Category		Title
NFR:	**1.B.3**	**Geothermal energy extraction**
SNAP:	**0507**	**Geothermal energy extraction**
ISIC:		
Version	**Guidebook 2009**	
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Contents

1 Overview

This chapter deals with the geothermal energy extraction. Emissions from this source category are very small, especially when comparing to emissions from the burning of fossil fuels.

2 Description of sources

2.1 Process description

Geothermal energy is defined as heat from the Earth. It is a clean, renewable resource that provides energy in the United States and around the world. It is considered a renewable resource because the heat emanating from the interior of the Earth is essentially limitless. The heat continuously flowing from the Earth's interior is estimated to be equivalent to 42 million megawatts of power (Energy and Geosciences Institute, 1997). The interior of the Earth is expected to remain extremely hot for billions of year to come, ensuring an inexhaustible flow of heat.

2.2 Techniques

Geothermal energy can be used for electricity production, for direct use purposes, and for home heating efficiency (through geothermal heat pumps). The explanations below are taken from the website of the Geothermal Energy Association (www.geo-energy.org/aboutGE/basics.asp).

Geothermal electricity: to develop electricity from geothermal resources, wells are drilled into the natural hot water or steam, known as a geothermal reservoir. The reservoir collects many meters below the groundwater table. Wells bring the geothermal liquid to the surface, where it is converted at a power plant into electricity (see below for more information about the different types of geothermal electricity production).

Direct use: direct use applications utilize geothermal heat without first converting it to electricity, such as for space heating and cooling, food preparation, industrial processes, etc. People have been taking advantage of direct use applications for centuries, with documentation of early uses tracing back to ancient Roman times.

Geothermal heat pumps (GHPs): geothermal heat pumps are devices that take advantage of the relatively constant temperature of the Earth's interior, using it as a source and sink of heat for both heating and cooling. When cooling, heat is extracted from the space and dissipated into the Earth; when heating, heat is extracted from the Earth and pumped into the space. Geothermal heat pumps can be used anywhere on Earth, and are considered by the Environmental Protection Agency (EPA) to be one of the most efficient heating and cooling systems available. For more information about GHPs, please visit www.geo-exchange.org.

2.3 Emissions

Steam from major geothermal fields has a content of non-condensable gases (CO_2, H_2S, NH_3, CH_4, N_2 and H_2) that ranges from 1.0 to 50 g/kg of steam (Barbier, 2002).

Carbon dioxide is the major component, but its emission into the atmosphere is well below the figures for natural gas, oil or coal-fired power stations per kWh generated (Barbier, 2002).

Hydrogen sulphide is the air pollutant of major concern in geothermal development. Its emissions generally range between 0.5 and 6.8 g/kWh. H_2S is oxidised to sulphur dioxide and then to sulphuric acid, and may cause acid rain. However, a direct link between H_2S emission and acid rain has not been established. Without abatement, the specific emissions of sulphur from geothermal power plants are about half of those from coal-fired plants. Geothermal plants do not emit nitrogen oxides; fossil fuel plants on the contrary exhaust these toxic chemicals (Barbier, 2002).

Geothermal gases in steam may also contain ammonia (NH_3), traces of mercury (Hg), boron vapours (B), hydrocarbons such as methane (CH_4), and radon (Rn). Boron, ammonia, and to a lesser extent mercury, are leached from the atmosphere by rain, leading to soil and vegetation contamination. Boron, in particular, can have a serious impact on vegetation. These contaminants can also affect surface waters and impact aquatic life. Geothermal literature reports that mercury emissions from geothermal power plants range between 45 and 900 micrograms/kWh, and are comparable with mercury emissions from coal-fired power plants. Ammonia is discharged into the atmosphere in concentrations between 57 and 1 938 mg/kWh, but due to atmospheric processes it is dispersed rapidly (Barbier, 2002).

2.4 Controls

No specific control options are available.

3 Methods

3.1 Choice of method

Only a Tier 1 default approach is presented in this chapter.

3.2 Tier 1 default approach

3.2.1 Algorithm

The Tier 1 approach for emissions from this source category uses the general equation:

$$E_{pollutant} = AR_{production} \times EF_{pollutant} \quad (1)$$

This equation is applied at the national level, using annual national statistics on the extraction of geothermal energy from the earth.

The Tier 1 emission factors assume an averaged or typical technology and abatement implementation in the country and integrate all different sub-processes within the geothermal energy extraction process.

3.2.2 Default emission factors

Default emission factors are presented in Table 3-1 below. Emission factors result from measurements performed by the Environmental Protection Agency of the Toscana region, Italy (ARPAT, 2007). This region is the main producer of geothermal energy in Europe.

Table 3-1 Tier 1 emission factors for source category 1.B.3 Geothermal energy extraction

Tier 1 default emission factors					
	Code	Name			
NFR Source Category	1.B.3	Geothermal energy extraction			
Fuel	NA				
Not applicable					
Not estimated	NOx, CO, NMVOC, SOx, TSP, PM10, PM2.5, Pb, Cd, Cr, Cu, Ni, Se, Zn, Aldrin, Chlordane, Chlordecone, Dieldrin, Endrin, Heptachlor, Heptabromo-biphenyl, Mirex, Toxaphene, HCH, DDT, PCB, PCDD/F, Benzo(a)pyrene, Benzo(b)fluoranthene, Benzo(k)fluoranthene, Indeno(1,2,3-cd)pyrene, Total 4 PAHs, HCB, PCP, SCCP				
Pollutant	**Value**	**Unit**	**95% confidence interval**		**Reference**
			Lower	**Upper**	
NH3	2100	g/MWh electricity produced	800	9000	ARPAT (2007)
Hg	0.44	g/MWh electricity produced	0.26	1.3	ARPAT (2007)
As	0.025	g/MWh electricity produced	0.02	0.045	ARPAT (2007)

For all other pollutants, no emission factors are available. Emissions may be assumed negligible if no better information is available.

3.2.3 Activity data

The total annual energy production from geothermal power plants in a country is the necessary activity statistics.

3.3 Tier 2 technology-specific approach

Not available for this source category.

3.4 Tier 3 emission modelling and use of facility data

Guidance on Tier 3 emission estimates is not available for this source category. However, due to the differences in chemical composition of the geothermal fluid, it is good practice to use site dependent emission factors (obtained by sampling) when these are available.

4 Data quality

There are no source specific issues in this source category.

5 References

Barbier E. (2002). 'Geothermal energy technology and current status: an overview, Renewable and Sustainable Energy Reviews 6, 3–65.

Energy and Geosciences Institute, University of Utah. Prepared by the U.S. Geothermal Industry for the Renewable Energy Task Force (1997). Briefing on Geothermal Energy, Washington, D.C.

ARPAT (2007). Agenzia Regionale per la Protezione Ambientale della Toscana, Monitoraggio

delle aree geotermiche. Rapporto Finale, Anno 2006, Novembre 2007.

6 Point of enquiry

Enquiries concerning this chapter should be directed to the relevant leader(s) of the Task Force on Emission Inventories and Projection's expert panel on combustion and industry. Please refer to the TFEIP website (www.tfeip-secretariat.org/) for the contact details of the current expert panel leaders.