

# SERENGEO Geothermal

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SERENGEO wants to **make geothermal energy** – nowadays a marginal source of clean energy – **a primary source of electricity and heat.**

The main goal of SERENGEO is the **spreading of efficient systems for the reduction of polluting emissions and of sustainable design** from a technical, economic and environmental point of view.

Our reference market is that of **geothermo-electric energy production**, internationally.

SERENGEO provides:

- support to Governmental Agencies evaluating **geothermal resource energetic potential**, using geostatistical approaches and reservoir engineering know-how;
- **geothermal reservoir modelling** for investors and energy industry;
- **design of geothermal systems for heating & cooling and for direct use of heat** for the industry and the building companies.

**Our approach is based on the adoption and in-house development of innovative scientific software, on the expert use of numerical modeling and on the application of mining geostatistics.**

## Why choose SERENGEO?

- We support and encourage the diffusion of **geothermal energy as an alternative to fossil fuels**, improving the underground knowledge and the forecast of the consequences of anthropic exploitation.
- We put at your service the **skills and expertise** gained through research activities in the area of Georesources.
- We use **software developed in-house**, which let us increase the productivity and improve the quality of the provided service.
- We have developed a **patented technology** for the installation of vertical geothermal heat exchangers, which reduces the maintenance cost, improves the efficiency and minimizes the damage risk.
- We provide **highly customized services**, to effectively meet clients' needs.

## Work tools

### Numerical codes

- FEFLOW
- TOUGH2



### Geostatistical codes

- SGems
- Geo-MS

### Pre & post-processing software

- TOUGH2GIS
- TOUGH2Viewer
- Petrasim



**TOUGH2Viewer**

**TOUGH2GIS**

**TOUGH2Path VORO2MESH**

### Geographical Information Systems and Scientific Visualization software

- GRASS GIS
- QGIS
- Paraview



### Database Management System

- SQLite
- Spatialite



## Geothermal Resource Assessment

Determining the underground thermal potential is the first step to **estimate the energy we can extract** and to properly **design economically viable and environmentally sustainable geothermal plants**.

SERENGEO provides a proper geothermal mapping for the production of thermal energy (district heating & cooling, geothermal heat pumps and direct use) and electric energy.

Resource mapping is performed using and processing all the available information with **advanced geostatistical tools**, representing the underground with **multidimensional models** (3D spatial representation, 4D temporal, nD parametrical).

**Several years of applied mining geostatistics and modeling in the hydrogeology and Oil & Gas fields guarantees an extremely accurate service.**

## Geothermal Reservoir Modelling

The design of a geothermal power plant requires a **careful analysis of the effects induced on the exploited reservoir by heat and fluid extraction**: numerical modeling is unavoidable to understand and describe these phenomena.

SERENGEO uses the **most advanced numerical codes** (TOUGH2 and FEFLOW), **geostatistic analysis software** (GeoMS and SGeMS) and **pre and post-processing softwares developed in house** (TOUGH2Viewer and TOUGH2GIS) to provide reliable results for the correct evaluation of project viability.

**The experience gained during industrial research projects on the design of geothermal power plants, in collaboration with DICAM and Saipem, ensures accurate analysis and reliable models.**

## Ground source Heating & Cooling plant design

The **proper design** of a complex heating and cooling geothermal heat exchanger **requires a detailed analysis of the interaction between the different geoexchangers**, in order to ensure efficient working condition of the plant during its entire lifetime.

SERENGEO provides the client with **integrated design, construction assistance and management** of large size ground source heat pump systems, where simplified methods and procedures cannot be applied.

**SERENGEO is able to offer a reliable design for ground source heating and cooling systems**, thanks to:

- the coupled use of geostatistical mapping of the underground;
- the adoption of advanced design techniques;
- the use of numerical modeling.

