over a given period of time, usually a year. For power generation, the capacity factor is the ratio of the actual output of a power plant to its output if operated at full nameplate capacity over a given time. A capacity factor of 1 would indicate a year-round use, and 0.5 would indicate a use of 4,380 full-load hours per year (Lund et al., 2005).

Coefficient of Performance (COP)/Seasonal Performance Factor (SPF): The COP describes the efficiency of ground source heat pumps. It is the ratio of the output energy divided by the input energy (electricity) and usually varies from 3 to 6 (Curtis et al., 2005). In Europe, this is frequently referred to as the SPF, which is the average COP over the heating and cooling season and takes into account system properties.

Geothermal energy: Thermal energy which is contained within the Earth. Geothermal energy derives from residual heat from the original formation of the Earth and from decay of naturally occurring radioactive isotopes. Heat from radioactive decay is estimated to contribute about half of Earth's total heat flux in newer studies (KamLAND Collaboration, 2011).

Geothermal power plants:

Dry steam plants use hot steam piped directly from a geothermal reservoir to drive turbines which spin a generator to produce electric power.

Flash steam plants are the most common form of geothermal plants. High-pressure hot water is converted to steam to drive turbines. The cooled steam condenses to water which is injected back into the ground to avoid a depletion of the reservoir.

Binary cycle power plants transfer heat from geothermal hot water to a working fluid with a lower boiling point in a second cycle. The working fluid is vaporized by passing the geothermal fluid through a heat exchanger. The vapour is used to drive a turbine to produce power and then condensed and reused in a closed cycle. Organic Rankine Cycle (ORC) plants use organic working fluids, Kalina Cycle plants a mixture of water and ammonia.

High/Medium/Low enthalpy geothermal reservoir: The enthalpy of a reservoir is used to express the thermal energy content of a system and is the most common criterion to classify geothermal resources (Dickson & Fanelli, 2004). A standard terminology to define low, intermediate or high enthalpy geothermal systems does not exist. The IPCC geothermal report 2008 (Fridleifsson et al., 2008) specifies a reservoir fluid temperature of 180 °C as the boundary between medium and high enthalpy and may serve as a guide value. The threshold for low/medium enthalpy is frequently given at 100 °C.

Installed capacity: Nameplate energy output of a power or heating plant.

Main activity producers generate electricity and/or heat for sale to third parties as their primary activity. This includes both public and private utilities as well as power plants (Ketilsson et al., 2015).

Operating/Running capacity: Actual capacity of a power or heating plant.

Thermal waters/Brines: Naturally occurring waters with temperatures above 20 °C.

Figure 2: The Champagne Pool at Wai-O-Tapu, New Zealand.

1.4 Geothermal applications data: an overview

Geothermal energy can be used for a wide range of applications from standard 12 kW_t heat pump systems in residential buildings up to geothermal power plants with electric capacities of 100 MW_e and more. The application depends mainly on the system's heat content (enthalpy) and on the designated use of the geothermal source. For geothermal power generation usually a minimum fluid temperature of 100 °C is required.

With signing of the IEA Geothermal Implementing Agreement, the current 16 members (13 countries, the European Commission, and two industry organisations/companies) have declared their intention to promote the sustainable utilisation of geothermal energy worldwide. Accounting for 50% of the world's geothermal power generation and 30% of the geothermal heat produced worldwide, IEA Geothermal member countries contribute a considerable share of the global energy use. Figure 3 gives an overview of the geothermal capacities and energy produced in member countries in 2017.

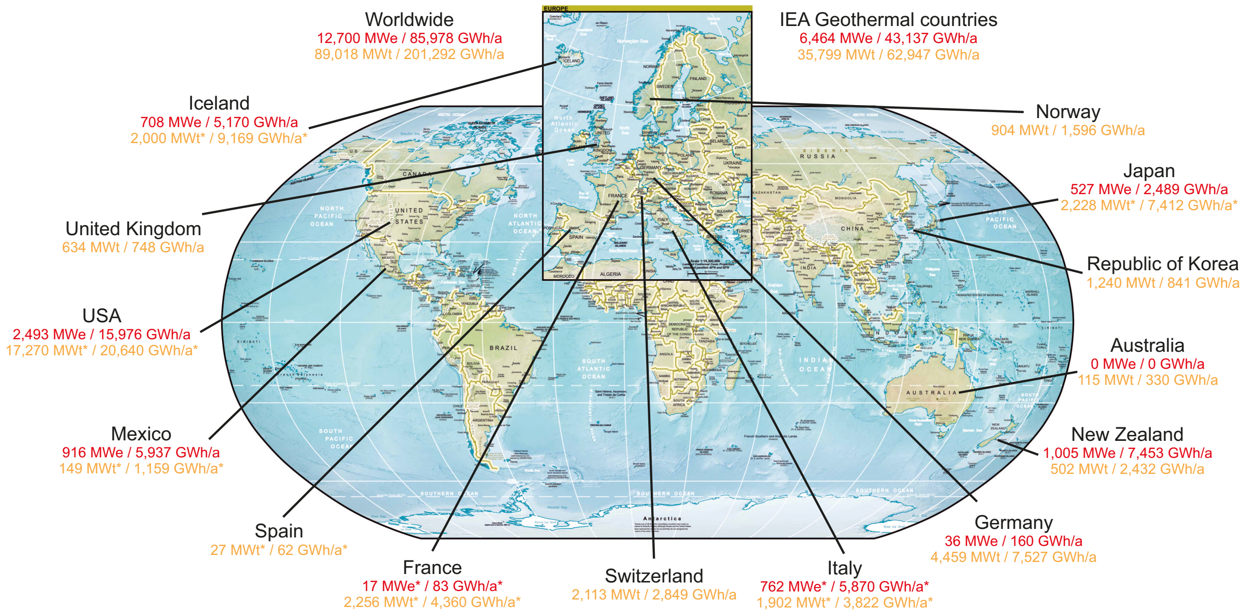

Figure 3: Overview of geothermal power (red) and heat (orange) utilisation in member countries and worldwide 2017. *Heat related data includes direct uses as well as geothermal heat pump use. Country data: WG 10 country reports 2017, electric capacities are running capacities; world data for power: IRENA (2019), electric capacities are net installed capacities; world data for heat: estimated assuming a compound annual growth rate of 7.9% for capacity and 6.9% for heat use. *includes data from previous years. Maps: The World Factbook 2013, CIA (www.cia.gov).*

Figure 4: 140 MW_e Nga Awa Purua triple flash power station near Taupo, New Zealand.

2 GEOTHERMAL POWER GENERATION

2.1 Introduction

The designed output of a power plant is indicated by its **installed** capacity which is usually denoted in megawatts [MW] and sometimes in kilowatts [kW]. Sometimes however, these installed capacity values do not represent the capacity that is available for energy production. For example, this may be due to a temporary shutdown of part of the facilities for longer term refurbishment or because of declining temperatures or flow rates in the geothermal fluid supply at which point the operator will usually advise the grid of the operational capacity that the grid can rely on.

Therefore, the IEA Geothermal has decided to collect and publish data on the **operating/running** capacity rather than on installed capacity in order to reflect the actual situation. This has the advantage that the average capacity factor for a country is not distorted by facilities that are out of service and not running. The capacity factor is the ratio of the actual output of a power plant to its potential output if operated at full nameplate capacity over a given period of time.

In 2017, eight of the member countries produced geothermal electricity (nine in 2016). With an existing net summer capacity of 2,492.6 MW_e used as **running** capacity for the USA, the USA contributed the largest share in the member countries, followed by New Zealand, Mexico, Italy, Iceland, and Japan (Table 3, Fig. 5).

New plants and changes in 2016 & 2017 were reported from Germany, Iceland, Japan, Mexico and the United States. In Iceland for example, the Þeistareykir power plant started operations on November 17, 2017. The plant is located in northeast Iceland and exploration and preparation has been ongoing in the area since 1999. The first phase consists of a 45 MW_e Fuji turbine, and a second phase will be added in 2018, for a total of 90 MW_e. The plant is owned and operated by Landsvirkjun, the National Power company of Iceland.

The total **running** capacity in the reporting countries slightly decreased to 6,400.5 MW_e in 2016 but increased again in 2017 to 6,463.7 MW_e.

Geothermal power generation amounted to 43,137.3 GWh in 2017 (43,195.2 GWh in 2016), with the USA being the biggest producer. In 2017, geothermal power worldwide reached a **net installed** capacity of 12,700 MW_e and an electricity production of 85,978 GWh (IRENA, 2019; Tables 3, 6 & 7, Fig. 6 & 7). About 50% of the geothermal power generation in the world is thus attributed to IEA Geothermal countries.

Based on the **net installed** capacity and electricity production reported by IRENA (2019) an average worldwide **capacity factor** of 0.77 was calculated for 2016 & 2017 (Table 3). The same value was calculated for all IEA Geothermal member countries on the basis of **running** capacities (Table 3).

Table 3: Geothermal power generation in member countries and worldwide in 2016 & 2017. *Country data: WG 10 country reports 2016 & 2017; #existing net summer capacity (EIA, 2017); world data: net installed capacity from IRENA (2019); *data from previous year*

Country	Running capacity (2016 / 2017) [MW_e]	Energy produced (2016 / 2017) [GWh/a]	Capacity factor (2016 / 17)
AUS	0.1 / 0.0	0.3 / 0.0	0.29/-
DEU	38.2 / 36.2	174.5 / 159.8	0.52 / 0.50
FRA	16.5* / 16.5*	83.0* /83.0*	0.57 / 0.57
ISL	662.4 / 707.6	5,067.3 / 5,169.6	0.87 / 0.83
ITA	762.0 / 762.0*	5,870.0 / 5870.0*	0.88 / 0.88
JPN	521.7 / 527.4	2,589.6 / 2,488.6	0.57 / 0.54
MEX	891.1 / 916.4	6,150.7 / 5,937.3	0.79 / 0.74
NZL	997.8 / 1005.0	7,434.0 / 7,453.0	0.85 / 0.85
USA	2,511.5# / 2492.6#	15,825.8 / 15,976.0	0.72 / 0.73
Total	**6,400.5 / 6,463.7**	**43,195.2 / 43,137.3**	**0.77 / 0.76**
World	**12,251 / 12,700**	**83,113 / 85,978**	**0.77 / 0.77**

A capacity factor of 1 indicates year-round use, or 8,760 full load hours. Among the member countries, capacity factors ranged from 0.29 in Australia (2,540 full load hours on average) to 0.88 in Italy (7,709 full load hours).

Reasons for low capacity factors are short-term downtimes due to maintenance, repair work, legal reasons.

Statistics of the International Energy Agency (IEA) include a breakdown of geothermal capacity and gross energy production according to **main activity producers** and **autoproducers** (see Chapter 1.3 for details) subdivided into pure power plants and combined heat and power plants (CHP).

This report provides a breakdown of running capacity and gross energy production in order to make statistics more comparable and comprehensible between different organisations (Tables 4 & 5).

