Current Issues

Energy and climate change

Deutsche Bank Research

February 23, 2010

Geothermal energy

Construction industry a beneficiary of climate change and energy scarcity

The global challenges of the future – checking the pace of climate change and mitigating energy price shocks – are only to be mastered if all available means of addressing them are activated. In this context, the potential of geothermal energy continues to be underestimated.

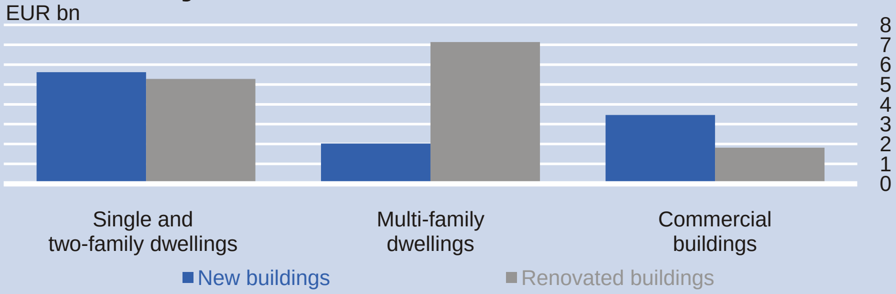
Over the past few years the competitiveness of geothermal energy has improved vis-à-vis fossil-based fuel sources. In Germany, where geothermal energy has so far led a quiet existence as a niche segment, government is helping in many areas to enhance the technologies for its use. In this light, the relevant promotion laws were revamped or amended at the beginning of 2009. The result is, for example, that new geothermal systems can be cheaper than oil or gas heating after just a few years. However, geothermal power stations will still contribute less than 1% of total supply in 2020.

Using geothermal energy as a source of heat is inconceivable without its intelligent integration into respective housing, living and working environments. From this aspect, geothermal energy and the building industry are "Siamese twins", so to speak. This is also why the expansion of geothermal energy will benefit the construction industry: In Germany, the growth of direct geothermal use will result in a cumulative construction volume of EUR 25 bn in 2030. Depending on the building segment, newbuild and renovation will weigh in with differing contributions. Moreover, geothermal power production – just getting off the ground in Germany – promises to create somewhat higher demand for building activity.

Going forward, sustainable stimuli will boost all construction segments including the building materials industry and many service providers. There appear to be virtually no technical limits on the possible range of applications. Good prospects are offered by: 1) the building of single and multi-family dwellings, 2) highrise construction (where the integration of geothermal energy is only just beginning and much more is possible), 3) larger residential and commercial complexes (a playground for innovative architectural solutions that frequently pay off for the builders), and 4) the multifaceted spectrum of public buildings.

Direct geothermal use: Cumulative building volume of up to EUR 25 bn by 2030

EUR bn



Source: DBR

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1. Climate change and energy scarcity call for new solutions[1]

Anthropogenic climate change and the foreseeable growing scarcity of fossil fuels are already causing serious headaches today. And the problems are likely to worsen noticeably in the years ahead.

— Despite the disappointing outcome of the Copenhagen climate conference there is still agreement among experts that bold new solutions are needed to keep in check the looming threats.

Energy prices increasing again

— At the same time, it is obvious that the correction of energy prices in late 2008 and early 2009 triggered by the global financial and economic crisis was only temporary in nature. As the global economy recovers it is only a matter of time before the price of fuel increases tangibly.

Geothermal gaining importance

The global challenges need to be addressed using many different approaches, including all aspects of geothermal energy. True, geothermal has been in use in many parts of the world for a long time. Its potential to overcome the two global challenges – checking the pace of climate change and mitigation of energy price shocks – continues to be underestimated, however, also in industrial countries such as Germany.

New opportunities for construction industry

Geothermal energy has made up ground over the past few years on both the cost side and the price side, and thus improved its competitiveness. Policymakers are helping in many areas to make the technology more attractive. Since using energy from beneath the Earth's surface as a source of heat does not make sense without its intelligent integration into the respective housing and living environments, geothermal and the building industry are "Siamese twins", so to speak, or two sides of the same coin. Therefore, geothermal energy in all of its manifestations offers many new opportunities especially for the construction industry in light of a changing climate and foreseeable scarcities of fossil fuel sources. The recent market success of geothermal energy gives us an inkling of all the things that might become possible in future.

2. Geothermal energy has many advantages

Geothermal energy renews itself

Geothermal is, by definition (e.g. in Germany's Renewable Energy Sources Act (EEG)), a type of renewable energy. Unlike in the case of bioenergy, though, human beings are not really able to "renew" the thermal energy used. Nonetheless, the fact that geothermal is classified as a renewable source of energy is attributable to international agreements and its origin. Some estimates say that about 50-70% of geothermal energy is from energy stored during the period of Earth's formation and about 30-50% from the natural decay of radioactive isotopes, so the latter share is a product of more or less "natural renewal".[2]

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[1] This report was prepared on behalf of the Hauptverband der Deutschen Bauindustrie and the Bundesverband Baustoffe – Steine und Erden. Deutsche Bank Research assumes sole responsibility for the content.

[2] In this broad interpretation of renewability, which also includes regeneration not caused by human intervention, however, fossil fuels would also be considered "renewable" since these can regenerate themselves naturally under favourable conditions over the very long term, too.

From the perspective of resource economics, geothermal is indeed more similar to energy sources such as solar, hydro/tidal and wind power. For from a resource point of view its major asset is that, in spite of its use for energy purposes, it is possible to maintain the energy potential of the resource on a sustainable basis. On this score, geothermal energy is better than all fossil-based fuels, which have a common feature of exhaustibility, i.e., there is always the possibility of exhausting reserves of oil, natural gas and coal.

Better than fossil fuel sources on many counts

Carbon-neutral in principle

The second major advantage of geothermal energy over fossil fuels – besides its virtually infinite availability from a human point of view – is to be seen in the climate context, i.e. that it is fundamentally carbon neutral. True, there are still environmental burdens linked with the production of the technology, the materials used and the boreholes. However, the use of geothermal energy results in virtually no pollutants from emissions today. Therefore, the substitution of geothermal energy for fossil fuels is an effective instrument for slowing the process of global warming. The comparative advantage of geothermal evident from a climate standpoint is likely to attain even greater relevance going forward, since the price of CO_2 emissions certificates will probably increase over the medium to long term.

Lower energy imports

Moreover, geothermal energy also has advantages over fossil sources because it does not normally – beyond the climate aspect – cause further negative external environmental effects such as land degradation or air contamination. In addition, the heavier use of domestic geothermal potential will enable the degree of dependence on energy imports to be reduced. These significantly increased not only Germany's energy bill up to 2008.[3] Energy imports – of natural gas in particular – have proved to be much less reliable over the past few years than promised by the supply countries. Besides the lesser degree of physical dependence, geothermal energy will also enable a greater degree of serenity in the face of the volatile and, in the longer term, very likely probability of rising prices on the markets for oil, natural gas and hard coal.

Suitable for baseload requirements

Nonetheless, geothermal energy even has several advantages over other renewable sources of energy. For instance, in the electricity segment it is more suitable for covering baseload requirements than traditional wind power or sun-dependent photovoltaics. People who – for various reasons – object to wind farms, bio-fuelled power stations or photovoltaic systems have virtually no reason to take offence at geothermal energy, as it is more or less "invisible", inaudible and odourless.

Source of hope for better energy and climate in future

The feasibility of geothermal energy, which invariably depends on location factors, has improved noticeably in recent years – even in Germany. The reasons are not only the structurally driven increase in the cost of competing fossil fuels. Geothermal is also benefiting from technological advances and amendments to the legislative framework. This includes, not least, the mandatory obligation to fulfil certain statutory requirements pertaining to the use of renewable energies when new buildings are being planned. All these factors make geothermal energy a major source of hope for a better energy and climate future.

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[3] See Auer, Josef et al. (2009). Prosperity through trade: Germany's wholesale and foreign trade in times of globalisation. Deutsche Bank Research. Current Issues. Frankfurt am Main. August 27, 2009. p. 14.

Temperature rises with increase in depth

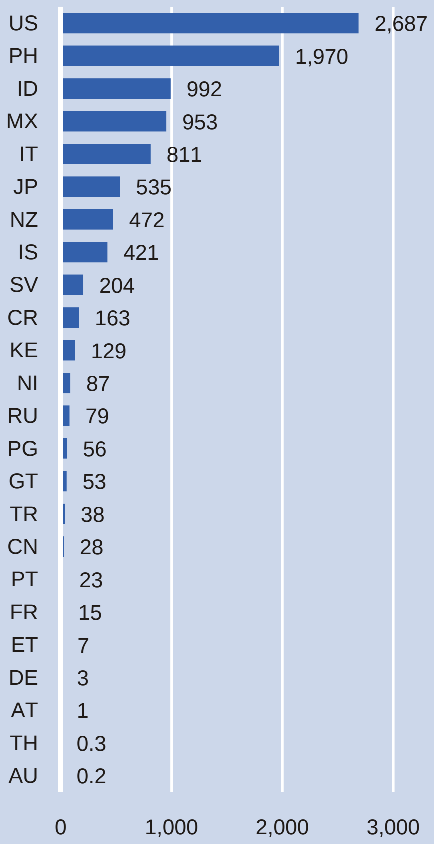
Structure of earth

	Depth (km)	°C
Crust	0-40	<1,000
Mantel	40-2,900	1,000-3,000
Outer core	2,900-5,100	3,000-4,500
Inner core	5,100-6,370	4,500-4,800

Source: GeothermieZentrum Bochum 1

Global capacities for geothermal power

2007*, installed capacity, MW



*Total 9,727.5

Source: Bertani, R. 2

3. Geothermal: Opportunities and risks

Geothermal's potential as an energy source is underestimated. In the past, geothermal energy was only used when it emerged naturally in the form of a thermal spring. It has been no secret since the first mines were dug that Earth's temperature increases palpably on the way down. However, only recently have the relevant technologies become sufficiently sophisticated to enable their commercial use in many parts of the world that do not feature simple geological prerequisites. The spectrum of innovations is broad, ranging from modern drilling technology and more powerful pump and deployment systems, right up to contemporary architectural solutions. The aim is by no means merely to drill as far as possible into the crust, but also to tap potential sources near the surface even though these are known to harbour less potential than deeper fields of the same size.