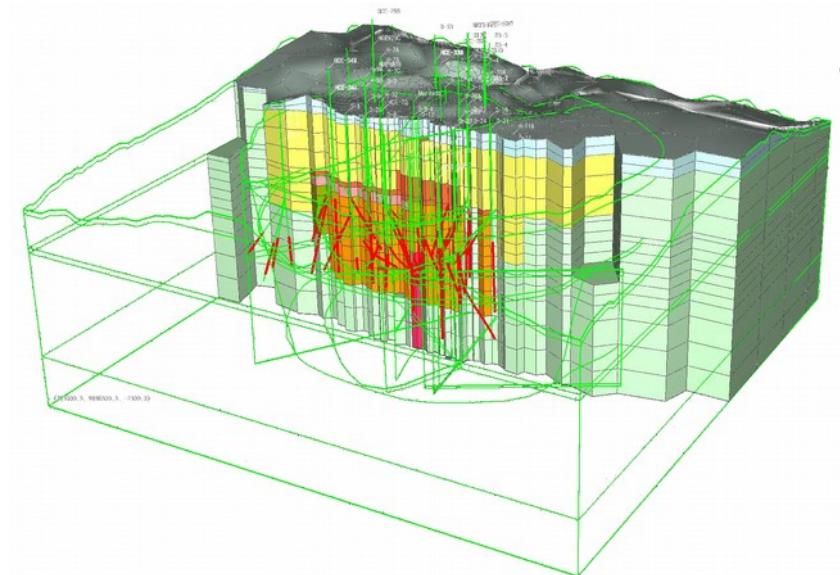
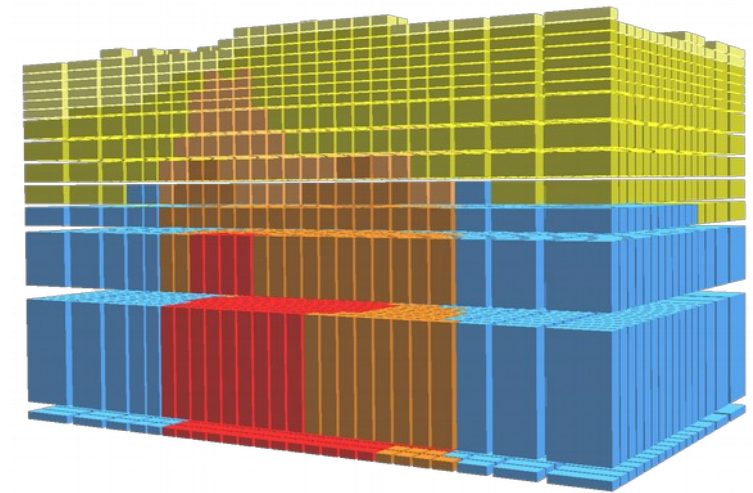
## Geothermal reservoir numerical modelling

### Tuscany

2007–2011. MAC-GEO project, National Interuniversity Consortium for Georesources Engineering (CINIGeo). Numerical modelling of Larderello – Travale and Monte Amiata geothermal fields.

### Indonesia

2012-2013. SERENGEO partner collaboration with SAIPEM and ELC. Numerical modelling of geothermal reservoirs.





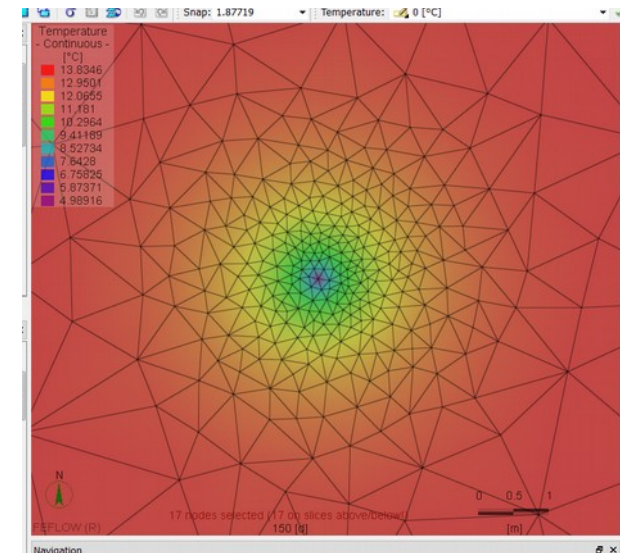
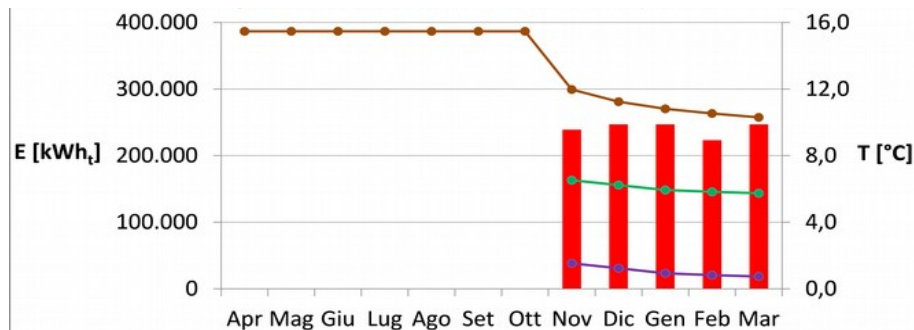
## Low enthalpy geothermal H&C plant design