Table 4: Breakdown of running capacity in member countries in 2017 by main activity producers and autoproducers. *Data: WG 10 country reports 2017. *data from previous year*

	Running capacity [MW_e]			
	Main activity producers		Autoproducers	
Country	Power	CHP	Power	CHP
AUS	0.0	0.0	0.0	0.0
DEU	17.2	19.0		
FRA	16.5*			
ISL	105.0	602.6		
ITA	762.0*			
JPN	514.9		12.5	
MEX	898.9		17.5	
NZL	1,005.0			
USA	2,492.6			
Total	**5,812.1**	**621.6**	**30.0**	**0.0**

The majority of running capacity and gross power production is provided by geothermal power plants operated by main activity producers which sell electricity to third parties. Iceland and Germany reported power supply by combined heat and power plants. Only in Japan and Mexico geothermal power is produced for own use by autoproducers.

Table 5: Breakdown of gross power production in member countries in 2017 by main activity producers and autoproducers. *Data: WG 10 country reports 2017. *data from previous year*

	Gross power production [GWh]			
	Main activity producers		Autoproducers	
Country	Power	CHP	Power	CHP
AUS	0.0	0.0	0.0	0.0
DEU	83.7	76.1		
FRA	83.0*			
ISL	558.6	4,611.0		
ITA	5,870.0*			
JPN	2,425.8		62.8	
MEX	5,784.0		153.3	
NZL	7,453.0			
USA	15,976.0			
Total	**38,234.1**	**4,687.1**	**216.1**	**0.0**

2.2 Trends 2000 - 2017: installed (2000 - 2009) and running (2010 - 2017) capacity

As already mentioned, the IEA Geothermal has decided to report on running capacity for which data is only available since the reporting year 2010. Therefore, table 6 is divided into columns for installed capacity for the years 2000 to 2009 and for running capacity from 2010 on.

From 2000 to 2017, the capacity for geothermal power generation worldwide grew from 7,974 MW_e to 12,700 MW_e (Huttrer, 2001; Bertani, 2005; IRENA, 2019).

In the same period, the capacity in IEA Geothermal member countries increased from 4,926 MW_e in 2000 (installed capacity) to 6,464 MW_e in 2017 (running capacity), contributing 51% to the geothermal electric capacity worldwide (Table 6, Fig. 6).

The United States accounted for the largest proportion of electric capacity in member countries with a net summer capacity of 2,493 MW_e in 2017. Significant growth from installed capacity in 2000 to running capacity in 2015 was reported from New Zealand with 568 MW_e and Iceland with 538 MW_e newly installed capacity (Table 6, Fig. 5).

In 2017, the total running capacity of member countries showed an increase of 479.5 MW_e compared to 2010. Significant growth in the same period was reported by New Zealand (+247.0 MW_e), Iceland (+132.6 MW_e), the United States (+88.0 MW_e), Italy (+33.9 MW_e), and Germany (+29.8 MW_e). However, from 2010 to 2017 running capacity decreased by 41.6 MW_e in Mexico and by 10.3 MW_e in Japan.

Table 6: Installed (2000-2009) and running (2010-2017) electric capacities in member countries and worldwide. *Years 2001 - 2004 and 2006 have been hidden for lack of space. For details see previous Trend Reports. Country data: WG 10 country reports (for 2010-2017), GIA Annual Reports (for 2003-2009) and Huttrer (for 2000). World data: 2000: Huttrer (2001), 2005: Bertani (2005), 2010-2017 (net installed capacity): IRENA (2019). * data from previous year;*

	Installed capacity [MW_e]					Running capacity [MW_e]							
Country	**2000**	**2005**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**
AUS	0.2	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.0
DEU	0.0	0.2	3.2	3.2	7.1	6.4	6.4	11.1	30.1	32.2	31.9	37.4	36.2
FRA	4.2	15.0	15.0	17.2	17.2	16.3	15.4	15.4	10.3	16.1	16.5	16.5*	16.5*
ISL	170.0	202.0	485.0	575.0	575.0	575.0	665.0	665.0	663.0	661.0	663.0	662.4	707.6
ITA	785.0	791.0	810.0	810.5	842.5	728.1	728.0	766.0	767.0	807.0	807.0*	762.0	762.0*
JPN	547.0	535.3	535.3	535.3	535.3	537.7	540.1	540.1	515.1	515.2	513.7	521.7	527.4
MEX	755.0	953.0	958.0	958.0	958.0	958.0	883.0	805.0	839.0	840.2	883.4	891.1	916.4
NZL	437.0	435.0	452.0	632.0	632.0	758.0	758.0	758.0	1,008.0	1,009.8	1,001.0	997.8	1,005.0
USA	2,228.0	2,534.0	2,936.5	3,040.0	3,168.0	2,404.6	2,409.2	2,592.1	2,607.0	2,514.3	2,541.5	2,511.5	2,492.6
Total GIA	**4,926.4**	**5,465.7**	**6,195.1**	**6,571.3**	**6,735.2**	**5,984.2**	**6,005.2**	**6,152.8**	**6,439.6**	**6,395.9**	**6,458.1**	**6,400.5**	**6,463.7**
World	**7,974.0**	**8,903.0**	na	na	na	**9,993**	**10,083**	**10,477**	**10,716**	**11,154**	**11,811**	**12,251**	**12,700**

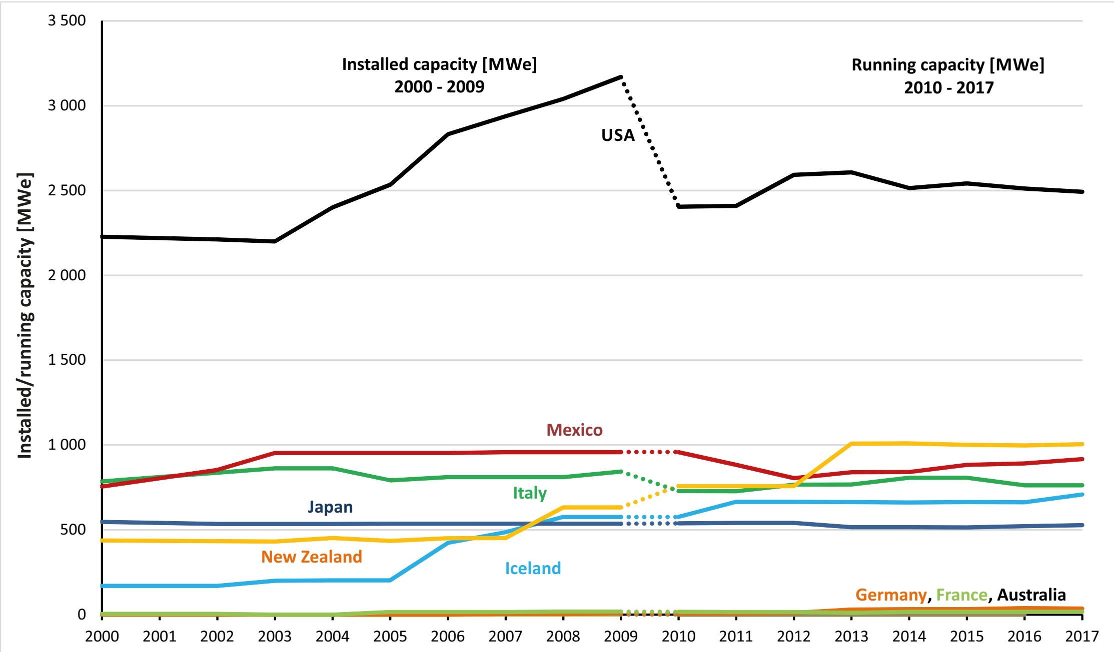

Figure 5: Installed and running capacities [MW_e] in member countries 2000 - 2015. *Data: WG 10 country reports (for 2010-2015), GIA Annual Reports (for 2003-2009) and Huttrer (for 2000).*

In 2017, the Philippines with an installed capacity of 1,916 MW_e and Indonesia (1,809 MW_e) were the main players in the geothermal market among the non-member countries, but also Turkey, Kenya, Costa Rica and El Salvador contributed a considerable amount to the worldwide installed capacity (1,064 MW_e, 673 MW_e, 207 MW_e, and 204 MW_e, respectively; IRENA, 2019). These six countries together with the IEA Geothermal member countries provided about 97% of the worldwide electric capacity.

This shows that a rather small number of countries contribute significantly to the world's geothermal power market.

A forecast of the development of running capacity in the member countries until 2020 was made on the basis of information made available in the WG 10 country reports and is shown in figure 6. According to this, running capacity is estimated to increase by about 750 MW_e and reach about 7,200 MW_e in 2020.

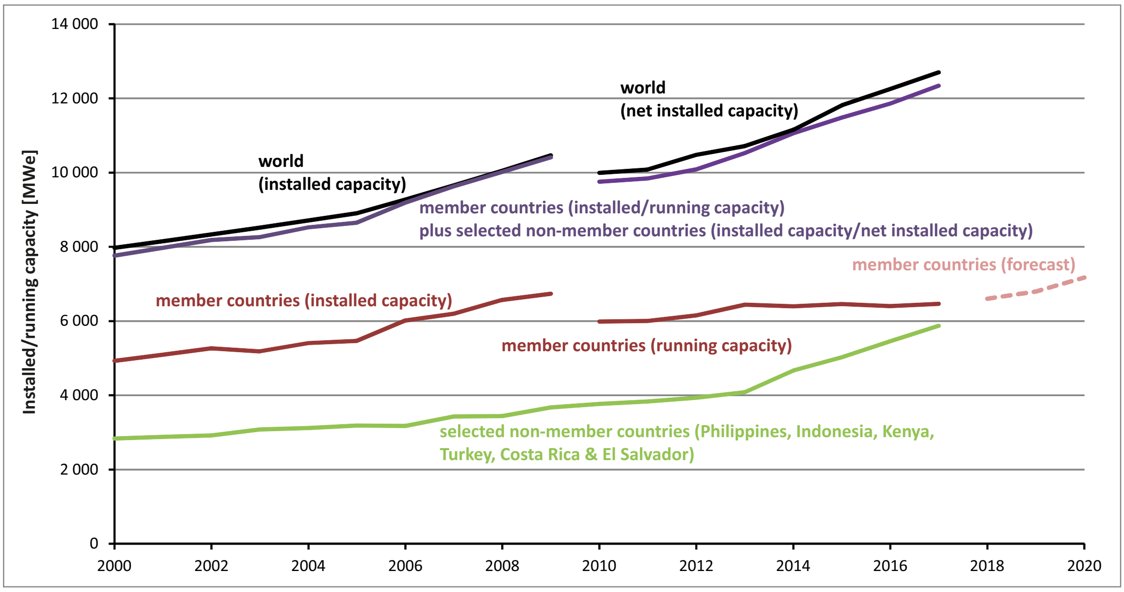

Figure 6: Installed and running capacities [MW$_e$] in member countries, selected non-member countries and worldwide 2000 - 2017, and forecast of the development of running capacities in member countries until 2020. *IEA Geothermal country data: WG 10 country reports (for 2010-2020), IEA Geothermal Annual Reports (for 2003-2009) and Huttrer (for 2000). World and selected non-member countries data: Huttrer (2001), Bertani (2005), IRENA (2019).*

2.3 Trends 2000 - 2017: electricity production

From 2000 to 2017, the electricity produced by geothermal power plants worldwide increased from 49,261 GWh in 2000 to 85,978 GWh in 2017 (Huttrer, 2001; Bertani, 2005; IRENA, 2019). Geothermal power generation in the IEA Geothermal member countries grew from 31,635.5 GWh in 2000 to 43,137.3 GWh in 2017 with a net increase of 2,958.9 GWh since 2010 (Table 7, Fig. 7).