The planet Earth has gigantic potential as an energy source. No less than 99% of our planet is hotter than 1,000 degrees Celsius. And of the remainder some 99% is still over 100°C. In this respect, a look from outer space at the anything but perfectly round Earth with its predominantly blue colour and white polar caps creates a false impression. In actual fact, our planet is a real "hot potato". Thus, the total flow of heat from Earth's interior comes as a surprise, for on balance it radiates the equivalent of about two and a half times humankind's global energy needs into the atmosphere unused – day in, day out.[4]

Geologists differentiate between the various depths of Earth's crust using geothermal gradients. For the outer 5 km the rule of thumb is that the temperature rises by about 3°C for every 100 m of depth. This means that at a depth of 1 km temperatures average in the 30-40°C range. In the inner core (solid material), at a depth of 5,100 to 6,370 km, some estimates say that temperatures probably run to about 5,000°C or more. In the outer core (fluid matter), from 2,900 km, the range is still 3,000-4,500°C. And even in the Earth's mantle, from 40 to 2,900 km, it is still likely to be some 1,000-3,000°C. These are all temperatures that are too high for life to exist. For people and geothermal applications, the Earth's crust is key; it has a depth of up to 40 km and protects all living creatures from the "fires of hell", but – depending on the location – its temperatures still reach 1,000°C at the extreme.

Since the heat flow of the Earth typically always moves towards a lower temperature (i.e. towards the surface), the crust is continually "recharged". Add to this the energy input from the sun, which warms the Earth as many as several metres below the surface. This contribution, strongly determined by the geographical location, can also – if used intelligently – lower the cost of supplying buildings with energy. The range of potential applications particularly in the construction industry in all its facets has still not been fully exhausted by any stretch of the imagination. Of course, the potential sites accessible for geothermal applications are by no means uniformly distributed in geographical terms.

Risks are manageable with proper use

Any work involving Earth's crust raises the issue of the environment. As long as all risks are weighed and considered in advance by

[4] See, for example, Bußmann, Werner (2008). Germany. The geothermal market is expanding. Geeste. pp. 2-3.

Precise testing in advance is key

means of a suitable location study (including tension measurements), there is nothing to argue against an increase in the use of geothermal energy. However, environmental damage can result from a poor assessment of the impact of the technology and/or improper handling – as is the case with all types of sophisticated technologies. As a consequence of an excessive withdrawal of warm water the groundwater level may fall; this problem does not occur if the water used is reinjected. In very unsuitable locations the withdrawal of heat causes local cooling of the underground, which is why – as in the case of changes in pore pressure – microseismic effects cannot be ruled out. Since microseismicity can trigger small earthquakes before their natural occurrence in zones that are at risk anyway, areas in question (e.g. in parts of southern Germany) must always be tested very precisely and comprehensively in advance. In locations that have been tested and found suitable it is very unlikely that the Earth's surface will cave in and damage building infrastructure as a result. Of course, salts or poisonous heavy metals might become dissolved in the water. In case this water is not returned to the Earth's crust it is essential for it to be purified or, if necessary, disposed of as waste.

Major processes in use of geothermal energy

Near-surface geothermal (often 8-25°C)

1. Groundwater well with natural recharge
   Open system
   Usually less than 50 m deep

2. Geothermal collectors, energy piles
   Closed-loop system
   About 10-50 m deep

3. Geothermal probes
   Closed-loop system
   About 10-400 m deep

Deep geothermal (20-200°C)

1. Hydrogeothermal energy
   Open system
   Several 100 m to over 3,000 m deep
   e.g. electricity generated with ORC or Kalina systems

2. Hot dry rock (HDR)
   Open system
   5,000 m deep or more

Sources: Environment Ministry of B-W, DBR 3

4. Potential technical uses for geothermal energy

Geothermal energy can be utilised in a variety of ways. This applies to both the technologies deployed and the concrete use of the energy captured. In principle, one must differentiate between two "utilisation paths":

— First, the direct use of geothermal energy for heating or cooling.

— Second, its indirect use via the transformation of thermal energy into electricity. Producing heat and electricity via combined heat and power generation (CHP), also known as cogeneration, is considered particularly effective as high efficiency levels are achieved.[5] One limit on geothermal CHP in some areas, however, is the lack of need for heating.

In future, the main areas of deployment, which so far have only covered the segments provision of heating/cooling, power generation and cogeneration, may possibly have to be extended. As lately not only experts but also the media have shown a surge of interest in everything pertaining to the future megatrend of electrically powered vehicles, it is becoming increasingly obvious that geothermal energy can also make a contribution here. Since geothermal power is generated in principle without any pollutant emissions, this will enable the electric car to meet the increasingly strict environmental standards and thus ensure a greater degree of societal acceptance than would be the case with electricity generated from fossil fuel sources. Moreover, geothermal would thus manage to metamorphose from being strictly a supplier of heat via the already more sophisticated provision of secondary energy in the shape of electricity to being a multi-talented provider to all the energy-significant sales markets – i.e. heating/refrigeration, electricity and even individual mobility.

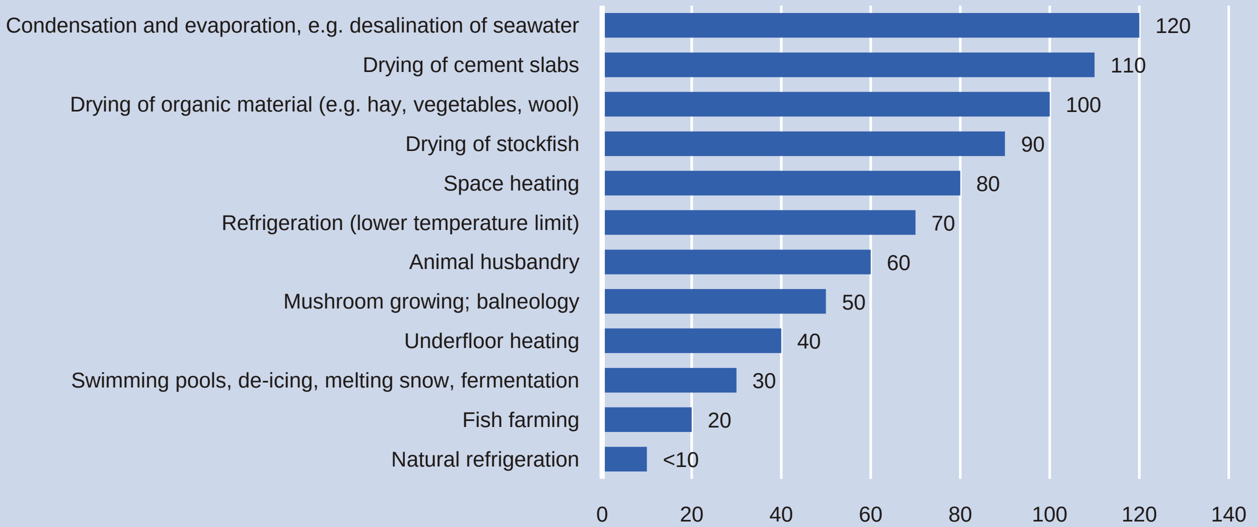
[5] For an overview of CHP see e.g. Auer, Josef (2008). Combined heat and power generation: A pillar of Germany's energy and climate programme. Deutsche Bank Research. Current Issues. May 14, 2008. Frankfurt am Main.

Direct use for heating and cooling

The direct use of geothermal energy goes back to the days of antiquity at the latest. Thermal water resources were tapped at a very early stage for the purpose of heating, bathing or cooking. However, the first geothermal district heating network, an unprecedented basic innovation at the time, did not go into operation until the 14th century, in Chaudes-Aigues, France. The so-called Lindal diagram gives a rough but useful overview of the required water temperatures for the most diverse direct applications of geothermal energy. The decisive factor for economic feasibility is the intelligent combination of application areas, so that the potentials of the temperature cascade can be realised as efficiently as possible.

Direct geothermal use, required temperature by application

°C (Lindal diagram)



Sources: Baldur Lindal, Bundesverband Geothermie 4

In direct applications worldwide, geothermal energy is mainly used as a source of heat. In such cases, it is by no means necessary that the thermal water itself be channelled to the final point of use. Heat exchangers, for example, enable energy to be extracted from the geothermal water and then fed into a district heating network.

Heat obtained via various procedures

Near-surface geothermal energy is tapped almost invariably for direct use. Heat is usually extracted via geothermal collectors (horizontal installation), geothermal probes (vertical), geothermal baskets (cone-shaped) or ground-coupled concrete building components. Typically, there is a plastic pipe system built into the thermo-active components enabling the circulation of a heat carrier fluid. The near-surface procedures often use heat pumps for heating purposes in winter. In summer, though, heat pump systems can also be used for cooling purposes. Typical applications of near-surface geothermal that do not involve heat pumps are natural air conditioning in buildings (underfloor or wall systems which use 8-10°C water from shallow underground sources) and increasingly also de-icing of, for example, roadways, bridges or train platforms (saving winter clearing and salting).

