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## Data Article

## Data analysis of atmospheric emission from geothermal power plants in Italy



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## ABSTRACT

Electric production from geothermal energy is still little exploited compared to its large potential and to the World renewable energy production from other sources. Some countries have exploited this energy source in order to enhance their transition to renewables. Today the largest geothermal energy producers in the world are New Zealand, U.S.A, Mexico, Philippines, Italy, Iceland, and, more recently, Turkey (Geothermal, 2012).

Differently from other renewable sources, geothermal energy produces impacts on the environment that are very site-specific because of the nature of the resource and its geological characteristics Bravi et al.,2010; Parisi et al.,2013. In the same way, the atmospheric emissions associated to the activity of geothermal power plants for electric or heat production (mainly CO<sub>2</sub>, H<sub>2</sub>S, NH<sub>3</sub>, Hg, CH<sub>4</sub>) are also site-specific. In fact, due to technological and geographical differences among the geothermal installations operating all over the World, it is quite impossible to identify and attribute typical emission patterns, to perform forecasts valid for multiple sites or to collect universal data. Furthermore, it is virtually impossible the comparison among technologies located in different regions or countries. Definitively, inventories of primary data, as accurate and complete as possible, are essential to

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correctly evaluate the peculiarities of geo-thermoelectric energy production Parisi et al.,2018.  
Data reported here try to fill the gap in respect to the Italian situation. To this end, a complete survey of the atmospheric emissions from all the geothermal power plants in operation in the Tuscany Region is performed. In addition to data reporting, also some statistical analysis is performed to process data and to operate a further level of simplification which averages the emissions on the basis of geothermal sub-areas.  
The data collected is related to the research article “Life cycle assessment of atmospheric emission profiles of the Italian geothermal power plants” Parisi et al.,2019.

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Specifications Table

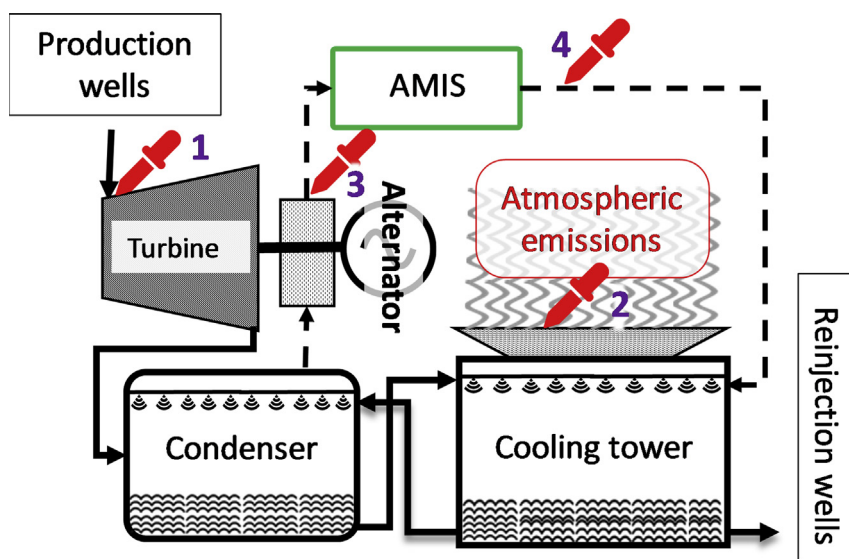
Subject area	Atmospheric emissions
More specific subject area	Atmospheric emissions from geothermal power plants based on flash and dry steam technology
Type of data	Tables and figures
How data was acquired	Environmental sampling at power plant and analytical determination through different standardized methods
Data format	Raw and processed
Experimental factors	Emissions data are collected and tabulated according to a common scheme to allow an easier analysis of the information
Experimental features	Samplings are performed by means of standardized methods, as well as chemical determination of the pollutants
Data source location	Tuscany Region (Italy): geothermal areas in the provinces of Grosseto, Pisa and Siena
Data accessibility	Data are partially reported here and partially accessible in Mendeley data in order to keep it updated and provide larger details ( <a href="https://doi.org/10.17632/gvpy69796n.1">https://doi.org/10.17632/gvpy69796n.1</a> )
Related research article	Parisi et al. “Life cycle assessment of atmospheric emission profiles of the Italian geothermal power plants”, Journal of Cleaner production, 234, 881–894 (2019)

Value of the data

- Data repository concerning environmental emissions information connected with geo-thermoelectric activity in Italy.
- Data are related to the operational phase of the Italian 34 Italian geothermal power plants that are all located in the Tuscany Region and spread over several years of samplings activity performed by the Regional Agency for Environmental Protection.
- Basic statistic elaboration is applied to illustrate the distribution of the emissions during the historical series and to generate average scenarios.