### Fattoria Grilli

Feasibility study for a geothermal heat pump application for a house + greenhouse, using a Geothermal Heat Pump and horizontal / vertical georexchangers.

### Nuovo Pignone

Thermal characterization of a geothermal reservoir with the purpose of feeding a CO<sub>2</sub> heat pump.



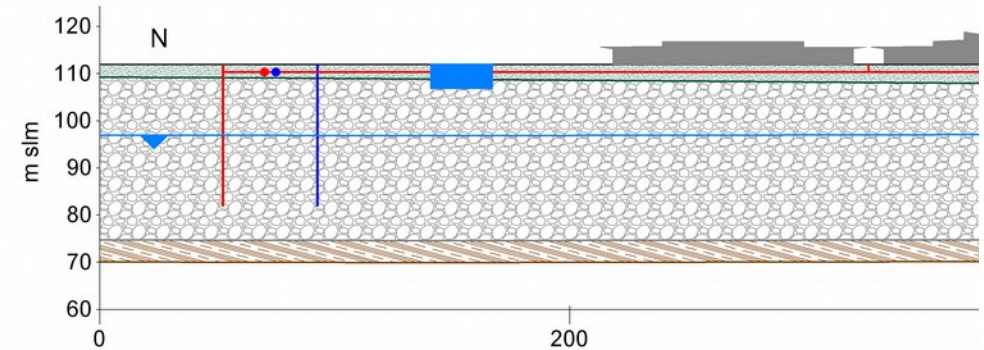
## Low enthalpy geothermal H&C plant design

### NIER Engineering

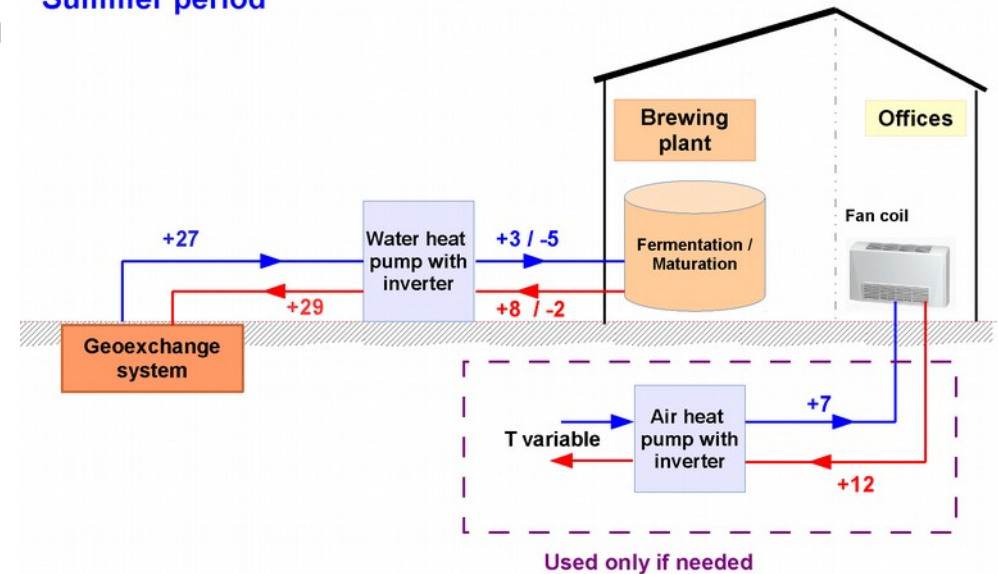
Geothermal open loop application for the requalification of a fruit & vegetable market.