Use of differing temperature fields

Typical of low-enthalpy resources

No volcanic activity

Low temperatures (less than 100°C)

Used for heating

Typical of high-enthalpy resources

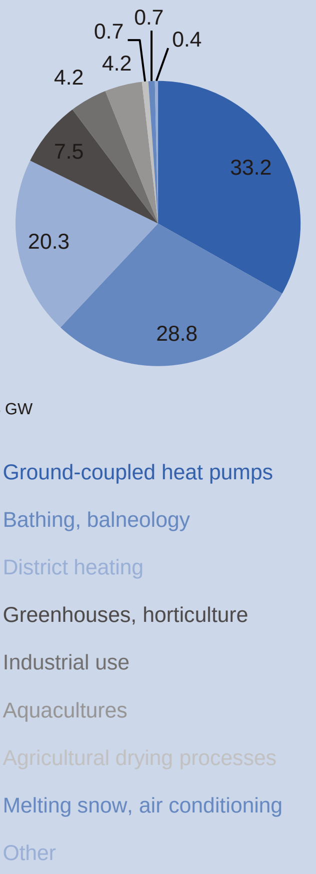
Heat anomalies owing to volcanic activity

High temperatures (200°C and more)

Used for power generation

Heating is the predominant global direct-use geothermal application

Type of use,* %



Sources: J. Lund et al., Bundesverband Geothermie

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Indirect use for electricity generation

Deep geothermal systems (> 400 m) make use of the increase in temperature related to the distance from the surface. The strong heat anomalies existing in the crust are mostly the result of volcanic activity:

— The high-enthalpy reservoirs in particular – these being areas of volcanic activity – are ideal for the generation of electricity. The advantage of these locations is that hot fluids (steam, water) are to be found at a relatively shallow depth and can be "harvested" comparatively cheaply with modern technology. So it is no wonder that the countries with high volcanic activity are the focus of geothermal power generation.

— In the absence of volcanic activity, deep boreholes have to be drilled in low-enthalpy fields in order to obtain temperatures high enough (usually >100°C) to generate electricity. If this is the site of an aquifer (also referred to as a groundwater or thermal reservoir or conductor), the water can be pumped to the surface where the heat energy is removed and the cooled water subsequently injected back into the reservoir (hydrothermal geothermal). By contrast, the heat from non-permeable rock can be extracted by systematically fracturing the rock formation, pumping water into the cracks and circulating it (experts refer to this as petrothermal geothermal). A third way to extract heat is to use a deep geothermal probe, with the heat carrier, often water (sometimes with additives such as ammonia), circulating in a closed system (depths of 2,000 to 3,000 m are not uncommon). There is one disadvantage, though, that being the comparatively small amount of energy obtained. In Germany, preference is given to hydrothermal systems because of the geological conditions.

5. Situation in Germany

Regional potential of geothermal energy in Germany

The following estimates of geothermal potential in Germany show that it is, in principle, a virtually inexhaustible source of energy. However, the estimates need to be evaluated critically, especially since the potentials differ substantially depending on whether they are assessed from a theoretical and physical, technical and/or business standpoint.

In Germany, the overall theoretical and physical potential of geothermal energy[6], disregarding economic and technical aspects, totals roughly 1,200,000 exajoules (EJ).[7] Under the additional restriction of maintaining ecological sustainability, though, this still leaves 1,200 EJ per year for electricity generation alone for a utilisation period of 1,000 years. This amount would be equal to 85 times annual primary energy consumption in Germany (2008: 14 EJ).

[6] Basic assumptions: the borehole is a maximum of 10 km in depth and the heat of the ambient rock can be reduced to 20°C.

[7] For more on the theoretical potential see Kaltschmitt, Martin et al. (2006). Erneuerbare Energien. Systemtechnik, Wirtschaftlichkeit, Umweltaspekte. Berlin. p. 527.

The technical supply and demand potentials are less clear, for these ultimately depend on the concrete options for their implementation.[8] These include not only the drilling depths that can be reached, the efficiency levels of the power-generating techniques, the technologies applied, technological advances, but also the assumptions on user behaviour.[9]

The crucial factor in practice is the difference between near-surface and deep geothermal energy. Near-surface use is possible virtually everywhere in Germany, even though naturally the temperatures vary from place to place. By contrast, the hot-water aquifers for geothermal production of electricity are spread anything but uniformly across the region. Suitable, inexpensive geothermal resources are to be found in the South German Molasse Basin (Unterhaching is located here, for instance), in the Upper Rhine Valley (stretching northward past the Frankfurt area) and in the North German Basin, which is the biggest by volume and also where about two-thirds of the energy stored in aquifers lies waiting to be tapped. These regions already boast a fairly long history of direct use of geothermal heat. Moreover, there are sizeable areas north of the Molasse Basin and in parts of Thuringia and Saxony-Anhalt with potential hydrothermal resources.

The regulatory framework for geothermal energy in Germany

The reason for the very broad thrust of the regulatory framework is that geothermal operations affect the depths of the Earth, and thus involve fundamental competences of the federal and state governments. In addition, in some cases special municipal by-laws have to be taken into consideration.

In addition to the applicable promotion laws such as the Renewable Energy Sources Act (EEG) and the Renewable Energies Heating Act (EEWärmeG), at least six federal laws (see box) are of relevance for geothermal energy projects.

Six federal laws at play in Germany

Besides the Baugesetzbuch (BauGB), which regulates construction planning, the laws include the Bundesimmissionsschutzgesetz (BImSchG) on protection from emissions, which applies to the aboveground parts of geothermal systems, and the Umweltverträglichkeitsprüfungsgesetz (UVPG) which covers environmental compatibility issues. Systems with supra-municipal significance fall under the Raumordnungsgesetz (ROG) that regulates regional zoning matters. Of particular relevance, also, are the Bundesberggesetz (BBergG) applicable to mountains and the Wasserhaushaltsgesetz (WHG) pertaining to water management issues.

On top of this, many of Germany's *Länder* have in the course of time passed special, state-specific rules which make certain provisions of water and mining legislation even more restrictive.

The great complexity of the regulatory framework often used to be a major, if not excessively high, hurdle for otherwise promising projects. For this reason, standard solutions have been formulated and established in the meantime to reduce the bureaucratic effort and thus support the trend towards geothermal energy.

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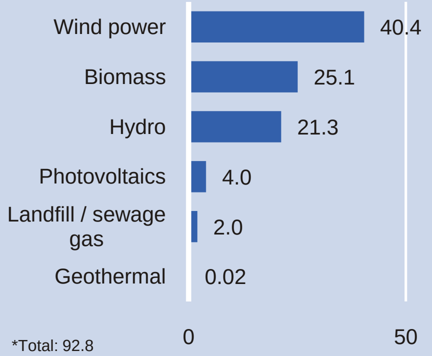
8 For more on the technical potentials see Paschen, Herbert et al. (2003). Möglichkeiten geothermischer Stromerzeugung in Deutschland. Sachstandsbericht. Berlin. Purkus, Alexandra (2008). Geothermische Stromerzeugung im Energiemarkt der Zukunft. Oldenburg. pp. 36-39.

9 The results vary additionally depending on whether only the most efficient technologies, such as modern CHP, are used; in this case (waste) heat also has to be factored in. Moreover, key technologies such as the Hot Dry Rock (HDR) process are not yet suitable for the mass market, but they would unlock a substantial amount of geothermal potential. This becomes obvious immediately once one realises that in Germany the aquifers tapped by means of hydrogeothermal processes represent merely 1% of total geothermal potential. The 95% latent potential of crystallised rock requires innovative technologies such as HDR to be activated.

Still very little geothermal power generation
Germany 2008*, TWh



Source: AGEE 6

More geothermal electricity in Germany since 2004

	Power generation GWh	Installed capacity MW
2004	0,2	0,2
2005	0,2	0,2
2006	0,4	0,2
2007	0,4	3,2
2008	18,0	6,6

Source: AGEE 7

The promotional instruments: EEG, MAP and EEWärmeG

The most important promotional instruments for geothermal in Germany are the EEG, MAP (a market incentive programme) and EEWärmeG.

EEG promotes deep geothermal energy for power generation

In Germany, deep geothermal was boosted decisively by initial pilot projects and the amendments to the EEG in 2004. For the first time, the EEG now guaranteed stable feed-in tariffs for 20 years.[10] The subsidies roughly matched those for wind energy, but fell substantially short of those for photovoltaics. This is the main reason why electricity generation driven by deep geothermal energy has also achieved a breakthrough in Germany.

Geothermal continues, in absolute terms, to deliver the smallest contributions to power generation from renewable sources in Germany. But the volume growth is quite impressive. 2008 saw the commissioning in Unterhaching of a third geothermal plant, after two had been established in Landau and Neustadt-Glewe. This doubled the installed electrical capacity to a total of 6.6 MW. In fact, electricity generation expanded from 400,000 kWh in 2007 to 18 million kWh in 2008, bringing the geothermal total to 0.003% of power consumption (wind power, by comparison: 6.6%).

According to Germany's environment ministry there were 15 projects for combined geothermal heat and power generation in the planning stage at end-2008. Moreover, applications had been filed for exploration permits for 150 locations. At several locations in Bavaria (e.g. Garching, Sauerland, Feldkirchen), the plans and/or drilling work are already quite far advanced. In the Upper Rhine Valley, where the Lindau plant is located, there are plans for two more plants (Bruchsal and Ischheim).

All things considered, the expansion forecasts are very optimistic. The environment minister's guideline study on renewable energies in Germany up to 2020 considers it realistic to expect installed geothermal power capacity to grow to 280 MW, ultimately enabling the generation of 1.8 billion kWh of electricity. The renewables industry's forecast for electricity generation comes to virtually euphoric results; according to its calculations, the current framework conditions even point to capacity expansion to over 560 MW (i.e. twice the ministry's forecast), which should then allow production of some 3.8 billion kWh of electricity. Regardless of whether these forecasts seem unduly optimistic considering the numerous pitfalls of public sentiment, official competences and red tape, it clearly emerges that geothermal energy is likely to make a noticeably greater contribution to domestic power generation in future than it does now. However, this share would still be less than 1% even in the bullish forecast.

EEG 2009 led to establishment of bonus system

Policymakers have seized on the occasion of the EEG update from 2009 to further enhance the attractiveness of the incentives for project planners and partners. A type of bonus system was intentionally established to flesh out the basic compensation regime:

— The basic compensation for plants of up to 10 MW rose to 16 cents/kWh (i.e. up 2 cents/kWh on 2004), and for those over 10 MW to 10.5 cents/kWh (i.e. up 1.55 cents/kWh).

[10] When the amended EEG came into effect the basic compensation for systems producing up to 10 MW of output totalled 14 cents/kWh, while systems producing over 10 MW still generated a respectable 8.95 cents/kWh.