1. Data

Data reported here concern the atmospheric environmental emissions generated by the activity of all the geothermal power plants in operation nowadays in Italy, more precisely in the Tuscany Region [2–5]. The on-site saplings activity is performed by the Regional Agency for Environment Protection of Tuscany (ARPAT). A skecth of the most important sampling points identified by ARPAT is showed in Fig. 1. Since sampling activities are not performed at regular time intervals, in Table 1 there is reported the actual state of samplings. Actually, the information described in this paper are only referred to data reported in Table 1.

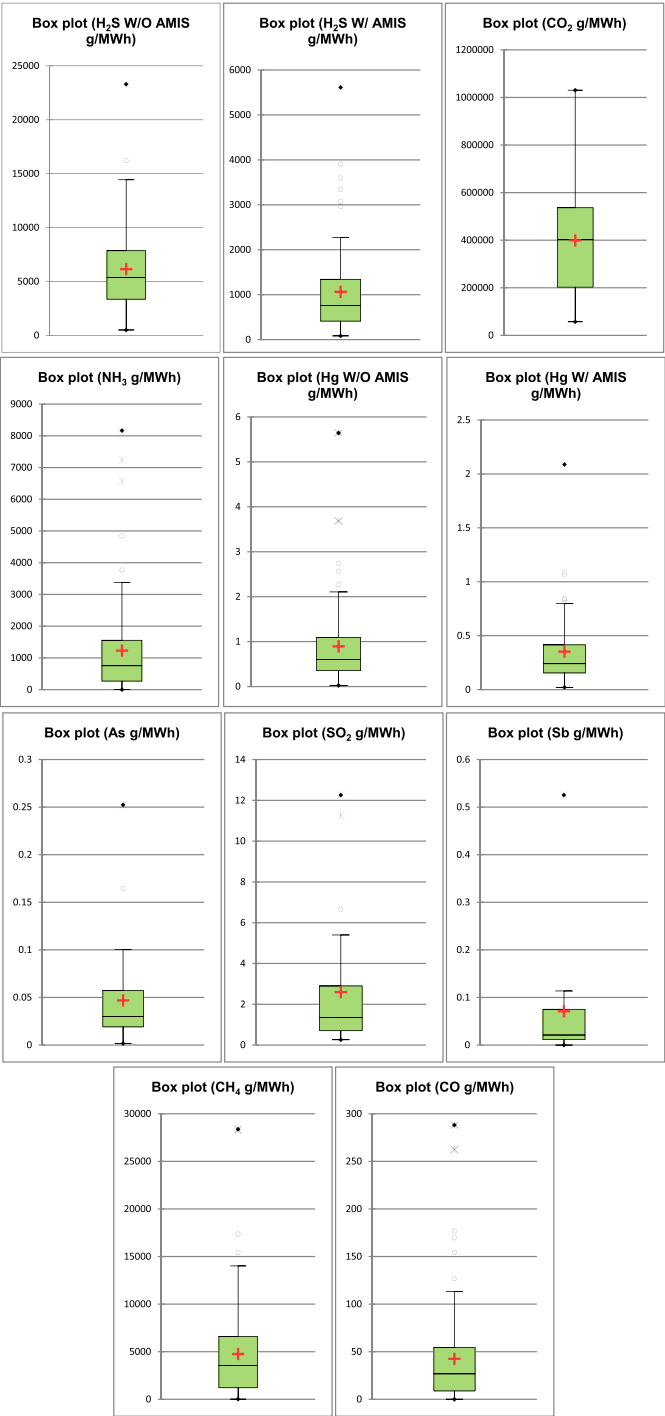


**Fig. 1.** Sketch of the geothermal power plant configuration; the red pipettes show the most important sampling points identified by ARPAT.