In 2017, geothermal electricity produced in eigth member countries made up about 50% of the world's total geothermal power generation (Fig. 7). Significant growth compared to 2010 was reported from New Zealand (+1,903 GWh), the United States (+757 GWh), Iceland (+705 GWh), and Italy (+494 GWh). In contrast, geothermal electricity production decreased in Japan (-419 GWh) and Mexico (-681 GWh) in the same period (Fig. 8).

Table 7: Geothermal electricity [GWh/a] produced in member countries and worldwide 2000 - 2017. *Years 2001 - 2004 and 2006 have been hidden for lack of space. For details see previous Trend Reports. Country data: WG 10 country reports (for 2010-2017), IEA Geothermal Annual Reports (for 2003-2009) and Huttrer (for 2000). World data: 2000: Huttrer (2001), 2005: Bertani (2005), 2010-2017: IRENA (2019). * data from previous year*

	Geothermal electricity produced [GWh/a]												
Country	**2000**	**2005**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**
AUS	0.9	0.5	0.5	0.8	0.6	0.0	0.6	0.5	0.5	0.6	0.3	0.3	0.0
DEU	0.0	0.2	0.4	18.0	19.0	27.5	18.7	25.4	54.3	80.0	133.6	174.5	159.8
FRA	24.6	102.0	95.0	90.0	89.0	14.9	56.6	50.6	80.6	79.0	83.0	83.0*	83.0*
ISL	1,138.0	1,483.0	3,600.0	4,000.0	4,553.0	4,465.0	4,701.0	5,210.0	5,245.0	5,238.0	5,003.0	5,067.3	5,169.6
ITA	4,403.0	5,340.0	5,233.0	5,181.0	5,200.0	5,376.0	5,315.0	5,235.0	5,659.0	5,916.0	5,916.0*	5,870.0	5,870.0*
JPN	3,532.0	3,467.0	3,102.0	3,064.0	2,765.0	2,908.0	2,652.2	2,688.8	2,620.4	2,604.7	2,587.3	2,589.6	2,488.6
MEX	5,681.0	6,282.0	7,393.0	7,056.0	6,740.0	6,618.0	6,524.0	5,817.0	6,070.0	6,000.0	6,331.0	6,150.7	5,937.3
NZL	2,756.0	2,981.0	3,354.0	3,966.0	4,589.0	5,550.0	5,774.0	5,843.0	6,053.0	6,847.0	7,410.0	7,434.0	7,453.0
USA	14,100.0	14,692.0	14,637.0	14,840.0	15,009.0	15,219.0	15,316.0	15,562.0	15,775.0	15,877.0	15,918.0	15,825.8	15,976.0
Total GIA	**31,635.5**	**34,347.7**	**37,414.9**	**38,215.8**	**38,964.6**	**40,178.4**	**40,358.1**	**40,432.3**	**41,557.8**	**42,624.3**	**43,382.2**	**43,195.2**	**43,137.3**
World	**49,261**	**55,709**	na	na	na	**68,454**	**69,744**	**70,716**	**72,132**	**77,155**	**81,048**	**83,113**	**85,978**

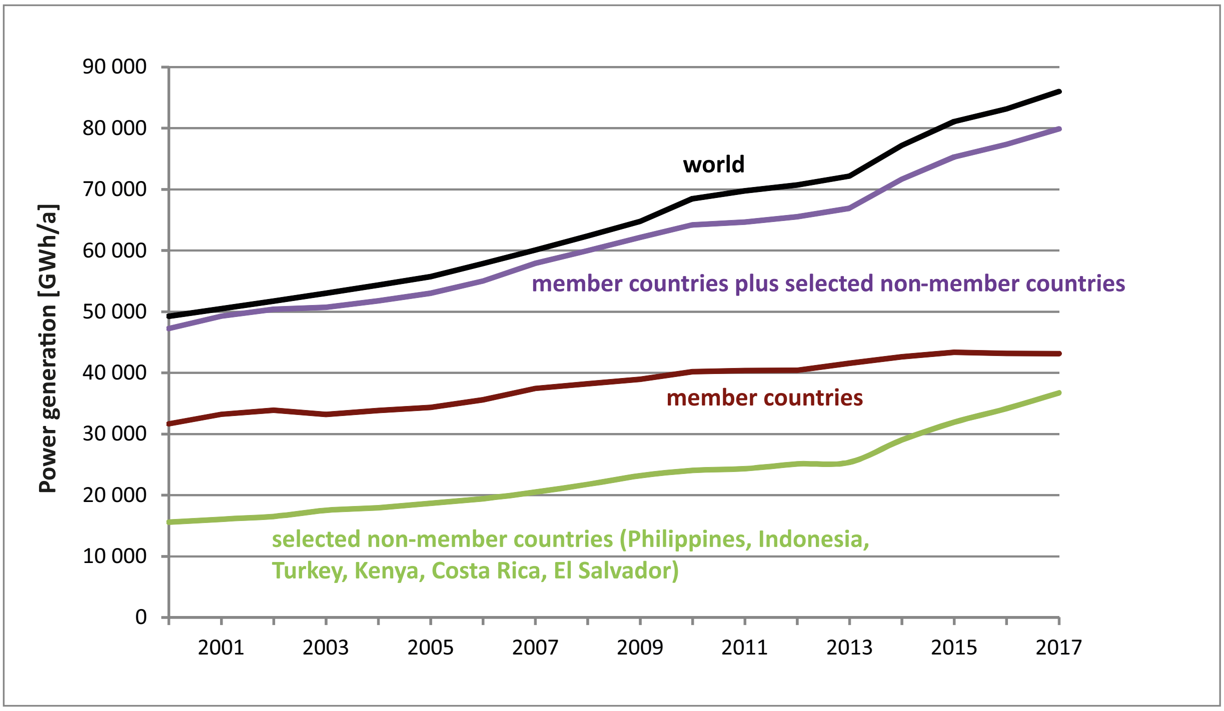

Figure 7: Geothermal power generation [GWh/a] in member countries, selected non-member countries and worldwide 2000 - 2017. *IEA Geothermal country data: WG 10 country reports (for 2010-2020), IEA Geothermal Annual Reports (for 2003-2009) and Huttrer (for 2000). World and selected non-member countries data: Huttrer (2001), Bertani (2005), IRENA (2019).*

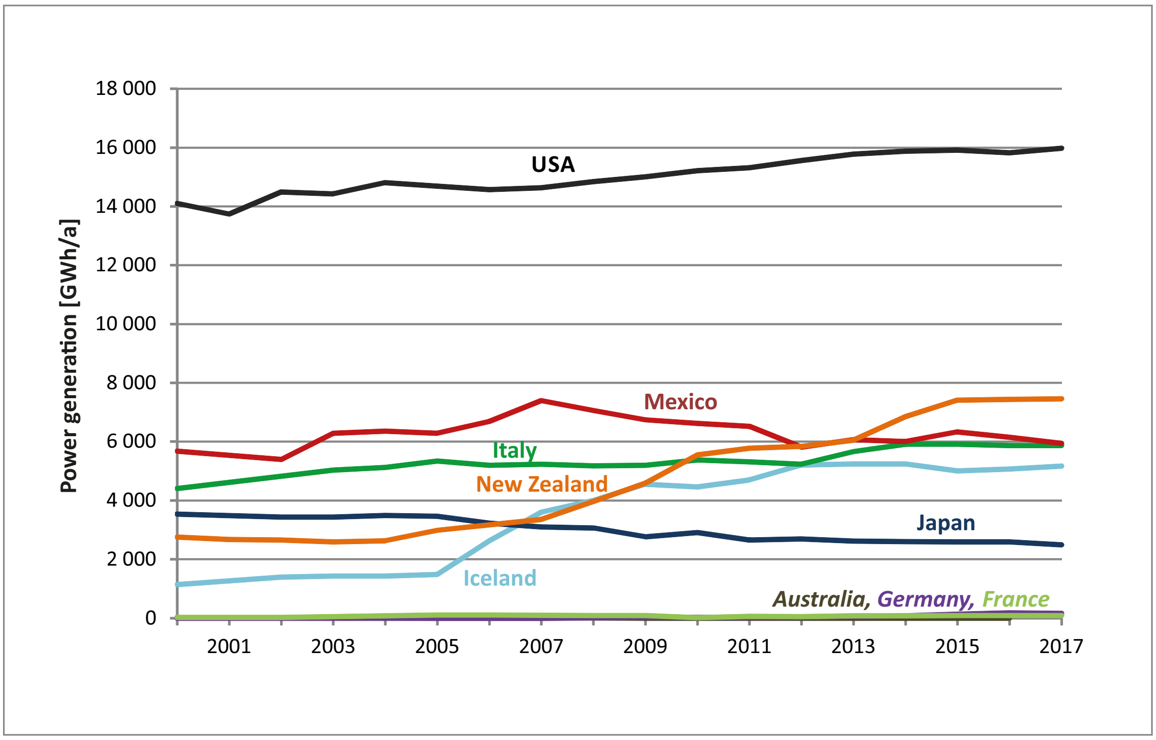

Figure 8: Geothermal power generation [GWh/a] in member countries 2000 - 2017. *Data: WG 10 country reports (for 2010-2017), IEA Geothermal Annual Reports (for 2003-2009) as well as Huttrer (for 2000).*

3 DIRECT USE OF GEOTHERMAL HEAT

3.1 Introduction

Direct use of geothermal energy is not only one of the oldest but also the most common form of utilisation. Thermal waters suitable for direct use applications usually originate from deep geothermal aquifers. Required water temperature may be reached near the Earth's surface due to a high geothermal gradient in high enthalpy fields. Separated waste water from geothermal power plants can also be used for heating or other purposes.

Common direct use applications are district or space heating, bathing, and the heating of greenhouses. In some regions, geothermal heat is used for snow melting, aquaculture/fish farming or industrial applications. In the Larderello geothermal field in Italy, waste heat from the San Martino power plant is used as cheap and eco-friendly process heat in a nearby dairy for cheese production.

The most widespread application of geothermal heat are geothermal heat pumps. They contribute the major part of geothermal heat use in the world (Lund & Boyd, 2016). As they use auxiliary energy to raise the fluid's energy level, they do not actually use geothermal heat in a "direct" way, though they are often summarised with other direct use applications.

In this report, we distinguish between centralised installations which directly use geothermal heat in a more exact sense, such as greenhouses, district heating and thermal spas, and geothermal heat pumps.

3.2 Centralised installations for direct heat uses

In 2017, direct use of geothermal heat by centralised installations in member countries accounted for an installed capacity of 7,545.7 MW_t, a net increase of 62.5 MW_t compared to 2015 (Table 8).