EEG bonus system for geothermal energy

System size	Up to 10 MW Cents/kWh	From 10 MW Cents/kWh
EEG 2004		
Basic compensation	14	8,95
EEG 2009		
Basic compensation	16	10,5
Early-bird bonus bef. Jan. 1, 2016	4	4
Heat use bonus	3	No
Technology bonus	4	No

Sources: EEG 2004, EEG 2009 8

Key MAP factors are*:

- Extraction and injection boreholes may be subsidised for up to EUR 750 per metre of vertical depth (the limits are around EUR 2.5 m per borehole and a maximum of EUR 5 m per project); in addition, there is cover for unforeseeable extra costs of up to 50%, but at most EUR 1.25 m per borehole.
- Subsidisation for installing deep geothermal systems, with up to EUR 200 being granted for each kW of nominal capacity, but there is a cap of EUR 2 m per investment.
- Support for deep geothermal energy via amortisation grants and low-interest loans. The loan total can cover up to 80% of the drilling costs. If, unexpectedly, no find is made, funds no longer have to be repaid from this point in time. De facto, this largely releases the borrower from bearing any risk.
- Moreover, the installation of heating networks is subsidised under certain conditions (among others, if promotion was rejected or cut back under the CHP law) to a maximum of EUR 1.5 m. However, approval is contingent on 50% or more of the heat being generated by renewable sources of energy.

*For details in German see for example Dorss, Werner (2009). Rechtliche Rahmenbedingungen der Geothermie in Deutschland. FPS Rechtsanwälte & Notare. Frankfurt am Main.

- In order to give the market an extra boost, a (new) additional early-bird bonus of 4 cents/kWh is to be paid for plants commissioned by January 1, 2016 – regardless of their output capacity. This means that compensation for plants of up to 10 MW will total no less than 20 cents for every kilowatt-hour fed into the grid.
- For plants up to 10 MW that extract at least one-fifth of the heat generated during geothermal electricity production for commercial use, a heat-use bonus of 3 cents/kWh will also be granted for the electricity generated.
- Strategically decisive significance is attached to the technology bonus. It totals 4 cents/kWh, but is only paid for systems with a capacity of up to 10 MW. The prerequisite is that power must be generated by means of petrothermal technology, so the use of particularly innovative and prospectively successful geothermal technologies is rewarded. These include hot-dry-rock (HDR) projects in which water, for example, is forced into artificially created cracks in granite rocks that because of their depth are very hot.[11]

It follows from the bonus system that plants whose capacities exceed 10 MW and thus are not entitled to the heat and technology bonus can obtain a maximum subsidy of 14.5 cents/kWh. The outlook is more favourable for systems up to 10 MW. Simultaneous availment of the early-bird and heat bonuses paves the way for total compensation of 23 cents/kWh. For HDR plants commissioned before the deadline it is theoretically possible in fact to obtain 27 cents/kWh; however, such systems will probably remain the exception for the time being. Nevertheless, the theoretical potential is immense. Since the innovative technology does not depend on the presence of geothermal water in the ground, it may in principle be deployed at every location. Estimates say that about four-fifths of Germany's surface area might be suitable, so the deployment scope for the relatively clean technology is virtually unlimited.

According to the EEG 2009, the degression scale for geothermal energy is 1% per annum on compensation and bonuses. The subsidy is guaranteed for 20 years.

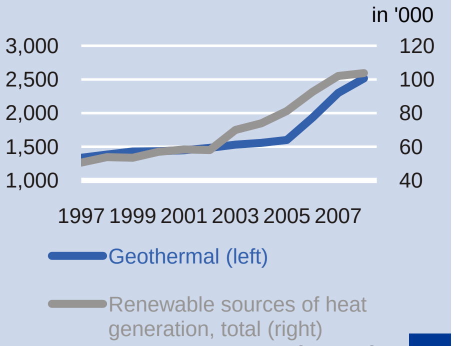
Market incentive programme gives geothermal extra boost

As it appeared in early 2009 that the incentive effect of the EEG 2009 might fail to meet expectations for the still new field of deep geothermal because of the still relatively high risks (e.g. drilling, discovery and thus feasibility risks), the policymakers reacted and created the additional instrument of MAP. This should provide the deciding boost for the realisation of up to 40 geothermal energy projects with an investment volume of no less than EUR 400 m. To simplify the MAP procedures, the KfW funds are applied for directly via the respective bank.

Despite the considerable subsidisation of deep geothermal energy in Germany, the scope for expansion is subject to certain limits simply for organisational reasons. For to press ahead with the sophisticated technology one major prerequisite is to have well-trained, experienced workers with the appropriate skills; however, they are not yet available in sufficient numbers in this still fledgling

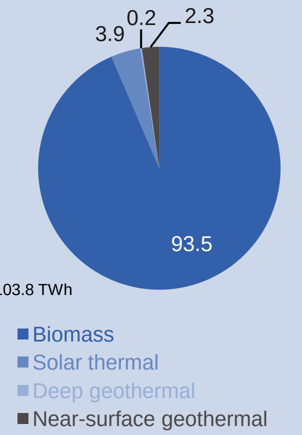
[11] HDR projects may very easily harbour risks. This is shown by the example of Basle, where high water pressure in artificial fissures is blamed for a number of small earthquakes, which led to the project being stopped. A decision as to whether and how things should continue is to be taken in spring 2010 in the wake of new studies.

Geothermal heating showed growth before EEWärmeG
GWh



Source: AGEE **9**

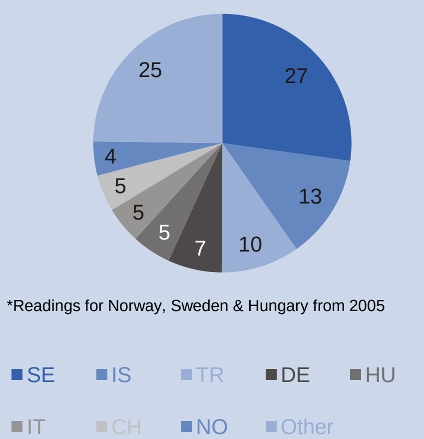
Geothermal: 3rd pillar of renewable heating
Germany, 2008*, %



*Total: 103.8 TWh

Spurce: AGEE **10**

Germany is No. 4 in Europe
Europe, direct geothermal use, 2007*, %



*Readings for Norway, Sweden & Hungary from 2005

Sources: M. Antics and B. Sanner **11**

market segment. Besides, the drilling technology is currently a bottleneck, and thus expensive, because of the current rash of new projects and plans. In addition, the fact that the projects vary according to local conditions is a curb on developments.

EEWärmeG gives stimuli for greater heat provision

At around 2.5 bn kWh, geothermal energy produced considerably more heat in 2008 than in 2007 (2.3 bn kWh). This volume corresponds to about 61% of that produced by solar thermal, but to only 2.4% of heat generated by renewables as a whole. Deep geothermal contributed 0.16 bn kWh of the heat from this source and near-surface geothermal the sizeable remainder at roughly 2.3 bn kWh.

Most of the 167 deep geothermal systems provided building complexes and thermal baths with heat. Thirteen geothermal generating plants fed heat into district heating networks; these include the three CHP plants mentioned above which generate not only electricity but also heat. The German Federal Ministry for the Environment, Nature Conservation and Nuclear Safety says 20 new deep geothermal projects were launched in 2008 (investment volume of some EUR 200 m). And 15 geothermal heating plants were on the drawing board in 2009. The dynamics of deep geothermal heat generation counteract the organisational restrictions discussed above. In addition, systems designed solely for deep geothermal heat production incur substantially higher costs for heat distribution than do CHP plants. The expenditures on drilling and heating plant now account for only 30% of the investment costs, while the infrastructure of heat distribution (e.g. district heating network) eats up the lion's share of 70%. For this reason, locations with existing district heating networks are particularly sought after. To mitigate the network problem the subsidies were improved – as discussed above – in the framework of the MAP and CHP legislation.

Heat pumps are undoubtedly the biggest contributors to geothermal heat production, and they are smaller and more decentralised than the technologies discussed hitherto. They are becoming increasingly popular in Germany in single-family and multi-family dwellings, where they are used to provide hot water and space heating. In 2008, the number of buildings supplied by geothermal collectors, probes or similar near-surface systems rose to roughly 150,000. In the past two years alone, over 61,000 new installations have been set up. Turnover in the near-surface geothermal segment totalled EUR 850 m in 2008. According to the Bundesverband Geothermie (GtV-BV), the national geothermal association of Germany, the segment provides jobs for at least 7,000 workers.

In 2008 already, the heat pump was used for 10-20% of all buildings in the newbuild segment. Going forward, the topics of heat storage and air conditioning in newbuilds will gain importance. In existing homes, the widespread use of radiators that depend on high input temperatures limits potential sales. Retrofitting e.g. underfloor heating systems is often prohibitively expensive.

The heat pump looks set to enjoy an extra boost from the EEWärmeG, which took effect in early 2009 after protracted debate. The new law stipulates that in newbuilds a certain share of heating must be achieved via renewable sources of energy. In the case of geothermal energy, the share is at least 50%. Between 2009 and 2012 the German government will earmark up to EUR 500 m per year to subsidise heating generated on the basis of renewables. Additionally, particularly efficient heat pumps may be subsidised via the MAP.

By no means negligible is the subsidisation of heat pump systems in some areas by the electric utilities (which are often owned by the municipalities); it is very common for direct grants in the investment phase and/or indirect funding breaks via reduced electricity rates for households and small and medium-sized businesses. Subsidisation pays off for the electric utility on balance, since the pump systems use more electricity than oil heating, for instance.

Geothermal has potential in Germany

Geothermal heating has substantial potential in Germany. For hydrothermal geothermal alone the potential totals about 300 bn kWh per year, and for near-surface geothermal around 260 bn kWh, if all suitable fields are factored in.[12] This means that even the already widespread use of near-surface geothermal still harbours the theoretical potential to grow by a factor of over 100.