Table 1

The table shows the temporal distribution of sampling campaigns detailed in the ARPAT reports. F: most of the pollutants are determined; P: only few of the pollutants are determined.

	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Bagnore 3	F		F	F	F		F	F		F	F	F	F	F	F
Bagnore 4														F	F
Carboli 1		F							F			P	F		
Carboli 2															
Cornia 2			F									F	F		
Monteverdi 1		F					F					P			
Monteverdi 2															
Nuova Lago				F							P				
Nuova Lagoni Rossi												F			
Nuova Monterotondo									F						F
Nuova San Martino			F			F		F				P		F	
Nuova Sasso									F			P			F
Nuova Serrazzano		P												F	
Selva 1		P											F		
Farinello				F						P	F	F		F	
Nuova Castelnuovo		P			F						F		F		
Nuova Gabbro								F			F				
Nuova Larderello 3							F				F		F	F	
Nuova Molinetto			F			F						F			
Sesta 1			F						F						
Vallesecolo				F						F	F	F	F	F	
Piancastagnaio 3	P		P	F	F	F	F	F					F		P
Piancastagnaio 4	P						P			P			F		P
Piancastagnaio 5	P					F		F		F		P	F	P	
Chiusdino 1										F			F		P
Nuova Radicondoli								F			P		F		
Pianacce								P		P					
Rancia 1									F				F		
Rancia 2						F							F		
Travale			F	F	F				F			P			



**Table 2**

Emissions calculated for the average scenario based on data collected from all the Italian geothermal fields.

	Actual Scenario	Scenario without AMIS
H <sub>2</sub> S (g/h)	1.34E+03	6.12E+03
CO <sub>2</sub> (g/h)	4.83E+05	4.85E+05
SO <sub>2</sub> (g/h)	1.99E+00	
NH <sub>3</sub> (g/h)	1.23E+03	3.07E+03
As (g/h)	4.00E-02	4.00E-02
Sb (g/h)	4.10E-02	4.11E-02
Hg (g/h)	3.72E-01	9.42E-01
CH <sub>4</sub> (g/h)	7.10E+03	7.12E+03
CO (g/h)	4.96E+01	4.98E+01
Produced Energy (MWhe)	1	1

Due to the large amount of data, a database containing all the sampling values has been generated and is hosted on Mendeley Data [6]. The latter will be updated as soon as new emissions information will be available. In addition to raw data, a basic statistical manipulation has also been performed in order to assess data quality (Table 3 and Fig. 2) and to elaborate average emission patterns (Table 2) [2–5].

## 2. Experimental design, materials, and methods

Raw data are collected from the public reports provided by the Regional Agency for Environment Protection of Tuscany (ARPAT). The public agency conducts several sampling campaigns each year to fulfil the regulation about the atmospheric emissions control of the power plants [7].

The analysis is performed in compliance with international and approved national standards. This methodological approach ensures the robustness and validation of data [8–11]. Fig. 1 describes a simplified scheme of a hydrothermal flash geothermal plant operating in Tuscany: the red pipette are the sampling points identified by ARPAT [6,12].

The sampling point n° 1 is used to record chemo-physical parameters of the entering fluids (pH, temperature, mass flow, pressure, etc.) as well as the chemical composition (H<sub>2</sub>S, CO<sub>2</sub>, CH<sub>4</sub>, NH<sub>3</sub>, Hg, As, Sb). At the sampling point n°2, in the area of the evaporative tower (in this section the extracted gaseous fraction, which is conducted into the towers, is deviated to avoid doubling the emissions), the emissions of pollutants dissolved into the drift are determined (H<sub>2</sub>S, NH<sub>3</sub>, Hg, As, Sb), as well as chemo-physical parameters (pH, air temperature, wet bulb temperature, air mass flow, etc). Sampling points n°3 and 4° only account for the gaseous fraction of the emissions; the pollutants determined in this sampling points are H<sub>2</sub>S, CO<sub>2</sub>, CH<sub>4</sub>, NH<sub>3</sub>, SO<sub>2</sub> (resulting from the catalytic oxidation of H<sub>2</sub>S) and Hg. As the abatement system (AMIS) is employed for the gaseous phase, the chemical determination is performed before and after the process to determine the abatement ratio [13].