Table 8: Direct use capacity [MW_t] of geothermal heat in member countries in different IEA categories and IEA Geothermal subcategories (other than heat pumps) 2010, 2015 - 2017. *Data: WG 10 country reports 2010 - 2017 (#row total; *no update: older data from previous years; [1]Conti et al., 2016).*

	Installed capacity of direct use categories 2017 and country total 2010, 2015 - 2017 (other than heat pumps) [MW_t]														
Category (IEA)	**Sub-category (IEA Geothermal)**	**AUS**	**CHE**	**DEU**	**ESP**	**FRA**	**GBR**	**ISL**	**ITA**	**JPN**	**KOR**	**MEX**	**NOR**	**NZL**	**USA**	**Total/ category**
Residential				**3.3**	**3.5***						**2.2**			**2.0**	**25.3***	**36.3**
	Space heating			3.3	3.5*						2.2			2.0	25.3*	36.3
Commercial and public		**54.6**	**24.7**	**370.3**	**2.6***		**3.0**			**1,906.8***	**41.3**	**148.7**		**120.0**	**226.8***	**2,898.6**
	Space heating		1.5	313.5			2.0			71.1*	8.7	0.5		62.0	128.5*	587.7
	Bathing/ Swim. (mon.)	54.6	23.2	56.8	2.6*		1.0			1,685.5*	32.6			58.0	75.5*	1,989.8
	Bathing/Swim. (unmon.)											148.2			21.0*	169.2
	Snow melting									150.2*					1.8*	152.0
Agriculture/ Forestry					**14.9***					**41.4***	**0.2**			**24.0**	**98.3***	**178.8**
	Green-houses				14.9*					35.4*	0.2			24.0	91.8*	166.3
	Crop drying									6.0*					6.5*	12.5
	Other															
Industry	Industry	**3.8**								**1.4***				**284.0**	**0.2***	**289.4**
Fisheries		**2.4**								**7.6***				**17.0**	**119.3***	**146.3**
	Aquaculture	2.4								7.6*				17.0	119.3*	146.3
Other	Other									**136.3***				**33.0**		**169.3**
	Total/country 2017	**60.8**	**24.7**	**373.6**	**21.0***	**456.0***	**3.0**	**2,000.0**	**1,371.0***	**2,093.5***	**43.6**	**148.6**	**0.0**	**480.0**	**469.9***	**7,545.7#**
	Total/country 2016	13.7	24.7	377.1	21.0*	456.0*	3.0	2,000.0	1,371.0[1]	2,093.5*	43.6	148.6	0.0	480.0	469.9	7,502.1#
	Total/country 2015	13.1	27.1	336.6	21.0*	456.0	3.0	2,609.0	787.0*	2,093.5	43.7	155.8*	0.0	480.0	448.6	7,483.2#
	Total/country 2010	106.0	39.0	163.2	22.3	345.0	na	na	500.0	2,086.2	43.6	156.0	0.0	371.6	563.8	4,396.7#

In 2017, most of the reported values for installed capacity were similar to year 2016. This is mainly due to poor data bases on direct heat use in the reporting countries. Only a few countries like Germany and Switzerland have annual statistics on heat utilisation, most other member countries provided annual estimates.

In 2017, geothermal direct heat uses (other than heat pumps) in the member countries amounted to 28,412.2 GWh, a net increase of 2,239.7 GWh compared to 2015 (Table 9). Iceland has the largest share of this increase with 1,479.1 GWh.

If values for installed capacity were stated but values for the produced heat were not provided, annual heat use was calculated using capacity factors for the various categories of use given in Lund & Boyd (2016) by the following equation (Pester et al., 2007):

$$E = \frac{P \cdot 8760 \cdot capacity\ factor}{1000}$$

where E = annual production in GWh, P = installed capacity in MW_t, and 8760 hours = 1 year

In addition to IEA Geothermal subcategories, tables 8 & 9 include IEA categories to enhance the comparability of geothermal energy statistics between different organisations.

In 2017, the application of thermal waters for spas and for swimming was the most common geothermal utilisation with 9,920.7 GWh (monitored and unmonitored=estimated). The main share was attributed to the widespread use of thermal springs in Japan which amounted to 5,758.7 GWh.

Iceland (9,169.0 GWh) and Japan (7,249.6 GWh) were the largest producers of geothermal direct heat among member countries in 2017, followed by Italy (2,916.0 GWh), New Zealand (2,397.0 GWh), and the USA (2,120.3 GWh; Table 9).

Table 9: Direct use [GWh] of geothermal heat in member countries in different IEA categories and IEA Geothermal subcategories (other than heat pumps) 2010, 2015 - 2017. *Data: WG 10 country reports 2010 - 2017 ([#]row total, *no update: older data from previous years; [c]calculated; [1]Conti et al., 2016).*

		Direct use in different categories 2017 and country total 2010, 2015 - 2017 (other than heat pumps) [GWh/a]														
Category (IEA)	**Sub-category (IEA-GIA)**	**AUS**	**CHE**	**DEU**	**ESP**	**FRA**	**GBR**	**ISL**	**ITA**	**JPN**	**KOR**	**MEX**	**NOR**	**NZL**	**USA**	**Total/ category**
Residential				**9.6**	**21.2***			**3,528.0***			**8.7**			**2.0**	**66.0***	**3,635.5**
	Space heating			9.6	21.2*			3,528.0*			8.7			2.0	66.0*	3,635.5
Commercial and public		**248.7[c]**	**197.6**	**1,367.2**	**14.6***		**14.8**	**4,622.0***		**6,184.1***	**155.8**	**1,158.6***		**542.0**	**960.6***	**15,466.0**
	Space heating		4.8	892.6			9.3	3,139.0*		305.4*	14.8	1.2*		160.0	327.6*	4,854.7
	Bathing/Swim. (mon.)	248.7[c]	192.8	474.6	14.6*		5.5	917.0*		5,758.7*	141.0			382.0	488.4*	8,623.3
	Bathing/Swim. (unmon.)											1,157.4*			140.0*	1,297.4
	Snow melting							566.0*		120.0*					4.6*	690.6
Agriculture/ Forestry					**26.2***			**139.0***		**125.0***	**0.4**			**122.0**	**242.7***	**655.2**
	Green-houses				26.2*			139.0*		103.7*	0.4			101.0	215.6*	585.8
	Crop drying									21.3*					27.1*	48.4
	Other													21.0		21.0
Industry	Industry	**23.1[c]**						**287.0***		**8.5***				**1,400.0**	**0.5***	**1,719.1**
Fisheries		**11.8[c]**	**2.0**					**593.0***		**34.2***				**55.0**	**850.5***	**1,546.5**
	Aquaculture	11.8[c]	2.0					593.0*		34.2*				55.0	850.5*	1,546.5
Other	Other									**898.0***				**276.0**		**1,174.0**
	Total/country 2017	**283.6[c]**	**199.6**	**1,376.8**	**62.0***	**1,300.0***	**14.8**	**9,169.0***	**2,916.0***	**7,249.6***	**164.9**	**1,158.6***	**0.0**	**2,397.0**	**2,120.3***	**28,412.2[#]**
	Total/country 2016	62.8	200.2	1,352.9	62.0*	1,300.0*	14.8	9,169.0	2,916.0*	7,249.6*	164.9	1,158.7*	0.0	2,397.0	2,120.3	28,168.1[#]
	Total/country 2015	60.1	215.9	1,115.6	62.0*	1,300.0	14.8	7,689.9	2,916.0[1]	7,249.6	164.9	1,158.7*	0.0	2,396.4	1,828.6	26,172.5[#]
	Total/country 2010	354.0	272.3	716.2	51.0	1,508.4	na	6,833.0	3,027.7	7,120.0	164.9	710.6	0.0	2,810.0	2,287.0	25,855.1[#]

As already mentioned in the chapter on geothermal power, statistics of the International Energy Agency (IEA) include a breakdown of geothermal capacity and gross energy production according to **main activity producers** and **autoproducers** (see Chapter 1.3 for details) subdivided into pure heat plants and combined heat and power plants (CHP).

The breakdown of installed thermal capacity and gross energy production for IEA Geothermal countries is shown in tables 10 & 11. Not all member countries provide information on main activity producers and autoproducers. Therefore, total numbers differ from tables 8 & 9.

Autoproducers which produce heat mainly for their own use play a more important role in the heat market than in the electricity market (cf. Chap. 2.1).

About 48% of installed capacity and 54% of gross heat production is attributed to the autoproducers. The largest proportion of this is contributed by thermal spas in Japan.

The largest share of gross heat production by main activity producers can be found in Iceland, where space and district heating is a widespread form of direct heat use.

Table 10: Breakdown of installed thermal capacity [MW_t] in member countries in 2017 by main activity producers and autoproducers. *Data: WG 10 country reports 2017. *no update: older data from previous years; #low estimate*

	Installed capacity [MW_t]			
	Main activity producers		Autoproducers	
Country	**Heat**	**CHP**	**Heat**	**CHP**
AUS	na	na	na	na
CHE	1.5		23.2	
DEU	177.8	139.0	56.8	
ESP	na	na	na	na
FRA	456.0*			
GBR	2.0		1.0	
ISL	2,000.0*,#			
ITA	na	na	na	na
JPN			2,093.5*	
KOR			43.6	
MEX			148.6*	
NOR				
NZL	301.0		179.0	
USA	89.5*		380.4*	
Total	**3,027.8**	**139.0**	**2,926.1**	

Table 11: Breakdown of gross heat production [GWh] in member countries in 2017 by main activity producers and autoproducers. *Data: WG 10 country reports 2017. *no update: older data from previous years; Iceland has no subdivision into pure heat and CHP plants (values are not included in total sum)*

	Gross heat production [GWh]			
	Main activity producers		Autoproducers	
Country	**Heat**	**CHP**	**Heat**	**CHP**
AUS	na	na	na	na
CHE	4.8		194.8	
DEU	656.7	246.2	474.6	
ESP	na	na	na	na
FRA	1,300.0*			
GBR	9.3		5.5	
ISL	8,215.0		954.0	
ITA	na	na	na	na
JPN			7,249.6*	
KOR			164.9	
MEX			1,158.6*	
NOR				
NZL	1,455.0		942.0	
USA	199.1*		1,921.2*	
Total	**3,624.9**	**246.2**	**12,111.2**	

3.3 Geothermal heat pumps (GHP)

Residental space heating using ground source heat pumps (GSHP) or geothermal heat pumps (GHP) is the most common application of geothermal energy. According to Lund & Boyd (2016), geothermal heat pumps accounted for 70.9% of the total installed capacity and 55.2% of total geothermal energy use in 2014.

Geothermal heat pumps use near-surface heat as a renewable heat source. Common systems are horizontal heat collectors, borehole heat exchangers (brine/water systems, Fig. 9), and groundwater systems with extraction and injection well(s) (water/water systems). Typical capacities of geothermal heat pumps for residential requirements range from about 10 to 14 kW_t (GZB, 2010). For heating and cooling of larger buildings, such as offices, commercial buildings and schools, ground source heat pump systems using borehole heat exchangers (BHE), ground water wells, or energy piles are becoming increasingly popular. Systems for heating and cooling of larger buildings often have installed capacities of several 100 kW_t.