Necessary to keep developments in perspective

Given such fantastic prospects it is advisable, though, to look at the absolute numbers as they help to put the figures into proper perspective: in any case, the two branches of geothermal heating combined – even when their growth potential is fully tapped, but additive measures are excluded – are still by no means able to supply as much heat as is actually needed in Germany at present. Germany's Renewable Energy Agency (Agentur für Erneuerbare Energien) estimates that domestic demand for hot water, space heating and other process heat totals no less than 1,400 bn kWh per year at any rate. For this reason, geothermal heat will – despite its sizeable potential – always only be able to cover domestic requirements in a mix with other energy sources. Nevertheless, this does not detract in any way from its positive contributions to the targets of energy policy.

Comparison of geothermal probe and oil heating

	Geo-thermal probe	Oil heating
	EUR	EUR
Investment costs	18.000	12.500
Higher geo-probe investment		5.500
Operating costs per year	680	2.000
Geo-probe savings/year		1.320
Amortisation period (years)		
- Without interest payments		just under 5
- At 6% interest		just over 5

Sources: Golder Associates, DBR 12

What are the costs of direct heat use in buildings in Germany?

Typically, near-surface geothermal applications go down to depths of about 200 m, though in some cases the boreholes are twice this deep. While the air temperature in continental Europe is subject not only to substantial seasonal but also daily fluctuations, the temperatures in the crust below 10 m in depth are relatively stable. By contrast, the temperature up to 10 m in depth follows an annual pattern. It therefore makes sense to use the soil near the surface as a heat reservoir in winter and as a cold reservoir in summer in order to generate the desired heat or cold energy.

In Germany, geothermal systems have become increasingly popular over the past few years. Now, renewable resources such as geothermal energy are being given an additional boost, since as of 2009 newbuilds are required to have an increased share of their heating system based on renewables. Of particular interest in this context are heat pumps, by means of which the original underground temperature near the surface (e.g. 12°C) can often be raised to a useable temperature of 38-45°C. The efficiency of heat pumps is measured by the coefficent of performance (heat provision to input energy, usually electricity), which in many cases is between 3 and 5. Assuming a coefficient of performance of 5, this means that 2 kW of input energy for the compressor can provide some 10 kW of heat energy. Usually the heat pump is combined with concrete core

[12] See Agentur für Erneuerbare Energien (2009). Marktentwicklung Geothermie in Deutschland 2008.

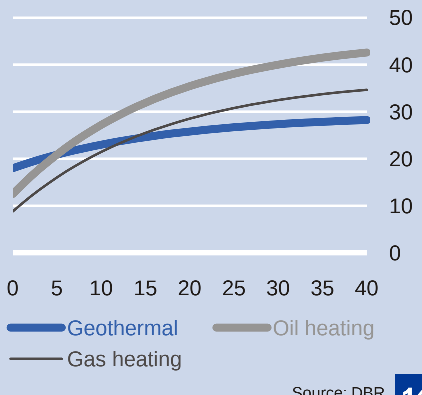
Comparison of geothermal probe and gas condensing heating

	Geo-thermal probe	Gas con-densing heating
	EUR	EUR
Investment costs	18.000	8.800
Higher geo-probe investment		9.200
Operating costs per year	680	1.720
Geo-probe savings per year		1.040
Years for amortisation		
- Without interest payments		9
- At 6% interest		13

Sources: Golder Associates, DBR 13

Geothermal investment pays off over time

Total costs over time, EUR '000



Source: DBR 14

activation or an underfloor heating system, since the input temperatures do not reach the level of traditional heat sources.

This raises the question as to the cost of direct geothermal use in Germany. The answer depends in principle on the location, architecture and building materials. However, what is even much more critical is the very different investment and fuel costs related to the relevant heating systems, since these ultimately determine the degree of profitability.

For the sake of comparison we will examine a standardised single-family dwelling with 150 square metres of living space, a heating system with 7.5 kW of installed capacity (heating needs) and an annual energy requirement of 18,000 kWh for 2,400 heating hours per year. At issue is whether and when a geothermal probe will pay off in comparison with oil heating or a gas condensing heating system. The following findings impressively document the pronounced attractiveness of geothermal heating for family homes:[13]

— Compared with oil heating, the geothermal probe is amortised as early as after 5 years, even though the investment costs for the probe, which include the outlays on assembly, storage medium and heat pump, are much higher (at EUR 18,000) than for oil heating (investment costs: EUR 12,500). Also, the operating costs are higher with the geothermal probe at 13.5 cents per kWh than with oil heating (9 cents/kWh). Nevertheless, the annual operating costs (pump fuel, maintenance and meter fee) totalling EUR 680 are EUR 1,320 lower than the EUR 2,000 for oil heating (main cost factor: heating oil). So the much lower operating costs finance the more expensive investment in just a little under 5 years. If the present value of the money is also taken into account, which makes sense, this of course has implications for the amortisation period. The length of the period changes in line with the discount rate. Assuming a rate of 6% p.a., a geothermal probe amortises itself after just over 5 years, i.e. only a little later than without discounting.

— Compared with a gas condensing heating system the geothermal probe amortises itself after about 13 years. Since the condensing system only costs EUR 8,800, the investment even costs EUR 9,200 less than a heat pump. The annual operating costs per kWh also put gas heating (7.5 cents) ahead of geothermal. But in this case, too, the geothermal probe saves a total of EUR 1,040 per year because of the higher total annual operating costs of gas heating (EUR 1,720). From this perspective, the geothermal solution would have paid for itself after 9 years. But if – more realistically – a discount rate of 6% is factored into this calculation, the geothermal probe is not amortised until after 13 years.

Since geothermal systems are normally purchased for a period of at least 20 years, the comparisons document the fundamental attractiveness of geothermal energy. Assuming that the prices of heating oil and natural gas are likely to increase over the coming years, an investment in geothermal will pay off even sooner. Moreover, economies of scale will make investments in geothermal even more interesting in future.

[13] For similar planning values for the heat pump see also dena (2007). Wärme aus Erneuerbaren Energien. Kosten sparen, Wohnwert steigern, Umwelt schonen. pp. 32-35. For details see also Golder Associates (2009). Oberflächennahe Geothermie in Deutschland. Aktuelle Themen.

Planning values for wood pellet heating*

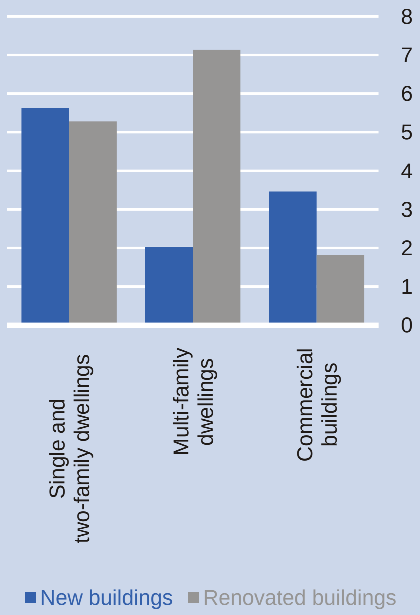
Investment costs (EUR)	10,000-14,000
Annual heating requirements (kWh)	16,000
Boiler capacity (kW)	9
Pellet consumption (t/year)	3-6
Energy costs per year (EUR)	900
Pellet storage (m^2)	8-14

*Single-family dwelling, 150 m^2 living space

Source: dena 15

Direct geothermal use: Cumulative building volume of up to EUR 25 bn by 2030

EUR bn



Source: DBR 16

Naturally, though, geothermal will have to hold its own vis-à-vis other alternative heating systems as well. These include, for example, solar thermal and wood pellet systems. Some of geothermal energy's advantages over comparable pellet systems, which cost about EUR 12,000, include the fact that geothermal needs less space, for the pellet stockpile and the burner unit require at least one room of their own. In addition, the price of pellets fluctuates in line with supply and demand. In urban areas, widespread use of pellet systems can lead, moreover, to conflicts with neighbours (e.g. owing to particulate emissions in cases of poor combustion). This is not to be expected with geothermal energy. Further advantages of geothermal over pellet systems and fossil-fuelled heating systems are time savings and lower auxiliary costs thanks to the absence of a combustion process; the lower costs result from the fact that there is no need for a chimneysweep nor for otherwise obligatory regular inspections.

How much building potential is harboured in future direct geothermal use?

To calculate the building potential entailed by the expansion of direct geothermal in Germany up to 2030, we have made individual estimates on newbuild projects and on the renovation of single and multi-family dwellings as well as on commercial buildings and then aggregated them.

In the single and two-family home segment, we took account of the fact that renovation requirements are continually growing in importance, while the number of newbuilds is actually shrinking in comparison with the low starting level. This means that around the year 2030 there will probably be not quite 110,000 new single and two-family dwellings built, while we expect over 180,000 renovations. Geothermal will be used more heavily than today in both areas. In the case of newbuilds, one single-family dwelling in three could use geothermal in 2030. And even for renovations it might be the solution for one home in four. Our calculations factored in that today geothermal solutions are chosen for 20% of new single-family dwellings, while the share for renovations is still far below 10%.

In the multi-dwelling segment we also factored in the relative loss of significance for newbuilds versus renovations. For 2030 we look for 20,000 renovations, but only 7,600 newbuilds. Moreover, the construction costs related to renovating an average multi-family dwelling to install a geothermal system are very much higher than those for newbuilds. Old multi-family dwellings are typically not designed for low-temperature systems. This means that retrofitting with geothermal systems usually requires implementing a host of additional building measures. These include issues such as insulating the shell of the building (roof, facade and cellar) and if necessary also modernising the circulation system. The construction-specific renovation costs surrounding the ex post installation of such a system in multi-family dwellings can easily run to EUR 100,000 (this contrasts with EUR 8,000 for single-family homes).[14] As in the case of single and two-family homes,

[14] The data from the Bundesverband Wärmepumpen, the German heat pump association, on the renovation costs for multi-family dwellings are exaggerated in comparison with the amount for single-family homes, for with multi-family dwellings only a complete overhaul makes economic sense. With single-family homes, by contrast, processes are often more flexible with less extensive construction measures. The measures directly linked with geothermal energy also for multi-

geothermal energy is also likely to be deployed from 2030 in one-third of new multi-family buildings, and 25% of renovations.