### Azienda agricola Mirri Piana

Feasibility study of a geothermal application for a small brewing plant



Summer period



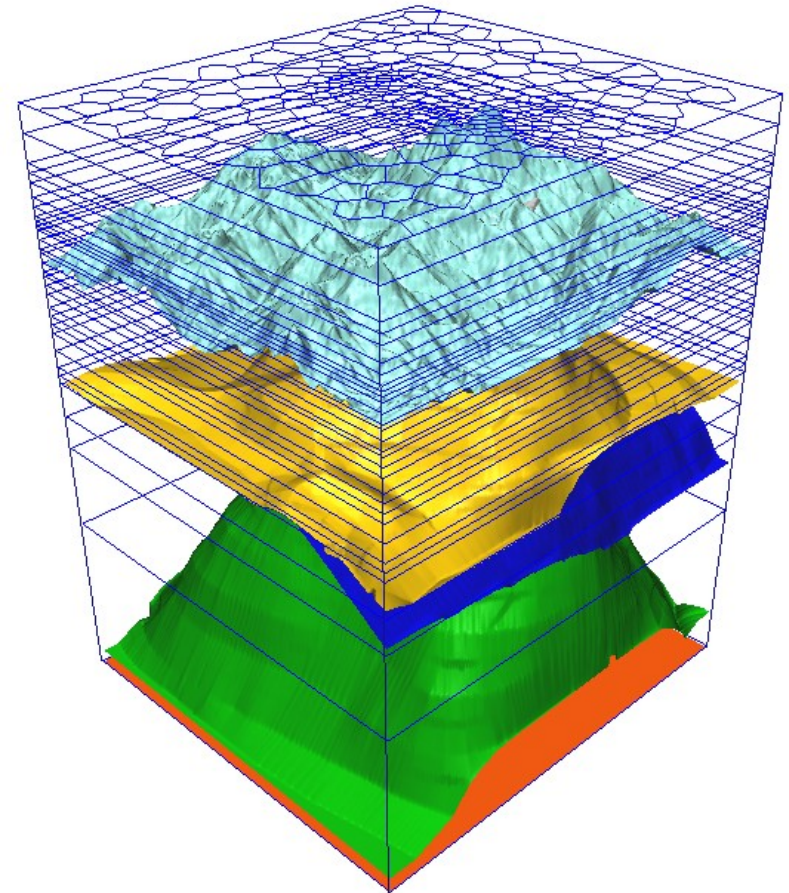
## Pre & post-processing software for numerical modelling

### TOUGH2GIS

(<http://software.dicam.unibo.it/tough2gis>)

TOUGH2GIS its a suite of tools for:

- The creation of unstructured 3D grids (Voronoi or Delaunay);
- Automatic rock type assignment to grid block using 3D isosurfaces (isothermal, isobar, geological strata, etc.);
- TOUGH2 geometrical input file creation.