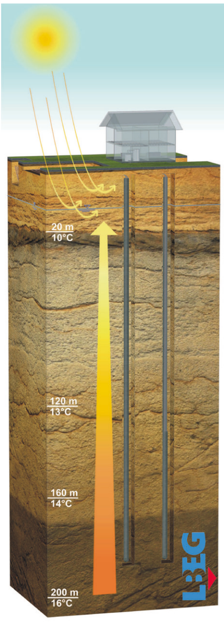

Figure 9: Principle of GSHP systems using borehole heat exchangers. *The yellow arrow shows the average geothermal gradient. The enthalpy of near-surface systems, indicated by the shallow cavities on the left side, derives mainly from solar radiation. Image: Courtesy of State Authority for Mining, Energy and Geology, Lower Saxony, Germany (LBEG).*

For the Trend Report, we aimed to distinguish between individual use of small heat pumps in private houses and utilisation in commercial and public buildings. Furthermore, we also tried to collect data on geothermal cooling with GHPs. However, in most countries statistics on heat pumps are poor and reliable data were often not available. Therefore, data on small residential systems and larger systems are combined in this report. But this may change in the near future.

GHP numbers

As not all member countries reported current numbers of total and newly installed units for 2017, the 2.158 million units given in table 12 are only a rough approximation of the total number of geothermal heat pumps in operation. In 2017, the majority of heat pumps were operating in the United States with about 1.4 million units, followed by Germany (362,000), France (200,000), and Switzerland (102,536). Numbers on newly installed heat pumps have only been reported by 5 member countries and added up to a total of 29,372. Therefore, the real number should be higher.

Calculation

1. Annual heat use: The annual heat use can be calculated using the installed capacity and the annual full load hours of geothermal heat pumps, which differ due to regional aspects and modes of use. If data for annual heat use were not provided, values were calculated for a given number of heat pumps assuming an average installed capacity of 12 kW_t and a mean runtime of 2,200 full load hours per year; stated average values for common heat pump systems worldwide according to Lund & Boyd (2016).

2. Geothermal contribution: Heat pumps need auxiliary power - usually electricity - to operate. For this report, we outline the geothermal heating contribution of GHP installations (the renewable share of the produced heat). The renewable (geothermal) contribution can be calculated according to Annex VII of the EU Directive 2009/28/EC "Renewable Energy" by the equation:

$$E_{geothermal} = Q_{usable} \cdot \left(1 - \frac{1}{SPF}\right)$$

where $E_{geothermal}$ = geothermal energy in GWh, Q_{usable} = the estimated total usable heat delivered by heat pumps in GWh, and SPF = seasonal performance factor

For the calculation, a mean SPF of 3.5 was used, following various authors (GZB, 2010; Sonnenfroh et al., 2010). The SPF equates to the average coefficient of performance (COP) of the heating and cooling season and takes into account system properties (Curtis et al., 2005).

Heat pump utilisation 2017

In 2017, the total installed capacity (including auxiliary power) of geothermal heat pumps in member countries amounted to 28,252 MW_t, nearly four times the capacity of all other thermal uses (Tables 8 & 12). The geothermal contribution of the annual heat use was 34,533 GWh or 124,319 TJ. In 2017, the worldwide total capacity of GHPs was estimated at 64,530 MW_t with an estimated renewable annual heat use of 121,853 GWh or 438,671 TJ (Table 12). Thus, IEA Geothermal member countries contribute a large share to the worldwide installed capacity (44%) and heat use (28%).

Geothermal cooling with heat pumps is a low-emission form of air conditioning and a very common use of geothermal heat pumps, which can be used for both heating and cooling. Most countries lack reliable statistics on geothermal cooling. Only three countries, Australia, Japan and Korea, provided data on geothermal cooling. The supply of 24.0 GWh of geothermal cooling in Australia indicates that in warm climate zones, cooling is an important option of GHP use. In Korea, geothermal cooling (549.7 GWh in 2017) nearly reaches the value of annual heat use (675.7 GWh). And in Japan, cooling (305.9 GWh) with heat pumps is much more important than heating (162.2 GWh).

Table 12: Geothermal heat pumps in member countries: installed capacity and annual heat use (geothermal contribution) 2015 - 2017. *Country data: WG 10 country reports 2015 - 2017; world data: estimated assuming a compound annual growth rate of 8.7% for capacity and 10.3% for annual heat use. This table only contains data for the heating mode. (*data from previous year; [1]Boissavy et al., 2016; [2]Conti et al., 2016)*

Country	Total number of GHP 2017	Number of new GHP in 2017	Installed capacity (total) [MWt]			Annual heat use (geothermal contribution) [GWh/a]			Annual heat use (geothermal contribution) [TJ/a]		
			2015	2016	2017	2015	2016	2017	2015	2016	2017
AUS	3,790	61	35	38	54	31	35	47	111	125	167
CHE	102,536	2,453	1,926	2,009	2,088	2,320	2,562	2,649	8,353	9,223	9,537
DEU	362,000	22,000	3,794	3,880	4,085	5,514	5,800	6,150	19,850	20,880	22,140
ESP	na	na	6	6*	6*	na	na	na	na	na	na
FRA[1]	200,000*	na	1,800	1,800*	1,800*	3,060	3,060*	3,060*	11,016	11,016*	11,016*
GBR	29,117	2,358	535	598	631	611	680	733	2,199	2,448	2,638
ISL	na	na	na	na	na	na	na	na	na	na	na
ITA[2]	13,200*	na	531*	531*	531*	906*	906*	906*	3,261*	3,261*	3,261*
JPN	2,230*	na	18*	134	134*	29*	162	162*	103*	584	584*
KOR	na	na	946	1,102	1,197	536	624	676	1,928	2,245	2,433
MEX	na	na	na	na	na	na	na	na	na	na	na
NOR	45,000	2,500	na	na	904	na	na	1,596	na	na	5,746
NZL	158	0	12	22	22	25	47	35	89	169	127
USA	1,400,000*	na	16,800*	16,800*	16,800*	18,519*	18,519*	18,519*	66,670*	66,670*	66,670*
Total	**2,158,031**	**29,372**	**26,403**	**26,920**	**28,252**	**31,551**	**32,395**	**34,533**	**113,580**	**116,621**	**124,319**
World	na	na	**54,625**	**59,371**	**64,530**	**100,148**	**110,469**	**121,853**	**360,532**	**397,688**	**438,671**

3.4 Trends in geothermal heat use 2000 - 2017

In 2000, geothermal heat use in the world amounted to 52,972 GWh with an installed capacity of 15,145 MW_t. In 2010, 78 countries reported geothermal heating utilisations with a total installed capacity of 48,493 MW_t and an annual use of 117,731 GWh, and in 2014, 82 countries had 70,885 MW_t in operation with a geothermal heat use of 164,635 GWh (Lund & Boyd, 2016). Estimates for 2017 indicate a worldwide heat use of 201,292 GWh with a capacity of 89,018 MW_t (Table 13).

In the member countries, the installed thermal capacity for all uses (direct use and GHP use) amounted to 8,927 MW_t in 2000 and 35,799 MW_t in 2017 (Table 13). Geothermal heat use increased from 25,894 GWh in 2000 to 62,947 GWh (226,602 TJ) in 2017.

Altogether, the 14 member countries accounted for about 40% of the worldwide thermal capacity and 31% of heat use in 2017.

Figures 10 & 11 show installed capacities and heat use of geothermal energy worldwide (based on data from Lund & Freeston, 2001; Lund et al., 2005 and 2011; Lund & Boyd, 2016; and estimates for 2015-2017) and in IEA Geothermal member countries from 2000 to 2017.

Overall, efforts to show trends for geothermal heat use in member countries are based on miscellaneous data sources. Attempts to collect standardised data within the IEA Geothermal from 2010 on, show that reliable and up-to-date statistical data on geothermal heat use is often not available in the reporting countries. It is the aim of WG 10 and WG 8 (Direct Use of Geothermal Energy) to further improve the data base. This is done in cooperation with other data collecting organisations.

Table 13: Geothermal heat use (direct and GSHP) in member countries 2015 - 2017. *Country data: WG 10 country reports (2015 - 2017); world data: estimated assuming a compound annual growth rate of 7.9% for capacity and 6.9% for heat use. *includes data from previous years.*

	Installed capacity (Direct use and GHP) [MW_t]			Heat use (geothermal contribution) [GWh/a]			Heat use (geothermal contribution) [TJ/a]		
Country	**2015**	**2016**	**2017**	**2015**	**2016**	**2017**	**2015**	**2016**	**2017**
AUS	48	52	115	91	98	330	328	351	1,188
CHE	1,953	2,033	2,113	2,536	2,762	2,849	9,130	9,944	10,255
DEU	4,131	4,257	4,459	6,630	7,153	7,527	23,868	25,750	27,097
ESP	27*	27*	27*	62*	62*	62*	223*	223*	223*
FRA	2,256	2,256*	2,256*	4,360	4,360*	4,360*	15,696	15,696*	15,696*
GBR	538	601	634	626	695	748	2,252	2,501	2,691
ISL	2,609	2,000	2,000*	7,690	9,169	9,169*	27,684	33,008	33,008*
ITA	1,318*	1,902*	1,902*	3,822	3,822*	3,822*	13,759	13,759*	13,759*
JPN	2,112*	2,228*	2,228*	7,279*	7,412*	7,412*	26,204*	26,683*	26,683*
KOR	990	1,146	1,240	700	789	841	2,521	2,839	3,026
MEX	156*	149	149*	1,159*	1,159*	1,159*	4,171	4,171*	4,171*
NOR	na	na	904	na	na	1,596	na	na	5,746
NZL	492	502	502	2,421	2,444	2,432	8,716	8,798	8,756
USA	17,249*	17,270*	17,270*	20,348*	20,640	20,640*	73,251*	74,303	74,303*
Total	**33,879**	**34,423**	**35,799**	**57,724**	**60,565**	**62,947**	**207,803**	**218,026**	**226,602**
World	**76,477**	**82,510**	**89,018**	**176,036**	**188,241**	**201,292**	**633,730**	**677,668**	**724,651**