Newbuild will still be predominant in commercial segment in future

By contrast, newbuild projects and not renovation will still be predominant in the commercial building segment in 2030. With industrial buildings, for example, this is partly because of the fact that with changes in requirements for production processes the buildings sometimes have to be fully redesigned and built anew. However, the area of industrial buildings – partly because of its sheer size – is of major significance to the construction industry and new energy systems, as it is substantially larger than office complexes in terms of square metres. However, even in office buildings the demands on all types of new technologies, e.g. the new information and communication systems, have changed so much that often it is less expensive to put up a whole new building than to renovate an old one. Nevertheless, we have based our estimates of the latent potential not only on assumptions on the development of new buildings but also on expectations regarding the renovation of commercial real estate to integrate geothermal energy. Our estimate that the number of newbuilds will firmly outstrip the number of renovations also takes account of the long observed trend in the distributive trades, for example, that – despite stiff competition and demographically tainted business prospects – there continues to be a noticeable expansion of selling space. As discussed in the section on concrete examples of geothermal applications, the recent past has also seen an increasing number of commercial buildings that are already designed so they can be retrofitted with modern low-energy systems such as geothermal or solar energy. Based on the still very low number today it is conceivable that by 2030 some 10% of commercial buildings may (also) be based on a low-energy concept such as geothermal energy.

Low-energy concepts are on the advance

All in all, the construction volume resulting from direct geothermal use is likely to total EUR 25 bn. The three main segments will make varying contributions to this development. At EUR 11 bn, single and two-family homes will generate the lion's share, with the distribution between newbuilds and renovations roughly equal. Multi-family dwellings add EUR 9 bn; with the construction volume increasingly triggered by the renovation side. With commercial buildings, where developers are increasingly also placing their bets on geothermal energy, by contrast, the greater volume of construction is also expected to be on the newbuild side. The scale becomes clear when the volume of construction set to be generated by the use of geothermal up to 2030 totalling EUR 25 bn is set in relation to German construction volume in 2008, i.e. EUR 282.5 bn. The cumulative increase in construction volume accounts for no less than 9% or so of current building.

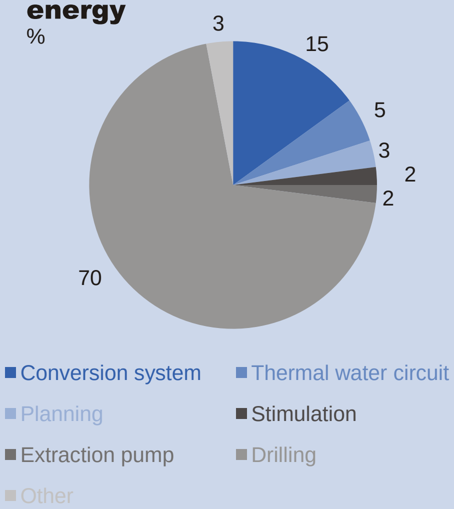
9% of current building volume

How much does it cost to generate electricity in Germany using a geothermal power plant?

The subsidisation of energy generated using geothermal sources must be weighed up against its costs in order to gain an impression of its profitability. In doing so, it immediately becomes evident that geothermal has a fundamentally different cost structure than an energy supply based on fossil fuels. While the coal, oil and gas costs are of substantial relevance for fossil-based electricity sources, with geothermal such costs are incurred at best indirectly

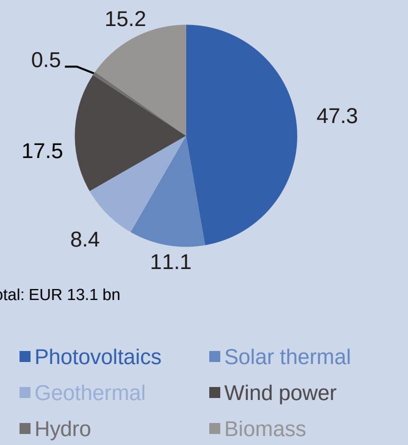
family dwellings (around 7 flats on average) are likely much lower than EUR 100,000.

Average investment cost allocation: Deep geothermal energy
%



Source: German Federal Ministry for the Environment **17**

Turnover from construction of renewable energy systems
Germany, 2008*, %



*Total: EUR 13.1 bn

Source: ZSW **18**

when the electricity consumption of the pumps is included. Much more important by far are the investment costs. Depending on the credit standing of the investor a major project could entail high interest costs. This automatically protracts the amortisation period, and can lead to the investment decision being made in favour of an alternatively fired (e.g. conventional fossil-based) energy system after all. As discussed, this is something the policymakers are attempting to counter via their incentive system.

The following cost factors determine the investment costs of a geothermal project:

— The pre-exploratory costs include seismic analyses and test drilling. They lay the basis for later injection and extraction holes.

— About 70% of the costs are swallowed up by the drilling costs, which depend on the type of rock formation and the respective geothermal gradient; the lower it is, the deeper the drilling must go. As a rule of thumb, the specific hole-drilling costs run to between EUR 1,000 and 3,000 per meter of depth, with the outlays for setting up the drilling platform, surveying, facility and equipment rentals, energy and personnel included.

— The costs of the systems above ground also include the outlays on the extraction pump and the thermal water loop. If use is only made of the heat component, the non-existence of a district heating network means that the expenditures for heat distribution must also be factored in. And in the other case that not only heat but also electricity is to be produced, the cost of the power station will be increased by the expenditures for an ancillary unit (e.g. cooling tower for an organic rankine cycle (ORC) system).

— In the absence of fuel costs, the operating costs are low. The cost of the electricity needed by the pumps and condensers themselves constitutes 20-40% of total operating costs. Naturally, there are also costs for maintenance, inspections, administration and insurance. Personnel expense is confined to monitoring and controlling the systems, so it is relatively low.[15]

The bottom line is that the efficiency of the systems is largely shaped by factors such as location, technology employed and promotion laws.

6. Which construction segments benefit from increased use of geothermal energy?

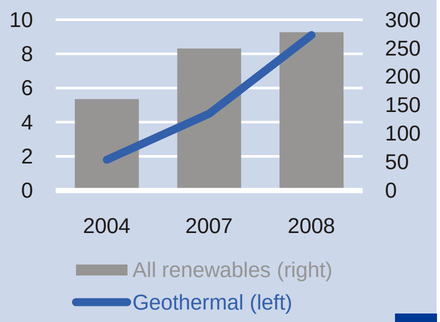
The ZSW (Zentrum für Sonnenenergie- und Wasserstoff-Forschung Baden-Wuerttemberg), a research centre for solar energy and hydrogen in southern Germany, has calculated the total turnover generated by renewable energies in Germany for 2008. It should be noted that the researchers differentiated between turnover in connection with the actual investment and that in the context of operating the systems:

— Under this definition, the setting-up of the geothermal systems (heat pumps and major plant) triggered turnover of EUR 1,100 m. This corresponds to no less than 8.4% of all investment costs involving renewable energies in that year (roughly EUR 13.1 bn).

[15] For further details see also German Federal Ministry for the Environment (2007). Tiefe Geothermie in Deutschland, pp. 20-22.

— By contrast, actual plant operation generates virtually no turnover. The ZSW puts the operating revenue of the geothermal segment at EUR 3 m. In relation to turnover generated by the operation of all renewables-based plants (EUR 15.7 bn), this is a negligibly small amount. However, it underscores the attractiveness of geothermal systems once they have been installed.

Number of geothermal energy jobs up fivefold since 2004
In '000



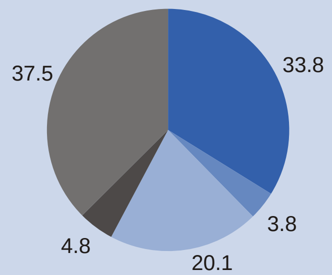
Source: AGEE 19

An interesting aspect from the construction industry's standpoint is that by far the biggest share of turnover is generated in the investment phase. Of course, the operating phase could become more interesting going forward. This is backed by the argument that most geothermal systems in Germany are still very new, particularly the ones for power generation. Add to this the tangible volume growth which has over time more or less automatically created its own markets; e.g. for maintenance, repairs and replacements. New business fields are arising here, not least for nimble service providers and skilled workers.

Boost to all construction segments, building materials and many service providers

The planning phase of geothermal projects places special demands on building engineers, architects and planning firms with geothermal expertise. In addition, it has emerged in practice that the earlier certified installers are included in the planning, the greater the success of a project. Naturally it is vital that the installation specialists understand the geological relationships and the architects and geologists the way the geothermal systems (e.g. heat pumps) function; otherwise, there cannot be a fruitful exchange of know-how.

Total turnover with investments and operation of renewable energy systems
Germany, 2008*, %



*Total: EUR 28.8 bn

Source: ZSW 20

It is crucial to the success of any geothermal project that the system is properly designed. Finding the most suitable depth and number of boreholes is the key. Moreover, it is vital to find the optimum dimensions, for too big (small) a design results in excessively high investment (operating) costs. Also important are the distances away from other probes or neighbouring systems. On balance, it is essential that the technical project partners precisely coordinate their efforts.

The drilling activities have to be performed by certified drilling businesses which, if possible, should already have a number of comparable, successful projects to their credit. An often underestimated challenge involving the drillhole activities is to adequately backfill the holes after the geothermal probe has been installed. Only when this backfilling is successful is it possible to establish the desired good thermal connection between the borehole and the probe, which ultimately also helps protect the groundwater. It is only natural that the manufacturers and suppliers of building materials such as concrete will benefit from the necessity of backfilling the holes.

Building materials industry offers innovations

The building materials industry has now responded to the various demands on backfilling materials via intelligent innovations. In the case of deep geothermal probes in particular, the backfilling materials must be as durable as possible, for this is the only way to ensure that the operating life of the probe as a whole can far exceed the amortisation period. A drywall material called ThermoCem produced from natural raw materials attains a high quality standard. It has good processing properties in comparison with conventional backfilling materials but double the degree of heat conductivity. The higher capacity of the geothermal probe increases the scope for savings on the length of the probe and raises system security.