## Pre & post-processing software for numerical modelling

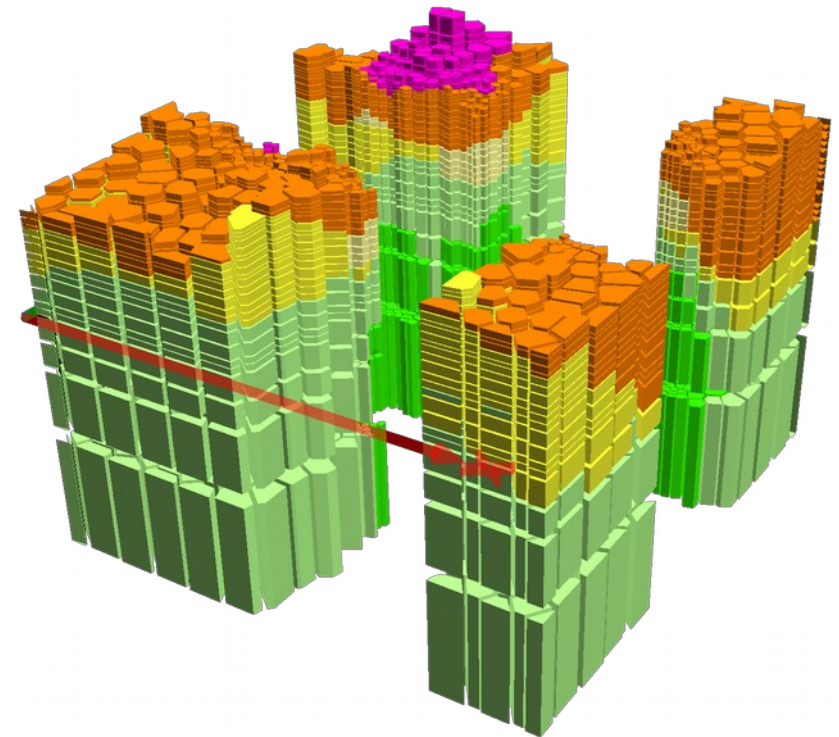
### TOUGH2Viewer

(<http://software.dicam.unibo.it/tough2viewer>)

TOUGH2Viewer is a 5D visualization software, developed to improve the analysis of the simulation of full-field geothermal reservoirs.

TOUGH2Viewer allows for the visualization and exploration of the simulated numerical model through an user-friendly GUI. The main functionalities are:

- 3D block model visualization;
- 3D vector model for heat transfer & mass flow;
- 3D isosurfaces and contour maps.



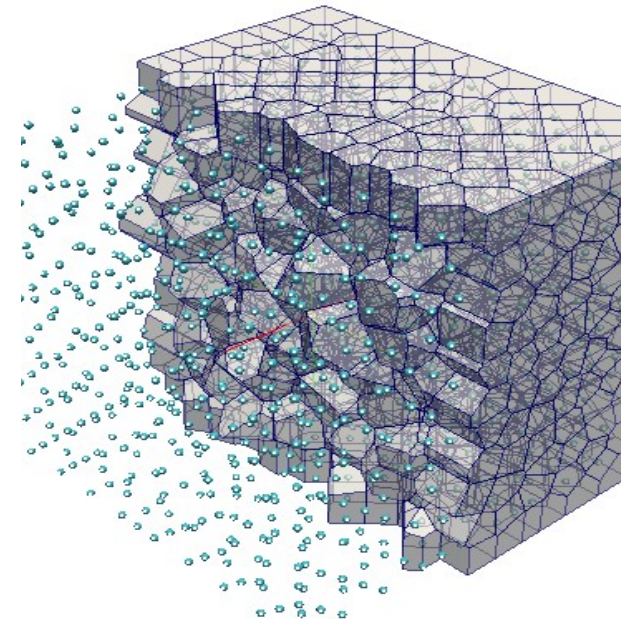
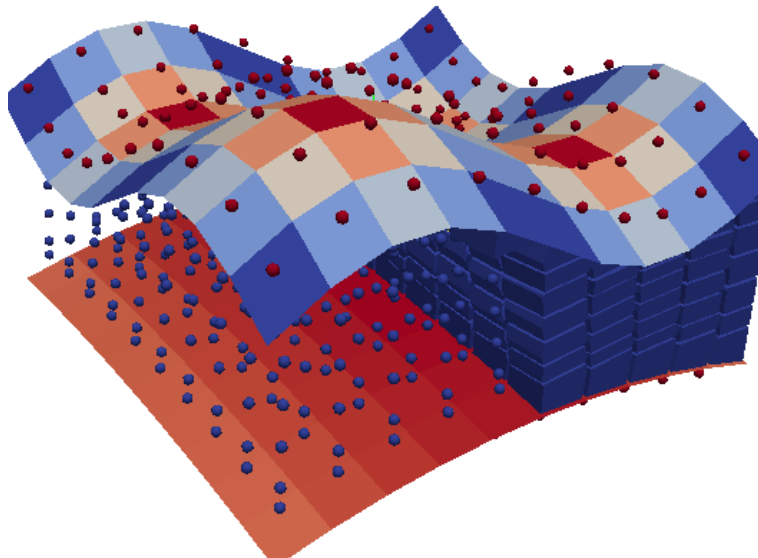
## Pre & post-processing software for numerical modelling