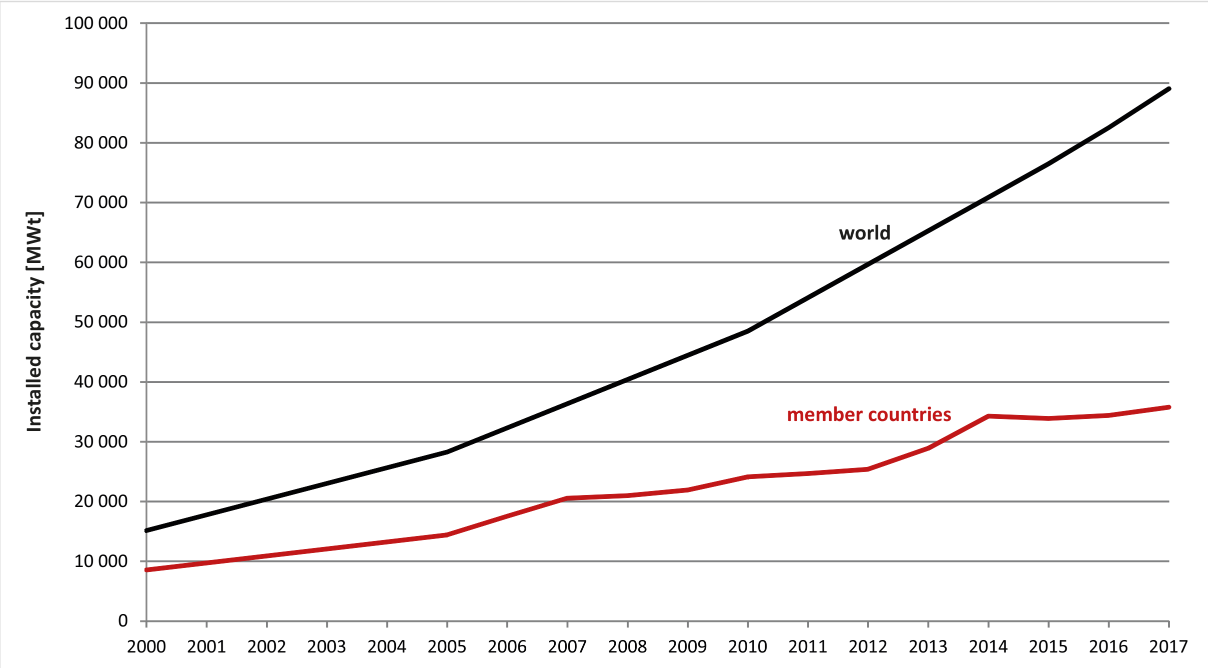

Figure 10: Installed capacity [MW$_t$] of all geothermal heat uses (direct use and GHP use) in member countries and worldwide 2000 - 2017. *Member country data: IEA Geothermal Annual Reports 2007, 2008 and 2009, and WG 10 country reports 2010 to 2017; world data: Lund & Freeston, 2001; Lund et al., 2005 and 2011; and Lund & Boyd, 2016; 2015-2017: estimated assuming a compound annual growth rate of 7.9%.*

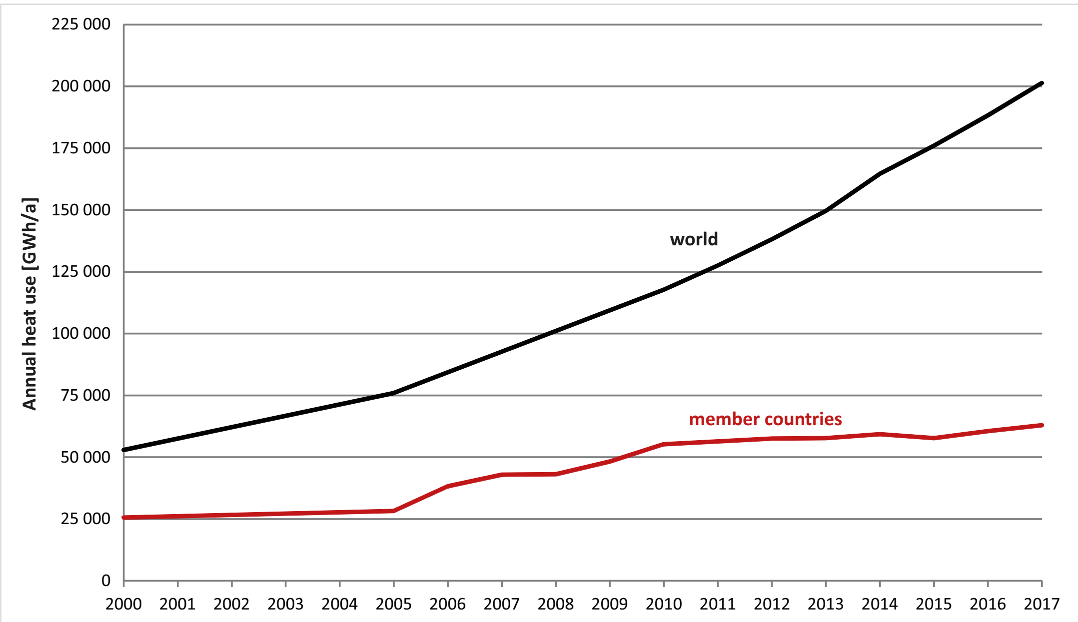

Figure 11: Annual heat use [GWh/a] of all geothermal heat uses (direct use and GHP use) in member countries and worldwide 2000 - 2017. *Member country data: IEA Geothermal Annual Reports 2007, 2008 and 2009, and WG 10 country reports 2010 to 2017; world data: Lund & Freeston, 2001; Lund et al., 2005 and 2011; and Lund & Boyd, 2016; 2015-2017: estimated assuming a compound annual growth rate of 6.9%.*

4 CO_2 AND FOSSIL FUEL SAVINGS

4.1 Fossil fuel savings by geothermal applications

The fuel oil savings factors used to calculate the savings in table 14 are based on the IEA Geothermal conversion (Mongillo, 2005) assuming an efficiency factor of 35% if the competing energy is used to replace electricity, and an efficiency factor of 70% for direct burning to produce heat according to Lund & Boyd (2016). Fossil fuel savings (Table 14) were estimated using the figures for produced geothermal electricity and heat given in the previous chapters.

Geothermal cooling with heat pumps also helps to reduce the use of fossil fuels for applications like air conditioning. A method for calculating fossil fuel savings by using geothermal cooling is currently being developed within IEA Geothermal working group 8.

Table 14: Fossil fuel savings by geothermal energy uses in member countries in 2017. *Calculation based on values for produced electricity and geothermal heat (all uses) given in the WG 10 country reports 2017. (toe = tonnes of oil equivalent)*

Country	Fossil fuel savings for geothermal power generation [toe]	Fossil fuel savings for geothermal heat utilizations [toe]	Fossil fuel savings for geothermal heat & power utilizations [toe]
AUS	0	41,822	41,822
CHE	0	360,930	360,930
DEU	40,493	953,646	994,139
ESP	0	7,855	7,855
FRA	21,032	552,412	573,444
GBR	0	94,721	94,721
ISL	1,309,977	1,161,712	2,471,689
ITA	1,487,458	484,247	1,971,705
JPN	630,611	939,077	1,569,689
KOR	0	106,505	106,505
MEX	1,504,512	146,793	1,651,305
NOR	0	202,213	202,213
NZL	1,888,590	308,172	2,196,763
USA	4,048,318	2,615,056	6,663,374
Total 2017	**10,930,992**	**7,975,161**	**18,906,155**
Total 2016	10,945,671	7,691,483	18,637,154
Total 2015	10,993,049	7,313,631	18,306,680
Total 2010	10,128,251	6,999,436	17,127,687

4.2 CO_2 emission savings

CO_2 savings for geothermal power generation

CO_2 savings in table 15 were calculated using savings factors given by Lund et al. (2005) assuming an efficiency factor of 35% for production of electricity. The savings were calculated by the equation:

$$CO_2\ savings = energy\ produced \cdot savings\ factor$$

By way of comparison, based on CO_2 emissions of different conventional plant types as stated by the German Federal Environment Agency (Klaus et al., 2009), a rather small coal-fired plant with 200 MW_e installed capacity and operating at 6,000 full load hours per year would produce over 1 million tonnes of CO_2 per year, and a gas plant of the same size about 400,000 tonnes of CO_2 per year.

In 2017, total CO_2 savings by geothermal power generation in member countries accounted for 41.1 million tonnes of CO_2 for the replacement of coal, 35.2 million tonnes of CO_2 for oil, and 8.3 million tonnes for the replacement of gas.

Table 15: CO_2 savings for geothermal electricity in member countries. *Calculation based on figures for produced electricity from WG 10 country reports 2017.*

	CO_2 emission savings for geothermal power generation [tonnes of CO_2]		
Country	Gas	Oil	Coal
AUS	0	0	0
CHE	0	0	0
DEU	30,841	130,557	152,289
ESP	0	0	0
FRA	16,019	67,811	79,099
GBR	0	0	0
ISL	997,733	4,223,563	4,926,629
ITA	1,132,910	4,795,790	5,594,110
JPN	480,300	2,033,186	2,371,636
KOR	0	0	0
MEX	1,145,899	4,850,774	5,658,247
NOR	0	0	0
NZL	1,438,429	6,089,101	7,102,709
USA	3,083,368	13,052,392	15,225,128
Total 2017	**8,325,499**	**35,243,174**	**41,109,847**
Total 2016	8,336,679	35,290,503	41,165,054
Total 2015	8,372,765	35,443,257	41,343,237
Total 2010	7,714,098	32,655,018	38,090,859

It has to be noted that these numbers do not take into account the natural emissions of CO_2 through geothermal power plants which operate without a closed circuit and produce steam from high-temperature geothermal fields. On a global average these contribute about 122 g CO_2/kWh (Fridleifsson et al., 2008). For example, geothermal power plant natural CO_2 (equivalent) emissions in New Zealand amounted to 874,000 tonnes (average: 118 g CO_2/kWh) in 2015.

CO2 savings for geothermal heat

CO_2 savings calculations in table 16 are based on savings factors according to Lund et al. (2005), assuming an efficiency factor of 70% for direct burning to produce heat. The savings were calculated using the figures for geothermal heat production (all uses) presented in the previous chapter by the equation:

$$CO_2\ savings = energy\ produced \cdot savings\ factor$$

In 2017, total CO_2 emission savings by geothermal heat uses in member countries amounted to 30.0 million tonnes of CO_2 for coal replacement, 25.7 million tonnes CO_2 for oil, and 6.1 million tonnes for gas replacement.

Additional CO_2 savings could be achieved by geothermal cooling with GHP in Australia, Japan and Korea. A calcuation method is also developed for this purpose within working group 8.

Table 16: CO_2 savings by geothermal heat uses in member countries 2017. *Calculation based on figures for geothermal heat (all uses) from WG 10 country reports 2017.*

	CO_2 emission savings for geothermal heat [tonnes of CO_2]		
Country	**Gas**	**Oil**	**Coal**
AUS	32,019	135,006	157,452
CHE	276,324	1,165,118	1,358,830
DEU	730,100	3,078,461	3,590,284
ESP	6,014	25,358	29,574
FRA	422,920	1,783,240	2,079,720
GBR	72,517	305,768	356,605
ISL	889,393	3,750,121	4,373,613
ITA	370,734	1,563,198	1,823,094
JPN	718,947	3,031,434	3,535,438
KOR	81,539	343,810	400,971
MEX	112,383	473,862	552,645
NOR	154,812	652,764	761,292
NZL	235,933	994,811	1,160,207
USA	2,002,055	8,441,655	9,845,158
Total 2017	**6,105,689**	**25,744,606**	**30,024,883**
Total 2016	5,874,597	24,770,207	28,888,481
Total 2015	5,599,228	23,609,116	27,534,348
Total 2010	5,358,682	22,594,858	26,351,460

Figure 12: Los Azufres geothermal power plant, Mexico.

5 REFERENCES

Bertani, R. (2005): World geothermal power generation in the period 2001-2005. *Geothermics* 34, Issue 6, 651-690.

Boissavy, C., Rocher, P., Laplaige, P. & Brange, C. (2016): Geothermal Use, Country Update for France. *Proceedings European Geothermal Congress 2016;* Strasbourg, France.