In the past, pressure grouting the boreholes proved to be a problem in some areas. However, experienced construction companies today can largely avoid such problems by having acquired greater expertise and empirical knowledge.

Germany's plant and mechanical engineering companies are benefiting in different ways from the geothermal trend. Generally, German companies offer all types of technology for geothermal energy. In the volume market for smaller-scale standard pumps the German manufacturers of course face fierce competition from foreign (low-cost) suppliers. By contrast, the margins on tailor-made large pumps which require more know-how are usually a bit more favourable. The German market for deep geothermal systems, by contrast, is still not very well developed. Nonetheless, German companies have a command of and already produce the necessary technologies (e.g. for deep drilling and laying pipe systems), since they are sought-after suppliers to the global oil and gas companies that are increasingly exploring for oil and gas fields at greater depths – and over the past few years even offshore.

Planning and consultancy firms as well as installers will benefit

The number of planning and consultancy firms has climbed steadily over the past few years. Moreover, there are more and more certified installers who know how to deal with the sophisticated issues surrounding geothermal energy. And last, but not least, administrative access has been made much easier thanks to simplified and generalised authorisation procedures.

New opportunities for financial institutions

As the degree of diffusion of the new technologies increases additional business opportunities for third parties are also arising beyond the construction sector; the spectrum ranges from the lending institutions and the insurance companies covering the potential risks, right up to the specialised legal experts for disputes which may unexpectedly crop up here or there during the construction or operation of the facility.

7. Concrete examples of geothermal applications

There appear to be virtually no technical limits on the possible spectrum of geothermal applications. The reason is that geothermal energy can be used both directly and indirectly. By transforming it into secondary energy in the form of electricity, geothermal is deployable practically everywhere. The restrictions tend to be more economic in nature, because – as discussed earlier – the transport and consumption of electricity generated by geothermal energy does not pay off in every location by any means.

Four application areas for geothermal energy

The following list of concrete applications is designed to give an idea of the broad spectrum available, but cannot claim to be comprehensive. The applications can be broken down roughly into four fields: first, the construction of single-family and smaller multi-family dwellings, which may already be considered conventional. Second, highrise construction, where the integration of geothermal is only just beginning. Third, larger residential and commercial buildings. And, fourth, the multifaceted spectrum of public buildings.

In the chief area of deployment to date, i.e. single-family and smaller multi-family dwellings with underfloor heating, two interesting options, geothermal probes and horizontal collectors, are already to be found in relatively widespread use. In Switzerland, about 80% of all new single-family homes are equipped with heat pumps. The key factor of relevance for the area to be fitted with a geothermal collector is the heating load required, and not so much the capacity of the heat pump.

More can be done in highrises – not just in Frankfurt

In the second application area, highrise buildings, a look at Frankfurt can be very informative. In Germany, Frankfurt is considered to be the city of skyscrapers. However, it is precisely skyscrapers that so far have not been paragons of energy efficiency. Still, this is the very area where the way to the future is being paved: the city has set itself ambitious targets with its new *Hochhausrahmenplan,* or "general highrise plan". The plan names 15 locations, for instance, at which a maximum of 22 new highrise buildings may be erected. In concrete terms, Frankfurt intends to far exceed the requirements of energy-related building regulations. For instance, the primary energy requirements of new highrises must not exceed 150 kWh per square metre of gross storey area per year. The scale of the project becomes obvious when one realises that the first tower block in Germany with explicit ecological pretensions still consumes about 500 kWh per square metre every year.

The fact that the Frankfurt targets are by no means out of this world is currently documented not only by the thorough renovation of Deutsche Bank's twin-tower headquarters, but also by the plans for the KfW's new building, the *Westarkade* (15 storeys, 57 m). Thanks particularly to the intelligent integration of geothermal energy, it will remain under 100 kWh per m^2/year in its primary energy requirements; this is an impressive one-third less than the city's newly proclaimed objective.

More and more builders are discovering the advantages of geothermal energy

Over the past few years more and more builders of large complexes have been discovering the advantages of geothermal energy. Thanks to the use of building components required for structural reasons anyway, such as site-mixed concrete piles for the foundation or for the lining as energy piles, the investment costs for energy consumption can be kept down. In this case, heat-exchanger pipes are built into the site-mixed piles attached to the reinforcing cage. The pipes connect the interior with the aquifer in which a carrier fluid circulates to equalise the temperature. Generally, the underground serves as a storage medium for cold and heat, which may be needed to differing degrees depending on the season and time of the day. Energy pile foundations were already used years ago in Frankfurt in the Mainforum, Main Tower and Gallileo skyscrapers, and now the latest project is the new PalaisQuartier complex on an area of 17,400 m^2. As a matter of fact, major building sites in other cities such as Cologne (Rheinauhafen project) and Vienna (underground railway lot U2/1) are also using energy piles in the meantime.

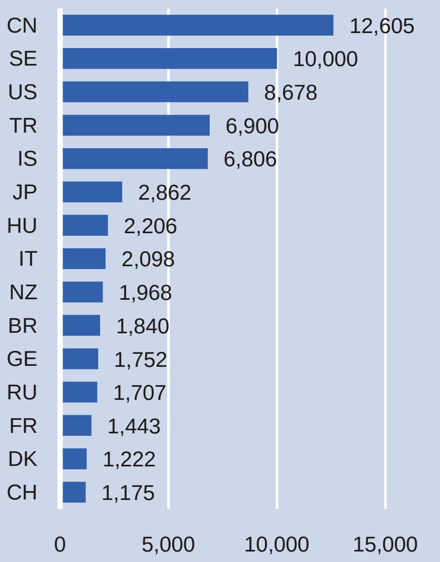
Many combinations for commercial buildings

In the third application area, that of larger residential and commercial building complexes, there are numerous possibilities for combinations with other technologies and measures:[16]

— In the Black Forest, for instance, a new area has been zoned for the construction of 14 houses, and the use of geothermal energy there is by no means confined to more traditional applications such as the heating and cooling of buildings. Geothermal applications will also keep roads (and also some stairways) cool

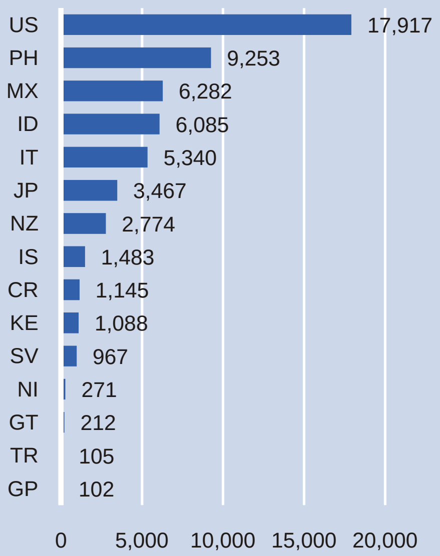
[16] For more on the first three examples in German, see Hauptverband der Deutschen Bauindustrie (2009). Bauen und Klimaschutz. Was die Bauindustrie leisten kann. Berlin.

Top 15 of direct geothermal use
2005, GWh/year



Source: I. Fridleifsson, R. Bertani et al. **21**

Top 15 of geothermal power generation
2005, GWh/year



Source: I. Fridleifsson, R. Bertani et al. **22**

in summer and free of ice and snow in winter. This means that, in winter, roads and walkways do not need to be cleared, while in summer there is less wear and tear on the (less soft) asphalt, prolonging its useful life.

— In the context of the energy-related renovation of residential and commercial buildings, one building in Bremen is particularly striking (the new head office of Rainer Brach GmbH & Co. KG) with its 100% heating and cooling via geothermal energy. This makes it the first German building of its size to be fully independent of outside supply. At its core is a heat pump system which uses 54 geothermal probes linked in a network that go down as much as 75 m into the crust. While the concrete core activation system is responsible for the baseload heat, a convection system covers the peak load.

— In Bietigheim-Bissingen, the new Dürr Campus combines no less than five sustainable energy sources at once. Besides a photovoltaic system, process heat from the neighbouring technology centre and two natural-gas-driven CHP units, there is a system of geothermal heat exchangers to ventilate the buildings and 30 geothermal probes to regulate the temperature of the interior. The “flagship” project could help achieve the breakthrough for modern energy, environmental and construction technology.

— The central administrative office of Süddeutscher Verlag, which was one of the first German office buildings registered for LEED (Leadership in Energy and Environmental Design) certification, relies on the thermal activation of concrete base plate, supporting pillars and 36 uncased piles. The uncased concrete piles range up to 25 metres in depth and make the ground temperature of 13°C useable via thermal activation.

— The firm Neumann Architekten GmbH recently completed the world‘s first integrated training centre for helicopter pilots, emergency doctors and paramedics at the air search and rescue base in Bonn-Hangelar. The entire building complex, i.e. the ADAC helicopter training centre with its two flight simulators and the training centre for first-aid workers and doctors with its medical simulator, is supplied with heating and cooling by 30 geothermal probes. This is a good example of modern flight operations buildings and buildings for special purposes using geothermal energy.

In many cases, budget restrictions in the investment phase currently prevent the immediate application of modern low-energy concepts in buildings for industry and small and medium-sized enterprises. For this reason, innovative architects have created a two-stage solution: in the first stage, the technical building systems are geared to future-oriented low-energy concepts. However, the system initially continues to depend on conventional fuels such as heating oil or natural gas. It is not until the second stage that, when the time is ripe (i.e. when there are no more budget restrictions and/or the traditional fuels have increased in price), the energy systems are upgraded or retrofitted for geothermal energy (and possibly solar energy). Two relatively new building completions show that the idea has already struck a chord. For example, Lufthansa Technik‘s new maintenance hangar and the new administration building of Helvetia, the insurers (both in Frankfurt), were built in such a way that it is relatively easy to upgrade, or retrofit, them for a geothermal energy supply. The reason is that the buildings’ technical systems were planned from the outset for this forward-looking type of energy use.

The fourth field of application, public buildings in the broader sense, is also typically marked by a large degree of diversity.