The complete dataset of atmospheric emissions is loaded and publicly available in Mendeley Data [6]. Information stored in the repository will be continuously updated as soon as new sampling will be available, in order to expand and keep updated the environmental information disseminated by ARPAT.

## 3. Data processing

Basic data processing is performed in order to average the emissions and obtain more general descriptions.

For each power plant the median of the samplings for each pollutant is calculated, then the g/h values are converted to g/year and weighted over the average electricity produced [1] to obtain emissions expressed as g/MWh. In case of emissions which depend on the abatement system (AMIS),

**Fig. 2.** Box plots describing distributions of data used. Lowest and highest whiskers represent 1.5 IQR, green box is delimited by the 1st and 3rd quartile divided by the median. Circles and stars are near and far outliers respectively, while the red cross is the mean value.

**Table 3**

Statistical descriptors of the data used.

Statistic	H <sub>2</sub> S W/AMIS g/ MWh	H <sub>2</sub> S W/O AMIS g/ MWh	CO <sub>2</sub> g/ MWh	SO <sub>2</sub> g/ MWh	NH <sub>3</sub> g/ MWh	As g/ MWh	Sb g/ MWh	Hg W/AMIS g/ MWh	Hg W/O AMIS g/ MWh	CH <sub>4</sub> g/ MWh	CO g/ MWh
Number of observations	463	463	463	463	463	463	463	463	463	463	463
Minimum	8.3E+01	5.0E+02	5.7E+04	2.6E-01	4.2E-01	1.7E-03	1.8E-05	2.1E-02	2.5E-02	1.6E+01	2.0E-03
Maximum	5.6E+03	2.3E+04	1.0E+06	1.2E+01	8.2E+03	2.5E-01	5.3E-01	2.1E+00	5.6E+00	2.8E+04	2.9E+02
1st Quartile	4.1E+02	3.4E+03	2.0E+05	7.0E-01	2.7E+02	1.9E-02	1.2E-02	1.6E-01	3.5E-01	1.2E+03	8.8E+00
Median	7.6E+02	5.4E+03	4.0E+05	1.4E+00	7.5E+02	3.0E-02	2.1E-02	2.4E-01	6.0E-01	3.5E+03	2.7E+01
3rd Quartile	1.3E+03	7.9E+03	5.4E+05	2.9E+00	1.6E+03	5.7E-02	7.5E-02	4.1E-01	1.1E+00	6.6E+03	5.4E+01
Mean	1.1E+03	6.1E+03	4.0E+05	2.6E+00	1.2E+03	4.7E-02	7.1E-02	3.5E-01	8.9E-01	4.8E+03	4.3E+01
Variance (n-1)	9.7E+05	1.8E+07	4.9E+10	9.1E+00	2.3E+06	2.1E-03	1.7E-02	1.1E-01	7.9E-01	2.2E+07	2.7E+03
Standard deviation (n-1)	9.8E+02	4.2E+03	2.2E+05	3.0E+00	1.5E+03	4.6E-02	1.3E-01	3.2E-01	8.9E-01	4.7E+03	5.2E+01
Skewness (Pearson)	2.2E+00	1.2E+00	5.7E-01	2.0E+00	2.6E+00	2.5E+00	3.1E+00	2.5E+00	2.6E+00	2.0E+00	2.6E+00
Kurtosis (Pearson)	6.0E+00	2.1E+00	-1.4E-01	3.5E+00	7.8E+00	8.0E+00	8.3E+00	9.4E+00	9.7E+00	6.1E+00	8.1E+00
Harmonic mean	5.2E+02	3.2E+03	2.7E+05	1.0E+00	3.2E+01	1.9E-02	2.0E-04	1.5E-01	3.5E-01	7.3E+02	1.1E-01

the annual emission is composed by two fractions which reflect the emissions with and without the abatement system, respectively multiplied by the amount of yearly hour in which the AMIS is working or not. The sum of the two fractions (g/year) is weighted over the yearly electricity produced to obtain emissions expressed as g/MWh. This process was applied for Hg and H<sub>2</sub>S, which are the compounds treated by the AMIS, for all the power stations. The spreadsheet loaded in Mendeley Data contains the formula used to perform the calculation. The power plants average emissions are unified by area according to geographic information reported in the data repository.