Conti, P., Cei, M. & Razzano, F. (2016): Geothermal Energy Use, Country Update for Italy (2010-2015). *Proceedings European Geothermal Congress 2016;* Strasbourg, France.

Curtis, R., Lund, J., Sanner, B., Rybach, L. & Hellström, G. (2005): Ground Source Heat pumps - Geothermal Energy for Anyone, Anywhere: Current Worldwide Activity. *Proceedings World Geothermal Congress 2005;* Antalya, Turkey.

Dickson, M. & Fanelli, M. (2004): What is geothermal energy? *International Geothermal Association,* http://www.geothermal-energy.org

Directive 2009/28/EC of the European Parliament and of the Council of 23 April 2009 on the promotion of the use of energy from renewable sources and amending and subsequently repealing Directives 2001/77/EC and 2003/30/EC.

EIA 2016: Electric Power Annual 2015. *U.S. Energy Information Administration*, U.S. Department of Energy, Washington, DC 20585, February 2017.

Fridleifsson, I.B., Bertani, R., Huenges, E., Lund, J.W., Ragnarsson, A. & Rybach, L. (2008): The possible role and contribution of geothermal energy to the mitigation of climate change. - In: O. Hohmeyer and T. Trittin (Eds.) - *IPCC Scoping Meeting on Renewable Energy Sources, Proceedings,* 2008, 59-80, Luebeck, Germany.

Geothermiezentrum Bochum (GZB): Analyse des deutschen Wärmepumpenmarktes. - Bestandsaufnahme und Trends. *Bochum University of Applied Sciences,* Bochum, Germany, (2010), 99 p.

Huttrer, G.W. (2001): The status of world geothermal power generation 1995-2000. *Geothermics* 30, Issue 1, 1-27.

IEA-GIA (2003): IEA Geothermal Annual Report 2002. Publication of the International Energy Agency - Geothermal Implementing Agreement, http://iea-gia.org/category/publications

IEA-GIA (2004): IEA Geothermal Annual Report 2003. Publication of the International Energy Agency - Geothermal Implementing Agreement, http://iea-gia.org/category/publications

IEA-GIA (2005): IEA Geothermal Annual Report 2004. Publication of the International Energy Agency - Geothermal Implementing Agreement, http://iea-gia.org/category/publications

IEA-GIA (2006): IEA Geothermal Energy Annual Report 2005. Publication of the International Energy Agency - Geothermal Implementing Agreement, http://iea-gia.org/category/publications

IEA-GIA (2008): IEA Geothermal Energy Annual Report 2006. Publication of the International Energy Agency - Geothermal Implementing Agreement, http://iea-gia.org/category/publications

IEA-GIA (2008): IEA Geothermal Energy Annual Report 2007. Publication of the International Energy Agency - Geothermal Implementing Agreement, http://iea-gia.org/category/publications

IEA-GIA (2009): IEA Geothermal Energy 12th Annual Report 2008. Publication of the International Energy Agency - Geothermal Implementing Agreement, http://iea-gia.org/category/publications

IEA-GIA (2011a): IEA Geothermal Energy 13th Annual Report 2009. Publication of the International Energy Agency - Geothermal Implementing Agreement, http://iea-gia.org/category/publications

IEA-GIA (2011b): IEA Geothermal Energy 14th Annual Report 2010. Publication of the International Energy Agency - Geothermal Implementing Agreement, http://iea-gia.org/category/publications

IEA-GIA (2012): Trends in geothermal applications. Survey report on geothermal utilization and development in IEA-GIA Member Countries in 2010, with trends in geothermal power generation and heat use 2000-2010. Publication of the International Energy Agency - Geothermal Implementing Agreement, 38 p, http://iea-gia.org/category/publications

IEA-GIA (2013): Trends in geothermal applications. Survey report on geothermal utilization and development in IEA-GIA Member Countries in 2011, with trends in geothermal power generation and heat use 2000-2011. Publication of the International Energy Agency - Geothermal Implementing Agreement, 40 p, http://iea-gia.org/category/publications

IEA-GIA (2014): Trends in geothermal applications. Survey report on geothermal utilization and development in IEA-GIA Member Countries in 2012, with trends in geothermal power generation and heat use 2000-2012. Publication of the International Energy Agency - Geothermal Implementing Agreement, 48 p, http://iea-gia.org/category/publications

IEA-GIA (2015): Trends in geothermal applications. Survey report on geothermal utilization and development in IEA-GIA Member Countries in 2013, with trends in geothermal power generation and heat use 2000-2013. Publication of the International Energy Agency - Geothermal Implementing Agreement, 48 p, http://iea-gia.org/category/publications

IEA-GIA (2016): Trends in geothermal applications. Survey report on geothermal utilization and development in IEA-GIA Member Countries in 2014, with trends in geothermal power generation and heat use 2000-2014. Publication of the International Energy Agency - Geothermal Implementing Agreement, 48 p, http://iea-gia.org/category/publications

IEA-GIA (2017): Trends in geothermal applications. Survey report on geothermal utilization and development in IEA Geothermal Member Countries in 2015, with trends in geothermal power generation and heat use 2000-2015. Publication of the International Energy Agency - Geothermal Implementing Agreement, 26 p, http://iea-gia.org/category/publications

IRENA (2019): "Featured Dashboard – Capacity and Generation". http://resourceirena.irena.org/gateway/dashboard/?topic=4&subTopic=16 (accessed 29th October 2019).

The KamLAND Collaboration (2011): Partial radiogenic heat model for Earth revealed by geoneutrino measurements. *Nature Geoscience* 4, 647-651.

Ketilsson, J., Sigurðsson, T. & Bragadóttir, E.R. (2015): International Collection of Geothermal Energy Statistics - Towards reducing fragmentation and improving consistency. *Publication of Orkustofnun* for the Geothermal ERA NET, 68p.

Klaus, T., Loreck, C. & Müschen, K. (2009): Climate Change Mitigation with a Secure Energy System - Developing a Sustainable Power Supply. *Climate Change* 13, Umweltbundesamt, Dessau-Roßlau, Germany. http://www.umweltbundesamt.de/publikationen

Mongillo, M.A. (2005): Savings Factors for geothermal energy applications. Document of the International Energy Agency - Geothermal Implementing Agreement.

Lund, J.W. & Boyd, T.L. (2016): Direct utilization of geothermal energy 2015 worldwide review. *Geothermics* 60, 66-93.

Lund, J.W. & Freeston, D.H. (2001): World-wide direct uses of geothermal energy 2000. *Geothermics* 30, Issue 1, 29-68.

Lund, J.W., Freeston, D.H. & Boyd, T.L. (2005): Direct application of geothermal energy: 2005 worldwide review. *Geothermics* 34, 691-727.

Lund, J.W., Freeston, D.H. & Boyd, T.L. (2011): Direct utilization of geothermal energy: 2010 worldwide review. *Geothermics* 40, 159-180.

Pester, S., Schellschmidt, R. & Schulz, R. (2007): Verzeichnis geothermischer Standorte - Geothermische Anlagen in Deutschland auf einen Blick. *Geothermische Energie* 56/57, 4-8.

Sonnenfroh, F., Imhasly, S., Signorelli, S. & Rybach, L. (2010): Statistik der geothermischen Nutzungen in der Schweiz - Ausgabe 2009. Geowatt AG. http://www.geothermie.ch/data/dokumente/miscellanusPDF/Publikationen/GeothermiestatistikCH_2009.pdf

References and data sources as given in WG 10 country reports 2017

References for the country data in the reporting period are specifically given in the WG 10 questionnaire by the person in charge for each reporting country. Country data are based on official numbers, publications, or personal communication with persons from official bodies and institutions. The contributing authors and their references for data sources stated in the country reports are listed below.

Australia

Person in charge: Betina Bendall (Energy Resources Division, Department of Energy and Mining, Government of South Australia)

France

Person in charge: Philippe Rocher (BRGM - French Geological Survey; Georesources Division - Geothermal Energy Department)

- AFPAC (2016): Statistiques des ventes de Pompes à chaleur (P = 2 à 50 kW) en 2015. Lettre d'information n° 28, février 2016, 1p.
- AFPG (2016): Etude du marché francais de la géothermie en 2015, Paris.
- Boissavy, C., Rocher, P., Laplaige, P. & Brange, C. (2016): Geothermal Energy Use, Country Update for France. European Geothermal Congress 2016, Strasbourg, France.
- CVT ANCRE, ENEA Consulting, BRGM (2015): Les filières de la valorisation énergétique du sous-sol profond. Final report, 205 p., November 2015.
- EurObserv'ER (2015): The State of Renewable Energies in Europe, December 2015 edition, 210p.
- IRENA (2016): Renewable Energy and Jobs - Annual Review 2016, Abu Dhabi, 300 p.
- Vernier, R., Laplaige, Ph., Desplan, A. & Boissavy, Ch. (2015): France Country update. *Proceedings World Geothermal Congress 2015,* 19-25 April 2015, Melbourne, Australia, 12p.

Germany

Persons in charge: Josef Weber (Leibniz Institute for Applied Geophysics, Hannover), Lothar Wissing (Forschungszentrum Jülich, Project Management)

- Agemar, T., Weber, J. & Schulz, R. (2014): Deep Geothermal Energy Production in Germany. *Energies,* 7, 4397-4416.
- GeotIS (Geothermal Information System for Germany): Data on geothermal direct use and electricity, http://www.geotis.de
- Weber, J., Born, H. & Moeck, I. (2019): Geothermal Energy Use, Country Update for Germany 2016 - 2018. *Proceedings European Geothermal Congress 2016*, Strasbourg, France.

Iceland

Persons in charge: María Guðmundsdóttir (Orkustofnun, Reykjavik)

- Orkustofnun Data Repository OS-2018-T005-01. https://www.nea.is/the-national-energy-authority/energy-data/data-repository/
- Orkustofnun (2017). OS-2017-T010-02: Final Heat Use in Iceland 2016 by District Heating Area. Available at the Orkustofnun Data Repository: http://www.nea.is/the-national-energy-authority/energy-data/data-repository/
- Orkustofnun. Unpublished data on electricity consumption.
- Landsvirkjun. Jarðvarmavirkjun við Þeistareyki (Þeistareykir Geothermal Power Plant, in Icelandic). https://www.landsvirkjun.is/fyrirtaekid/framkvaemdir/theistareykir
- Orkustofnun. License for power plant at Flúðir, May 2 2018 (In Icelandic). https://orkustofnun.is/gogn/Utgefin-leyfi/OS-2018-L008-01-Fludavirkjun-Kopsvatni.pdf
- Orkustofnun. Database on power plants, partly published on map.is/os (in Icelandic).

Italy

Persons in charge: Ruggero Bertani, Paolo Romagnoli (ENEL Green Power, Pisa)

- Cataldi, R., Grassi, W. & Passaleva, G. (2013): Geothermal development in Italy 2010-2030 - A challenge to win. *Proceedings European Geothermal Congress 2013,* Pisa, Italy, 3-7 June 2013.