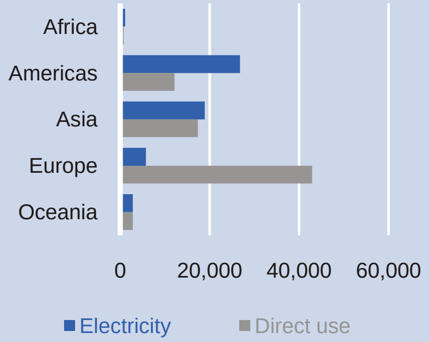
— The building of a comprehensive school in Rodenkirchen, a district of Cologne, impressively illustrates the simple maths of energy efficiency, as geothermal (heat pump extracts energy from groundwater), photovoltaics and insulation are intelligently combined.

— A geothermal heat pump is enabling the construction of Germany's first heatable bridge, which is being built in Schleswig-Holstein (near Berkenthin). The 59 m bridge across the Elbe-Lübeck Canal will use geothermal energy in winter to keep the roadway free of ice and snow. In summer, the high temperature of the road surface can be lowered, increasing its useful life.

— Innovative applications are emerging in the area of transport infrastructure. The heating of train platforms and innovative systems for heating the points are still in their infancy, but concrete projects already exist. There is already a Deutsche Bahn train station (Bad Lauterbach-Barbis, Harz) whose platforms/facilities are heated by geothermal energy. In this case – as with roadways – savings are achieved on salt, snow removal equipment and personnel. At the same time, those waiting can enjoy increased comfort. It follows the same principle as underfloor heating: an integrated, closed-loop pipeline system.

— A further innovative approach is to tap the energy potential of tunnels. On the rail line between Munich and Verona, in the community of Jenbach, Austria, a stretch of tunnel is being lined with energy tubbings and linked with a heat pump. This enables heat to be tapped from the ground-coupled construction and brought to the surface. The heat energy extracted from the tunnel is then supplied to individual buildings such as the town's public works facility. When infrastructure and construction measures are due anyway, the result is an extra dividend, so to speak.

Global generation of geothermal energy
2005, GWh/year



Source: I. Fridleifsson, R. Bertani et al. 23

8. Geothermal use in Europe and the world

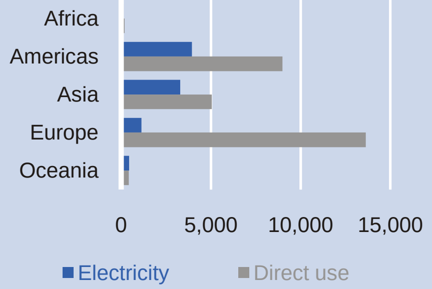
Every five years the International Geothermal Association (IGA) stages its World Geothermal Congress (WGC), where the data for all countries around the world are updated. The last global update was performed for the WGC 2005 (Antalya, Turkey). The data for Europe is somewhat more up to date since a European Geothermal Congress (EGC) is held every three years, most recently in 2007 (Unterhaching, Germany). In short, the geothermal statistics leave room for improvement.

Geothermal energy is a growth segment worldwide

Since electricity was generated by steam power from the Earth for the first time ever in 1913, the limits on its use have virtually evaporated.

— Worldwide, Europe is a leading player in the direct use of geothermal heat. This holds for both installed capacity, where Europe ranks ahead of the Americas and Asia, as well as for

Global installed geothermal capacities
2005, MW



Source: I. Fridleifsson, R. Bertani et al. 24

actual direct use, where Asia is in second place and the Americas follow in third.

— By contrast, the Americas are predominant in the indirect use of geothermal energy for generating electricity. Asia and Europe follow some way behind for both installed capacity and electricity production.

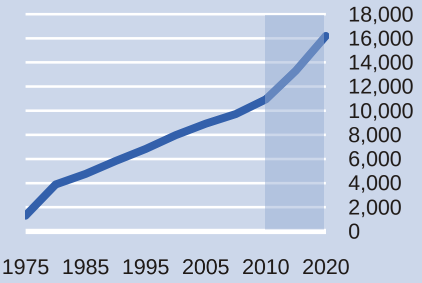
Large share of geothermal applications in volcanic regions

Thanks to technological progress the global production of geothermal electricity has grown very dynamically in the past few decades. While there had been only 1,300 MW of installed capacity in 1975, the reading topped 9,700 MW by 2007. This is in fact an increase of more than 600%. At present, 24 countries use geothermal energy to generate electricity. Measured in terms of installed capacity, the US is the leading generator, ahead of the Philippines, Indonesia, Mexico and Italy.

Geothermal accounts for a particularly large share of power generation in countries and regions with considerable volcanic activity, given relatively easy access to very high temperature fields. In the six countries of El Salvador, Kenya, the Philippines, Iceland, Costa Rica and Nicaragua some 10-22% of national power generation is based on geothermal energy. In Indonesia, too, the country considered to offer the greatest potential, geothermal is expected in future to supplant much of the power generation mix now dominated by fossil fuels (share today: 7%).[17]

Geothermal electricity capacity growing dynamically

Global installed capacity (MW)



Sources: R. Bertani, DBR 25

Until 2020, the capacities for geothermal electricity generation are likely to increase by 4% p.a., so this should bring the global available capacity at that point to over 16,000 MW. Capacity is thus set to grow by around two-thirds in the period 2007 to 2020. The new type of power generation will receive stimuli in the medium term from the general uptrend in the cost of generating electricity via competing fossil fuels.

Direct geothermal use is expected to post somewhat higher growth rates up to 2020 because of easier access than for use in generating electricity. In this context, the area of use likely to play an even more significant role going forward is buildings; in the industrial countries alone this is where about 35-40% of all primary energy is consumed. The provision of hot water and heating accounts for about 30% of total energy demand in Europe. And their share of energy consumption in buildings comes to 75%. As already shown, the greater use of geothermal makes sense from both an ecological as well as an economic standpoint.

The two main areas of use for direct geothermal will develop at different rates worldwide up to 2020:

— The capacities of the geothermal segment that uses heat pumps are likely to increase by 10% p.a. Heat pump technology is now tried and tested and virtually ideal for heating and cooling management in many parts of the world.

Direct geothermal use continuing to expand

— Direct geothermal without heat pumps will probably grow at only half the pace, at 5% p.a. Many countries, such as China, still harbour great potential since they have vast areas of low-temperature fields. These resources are increasingly being tapped because of the noticeable increase in the price of different fuels over the past decade.

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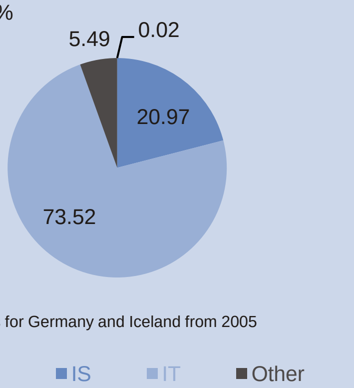
[17] See Fridleifsson, Ingvar, Ruggero Bertani et al. (2008). The possible role and contribution of geothermal energy to the mitigation of climate change. p. 10.

This means that, on balance, the capacities of direct geothermal are likely to increase from 28,239 MW to nearly 91,000 MW during the period 2005 to 2020, equal to expansion of around 220%.[18] Thanks to the above-average growth the share of geothermal heat pumps will rise from 54% at the start of this period to 71% at the end of it. By contrast, there will be a relative loss of significance for direct geothermal without heat pumps (from 46% to 29%); this segment can withstand the decline, though, since it is continuing to expand noticeably in absolute terms.

Italy predominant in geothermal power generation in Europe

2007*, %

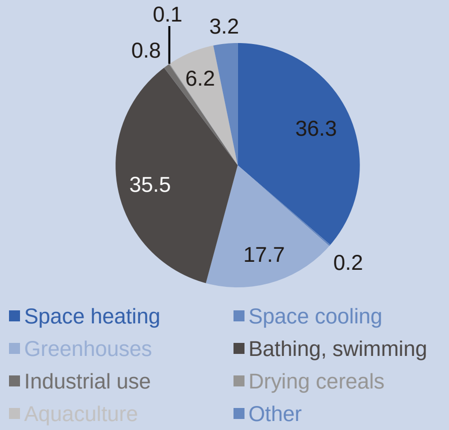


*Readings for Germany and Iceland from 2005

Source: M. Antics & B. Sanner **26**

Application of direct geothermal energy

Europe, direct use in 2007, %



Source: M. Antics & B. Sanner **27**

Geothermal widely used also in Europe

Depending on the geological prerequisites, geothermal is to be found in Europe in virtually all areas of application.

— The clear leaders in geothermal power generation Europe-wide are Italy and Iceland. Combined, these two countries account for roughly 90% of total capacities and actual generation; and this holds even if Russia is included in the European statistics, despite its facilities being in Kamchatka (i.e. actually a part of Asia).

— By contrast, direct geothermal use is common in very many more countries. In a European comparison, Sweden, Iceland and Turkey are the leading players and account for a combined 50% of capacities. Thanks to a period of strong expansion recently, Germany commands a respectable fourth place ahead of Hungary, Italy, Switzerland and Norway.

Geothermal energy is increasingly being used directly in Europe also for heating purposes. This application now carries roughly the same weight as the more traditional segment of bathing and swimming facilities, for a combined total of 72%. Direct use is also widespread in greenhouses (18%) and aquacultures (6%).

9. Conclusion: Geothermal offers considerable potential

In the light of climate change and the foreseeable scarcity of conventional fuels, geothermal energy offers new opportunities for the construction industry. The construction volume triggered by this renewable energy source of up to EUR 25 bn by 2030 is indeed impressive. Moreover, the greater use of geothermal energy makes sense in both macroeconomic and microeconomic terms; overall, it contributes positively towards the mitigation of climate problems. At the individual level, modern concepts that also tap the potential of geothermal energy are an intelligent response not least for builders to the real prospect of higher energy prices in future.

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[18] For an even more optimistic assessment see for example Fridleifsson, Ingvar, Ruggero Bertani et al. (2008). p. 23/24.

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ISSN 1612-314X

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Printed by: HST Offsetdruck Schadt & Tetzlaff GbR, Dieburg

ISSN Print: 1612-314X / ISSN Internet and e-mail: 1612-3158