Further simplification can be performed by averaging the emissions of all the power plants as reported in Table 2. Also, two different scenarios are calculated: one representing the actual emission (actual scenario) and another which corresponds to the emissions that could be obtained if no abatement system were employed (scenario without AMIS).

#### 4. Statistical description

All the collected data was statistically analysed to characterize the distribution and the errors connected to the database built. Table 3 and box plots in Fig. 2 report statistical indicators which describe the 463 observations collected at the time of the paper preparation.

The emissions obtained with the abatement system is indicated as W/AMIS, while the non-abated pollutants flow's is indicated W/O AMIS.

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#### Conflict of interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

#### References

- [1] EGEC Geothermal, EGEC Market Reports 2011; 2012; 2013-2014; 2015; 2016; 2018, 2018.
- [2] M. Bravi, M.L. Parisi, E. Tiezzi, R. Basosi, International journal of heat & technology: life cycle assessment of advanced technologies for photovoltaic panels production, *Int. J. Heat Technol* 28 (2010).
- [3] M.L. Parisi, S. Maranghi, A. Sinicropi, R. Basosi, Development of dye sensitized solar cells: a life cycle perspective for the environmental and market potential assessment of a renewable energy production technology, *Int. J. HEAT Technol.* 31 (2013) 160–167.
- [4] M.L. Parisi, R. Basosi, Geothermal energy production in Italy: an LCA approach for environmental performance optimization, in: M.L. Basosi, R. Cellura, M. Longo, S. Parisi (Eds.), *Life Cycle Assess. Energy Syst. Sustain. Energy Technol.*, Springer International Publishing, 2018, p. 184, <https://doi.org/10.1007/978-3-319-93740-3>.
- [5] M.L. Parisi, N. Ferrara, L. Torsello, R. Basosi, Life cycle assessment of atmospheric emission profiles of the Italian geothermal power plants, *J. Clean. Prod.* 234 (2019) 881–894, <https://doi.org/10.1016/j.jclepro.2019.06.222>.
- [6] N. Ferrara, M.L. Parisi, R. Basosi, Emissions Data from Geothermal Energy Exploitation in Italy, 2019, <https://doi.org/10.17632/gvpy69796n.1>.
- [7] ARPAT Tuscany Regional Agency for Environmental Protection (“in Italian”), Geothermal Reports (‘in Italian’) 2001-2003; 2004; 2005; 2006; 2007-2008; 2009; 2010; 2011; 2012; 2013; 2014; 2015; 2016, 2018. <http://www.arpat.toscana.it/documentazione/report/report-geotermia>. (Accessed 18 February 2019).
- [8] ARPAT, Tuscany Regional Agency for Environmental Protection (“in Italian”), Geothermal emissions control (‘in Italian’), (n. d.). <http://www.arpat.toscana.it/temi-ambientali/sistemi-produttivi/impianti-di-produzione-di-energia/geotermia/controllo-delle-emissioni>.
- [9] IGG-ICCOM, Sampling and Analysis Procedure for the Determination of Mercury Leaving Cooling Towers in Geothermal Power Stations IGG-ICCOM/CNR-3 METHOD, 2017, <https://doi.org/10.13140/RG.2.2.32982.34889> (M3).
- [10] UNI EN, 13211:2003, 2003.

- [11] US EPA, US E.P, A Method 29—Determination of Metals Emissions From Stationary Sources, 2017, pp. 1–37. [https://www.epa.gov/sites/production/files/2017-08/documents/method\\_29.pdf](https://www.epa.gov/sites/production/files/2017-08/documents/method_29.pdf).
- [12] R. Di Pippo, Geothermal Power Plants, in: Principles, Applications, Case Studies and Environmental Impact, fourth ed., Elsevier, 2015.
- [13] R. Bonciani, A. Lenzi, F. Luperini, F. Sabatelli, Geothermal power plants in Italy: increasing the environmental compliance, in: Conf. Eur. Geotherm. Congr., PISA, 2013, p. 2013.