- Cataldi, R. & Conti, P. (2013): Energy balance of the Italian hydrothermal spa system. *Proceedings European Geothermal Congress 2013,* Pisa, Italy, 3-7 June 2013.
- Conti, P., Cataldi, R., Grassi, W. & Passaleva, G. (2015): Geothermal Direct Uses in Italy: Country Update for WGC 2015. *Proceedings World Geothermal Congress 2015,* 19-25 April 2015, Melbourne, Australia.
- Montemaggi, M., Romagnoli, P. & Bertani, R. (2013): Geothermal Electricity, Country Update for Italy. *Proceedings European Geothermal Congress 2013,* Pisa, Italy, 3-7 June 2013.
- Razzano, F. & Cei, M. (2015): Geothermal power generation in Italy 2010-2014: country update report. *Proceedings World Geothermal Congress 2015,* 19-25 April 2015, Melbourne, Australia.

Japan

Persons in charge: Hiroyuki Kamenosono, Kasumi Yasukawa, Takayuki Oishi (Japan Oil, Gas and Metals National Corporation, JOGMEC)

- The Present State and Trend of Geothermal Power Generation of Japan in the Fiscal Year 2016. (Thermal and Nuclear Power Engineering Society, 2017)
- Survey on status of Geothermal Heat Pump System in the Fiscal Year 2016 (Ministry of the Environment, 2017).

Korea

Person in charge: Yoonho Song (Korea Institute of Geoscience and Mineral Resources, Daejeon)

- Korea Energy Agency, 2016, 'New & Renewable Energy statistics 2015' (2016 Edition), 149p.; www.energy.or.kr.
- Song, Y. & Lee, T.J. (2015): Geothermal development in Korea: Country update 2010-2014. *Proceedings World Geothermal Congress 2015,* 19-25 April 2015, Melbourne, Australia.

Mexico

Persons in charge: José M. Romo-Jones, Luis Carlos Gutiérrez-Negrín (CICESE/CeMIE-Geo)

- Gutiérrez-Negrín, L. C. A., Maya-González, R. & Quijano-León, J. L. (2015): Present Situation and Perspectives of Geothermal in Mexico. *Proceedings World Geothermal Congress 2015*, Melbourne, Australia, 19-25 April 2015.
- Diez León, H. D., Ramírez Montes, M. A., & Morales Alcalá, L. (2018): Capacidad Geotérmica Instalada de la CFE, Enero 2018. Geotermia, Vol. 31, No. 1, Ene-Jun 2018.
- Gutiérrez-Negrín, L. C. A. (2016): Mexico: Exploratory Drilling, more Exploration Permits, Second Electricity Auction. IGA News 105, October-December 2016, pp. 13-14.
- Romo-Jones, J.M. and Group CeMIE-Geo. The Mexican Center for Innovation in Geothermal Energy (CeMIE-Geo). *Proceedings World Geothermal Congress 2015*, Melbourne, Australia, 19-25 April 2015.

New Zealand

Person in charge: Chris Bromley (GNS Science, Wairakei Research Centre, Taupo)

- http://data.gns.cri.nz/geothermal/
- GHANZ (2018) New Zealand Geothermal Heat Pump Association: http://www.nzgeothermal.org.nz/ghanz/news-and-events/
- New Zealand Geothermal Association website for industry news and publications http://nzgeothermal.org.nz/elec_geo/
- NZGA Newsletters (2017) : http://www.nzgeothermal.org.nz/
- New Zealand Government Ministry of Business Industry and Enterprise website on official electricity generation statistics: http://www.mbie.govt.nz/info-services/sectors-industries/energy/energy-data-modelling/statistics/electricity
- Brian White (2017) "On the cusp of change" Article in "Energy Perspectives 2017" (p34) www.energynzmag.co.nz
- Carey, B., Dunstall, M., McClintock, S., White, B., Bignall, G., Luketina, K., Robson, B., Zarrouk, S. & Seward, A. (2015): 2015 New Zealand Country Update. *Proceedings World Geothermal Congress 2015,* 19-25 April 2015, Melbourne, Australia, 18p [updated 23rd September 2015].
- Climo, M., Bendall, S., & Carey, B. (2017): Geoheat Strategy for Aotearoa NZ, 2017–2030. New Zealand Geothermal Association, ISBN 978--0-473-38264-3 https://nzgeothermal.org.nz/app/uploads/2017/06/Geoheat_Strategy_2017-2030__Web_Res_.pdf
- Bromley, C. (2017): 2016 New Zealand Country Report, in IEA-Geothermal Annual Report.
- Bromley, C. (2018): 2017 New Zealand Country Report, in IEA-Geothermal Annual Report.

- Seward, A., Cllimo, M., Rutter, H., Etheridge, Z., Van Meer, P., Bendall, S., & Carey, B., (2017): Rebuilding Christchurch - using ground source heat pumps. 12th IEA Heat Pump Confernce, 2017 Rotterdam.

Norway

Person in charge: Jiri Muller (Institute for Energy Technology, Kjeller)

- Muller, J. (2018): IEA-GIA Norway Country Report 2017.
- Midttomme, K., Ramstad, R. & Müller, J. (2015): Geothermal Energy - Country Update for Norway. *Proceedings World Geothermal Congress 2015,* 19-25 April 2015, Melbourne, Australia.

Spain

Person in charge: Margarita de Gregorio (GEOPLAT, Spanish Geothermal Technology Platform)

- APPA, documentation pertinent to APPA Geothermal Department (Low and High Enthalpy); www.appa.es.
- GEOPLAT, Spanish Geothermal Technology Platform; www.geoplat.org.
- IDAE, documentation pertinent to IDAE Geothermal Department; www.idae.es.
- CDTI, Spanish Centre for the Development of Industrial Technology; www.cdti.es.

Switzerland

Person in charge: Katharina Link (Geo-Future GmbH)

- Blum, A. & Wyss, R. (2017): Statistik der geothermischen Nutzung in der Schweiz - Ausgabe 2016. Ein Bericht von energieschweiz.
- Link, K. (2018): Statistik der geothermischen Nutzung in der Schweiz - Ausgabe 2017. Ein Bericht von energieschweiz.

United Kingdom

Person in charge: Jonathan Busby (British Geologic Survey, London)

- Christidis, S. (2016): Heat pump market - United Kingdom. Report 59122/11, BSRIA Limited.

United States of America

Persons in charge: Jeffrey Winick, Lauren Boyd (United States Department of Energy - Geothermal Technologies Office)

- U.S. Energy Information Administration, Form EIA-860m, https://www.eia.gov/electricity/data/eia860m/
- U.S. Energy Information Administration, Form EIA-923, https://www.eia.gov/electricity/data/eia923/
- U.S. Energy Information Administration, https://www.eia.gov/electricity/monthly/
- U.S. Energy Information Administration, https://www.eia.gov/totalenergy/data/monthly/index.php#electricity
- U.S. Energy Information Administration, https://www.eia.gov/totalenergy/data/monthly/archive/00351801.pdf

Contact List

IEA Geothermal Executive Secretary
Brian Carey
GNS Science
Wairakei Research Centre
Private Bag 2000
Taupo 3352
NEW ZEALAND
Tel: +64-7-374-8211
Fax: +64-7-374-8199
E-mail: iea-giasec@gns.cri.nz

WG 10 Leader
Josef Weber
Leibniz Institute for Applied Geophysics
Geozentrum Hannover
Stilleweg 2
30655 Hannover
GERMANY
Tel: +49-511-643-3442
E-mail: josef.weber@leibniz-liag.de

Australia
Barry Goldstein
Energy Resources Division
DPC
Government of South Australia
GPO Box 1264
Adelaide SA 5001
AUSTRALIA
Tel: +61-8-8463-3200
E-mail: barry.goldstein@sa.gov.au

France
Philippe Rocher
BRGM
3, Avenue Claude Guillemin
BP 36009
45060 Orléans Cedex 02
FRANCE
Tel: +33-2-38-64-3106
E-mail: p.rocher@brgm.fr

Spanish Geothermal Technology Platform (GEOPLAT)
Margarita de Gregorio
Doctor Castelo 10, 3 C-D
28009 Madrid
SPAIN
Tel: +34-91-400-9691
E-mail: margadegregorio@geoplat.org

Germany
Lothar Wissing (ExCo Chair)
Forschungszentrum Jülich GmbH
Project Management Organization
D-52425 Jülich
GERMANY
Tel: +49-2461-61-4843
E-mail: l.wissing@fz-juelich.de

Iceland
Jónas Ketilsson
Orkustofnun
Grensásvegur 9
108 Reykjavik
ICELAND
Tel: +354-569-6000
E-mail: jonas.ketilsson@os.is

Italy
Sara Montomoli
Geothermal Innovation
ENEL Green Power
Via Andrea Pisano 120
56100 Pisa
ITALY
Tel: +39-328-726-4589
E-mail: sara.montomoli@enel.com

Japan
Kasumi Yasukawa
Councilor, Geothermal Unit
Japan Oil, Gas and Metals National Corporation (JOGMEC)
Toranomon Twin Building 2-10-1
Minato-ku
Tokyo 105-0001
JAPAN
Tel: +81-3-6758-8643
E-mail:
yasukawa-kasumi@jogmec.go.jp

Mexico
Jose Manuel Romo Jones
CEMIE-Geo
Depto. de Geofisica Aplicada
CICESE
Carretera Ensenada-Tijuana #3918
Fraccionamiento Zona Playitas
22860 Ensenada B. C.
MEXICO
Tel: +52-646-175-0500
E-mail: jromo@cicese.mx

New Zealand
Chris Bromley (ExCo Vice-Chair)
GNS Science
Wairakei Research Centre
Private Bag 2000
Taupo 3352
NEW ZEALAND
Tel: +64-7-374-8211
E-mail: c.bromley@gns.cri.nz

Norway
Jiri Muller (Exco Vice-Chair)
Institute for Energy Technology
P.O. Box 40
NO-2027 Kjeller
NORWAY
Tel: +47-6380-6185
E-mail: jiri.muller@ife.no

Republic of Korea
Yoonho Song
Geothermal Resources Department
Korea Institute of Geoscience & Mineral Resources (KIGAM)
92 Gwahang-no
Yuseong-gu
Daejeon 305-350
REPUBLIC OF KOREA
Tel: +82-42-868-3175
E-mail: song@kigam.re.kr

Switzerland
Gunter Siddiqi
Swiss Federal Ministry of the Environment, Transport, Energy and Communications - UVEK
Federal Office of Energy (BFE)
Division of Energy Economics/ Energy Research
CH-3003 Berne
SWITZERLAND
Tel: +41-31-322-5324
E-mail: gunter.siddiqi@bfe.admin.ch

United Kingdom
Noramalina Mansor
Sience and Innovation for Climate and Energy Directorate
1 Victoria Street
London SW1H 0ET
UNITED KINGDOM
Tel: na
E-mail: noramalina.mansor@beis.gov.uk

United States of America
Lauren Boyd
Enhanced Geothermal Systems (EGS)
Office of Energy Efficiency and Renewable Energy
U.S. Department of Energy
1000 Independence Ave., SW
Washington, DC 20585
UNITED STATES OF AMERICA
Tel: +1-202-287-1818
E-mail: Lauren.Boyd@ee.doe.gov

IEA Geothermal