### VORO2MESH

(<http://software.dicam.unibo.it/voro2mesh>)

VORO2MESH has been developed to improve the generation of unstructured 3D grid using the Voronoi method.

VORO2MESH allows a three-dimensional MESH generation letting the user to choose between several options to build the grid.



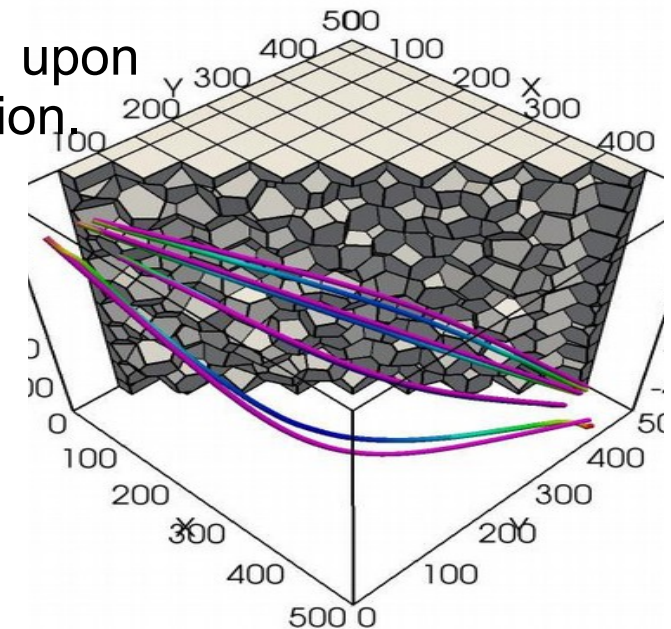
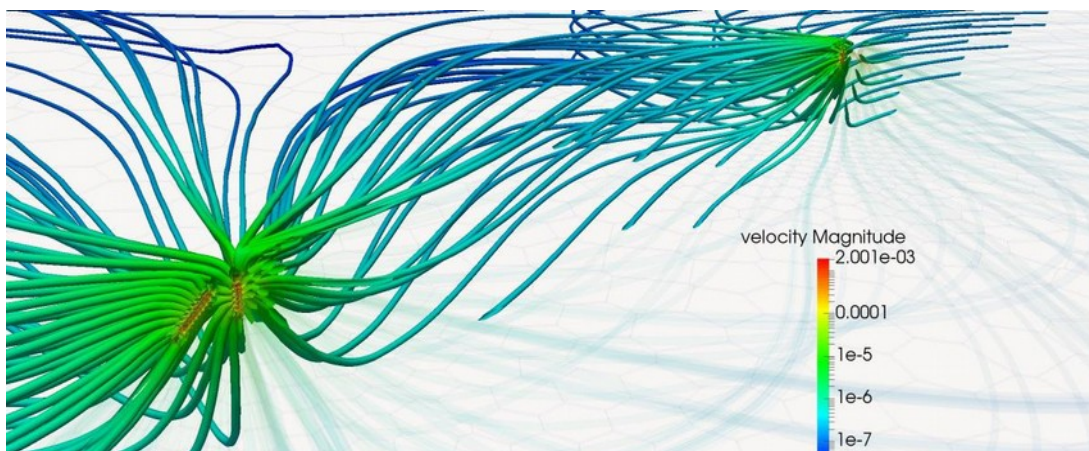
## Pre & post-processing software for numerical modelling

### TOUGH2Path

(<http://software.dicam.unibo.it/tough2path>)

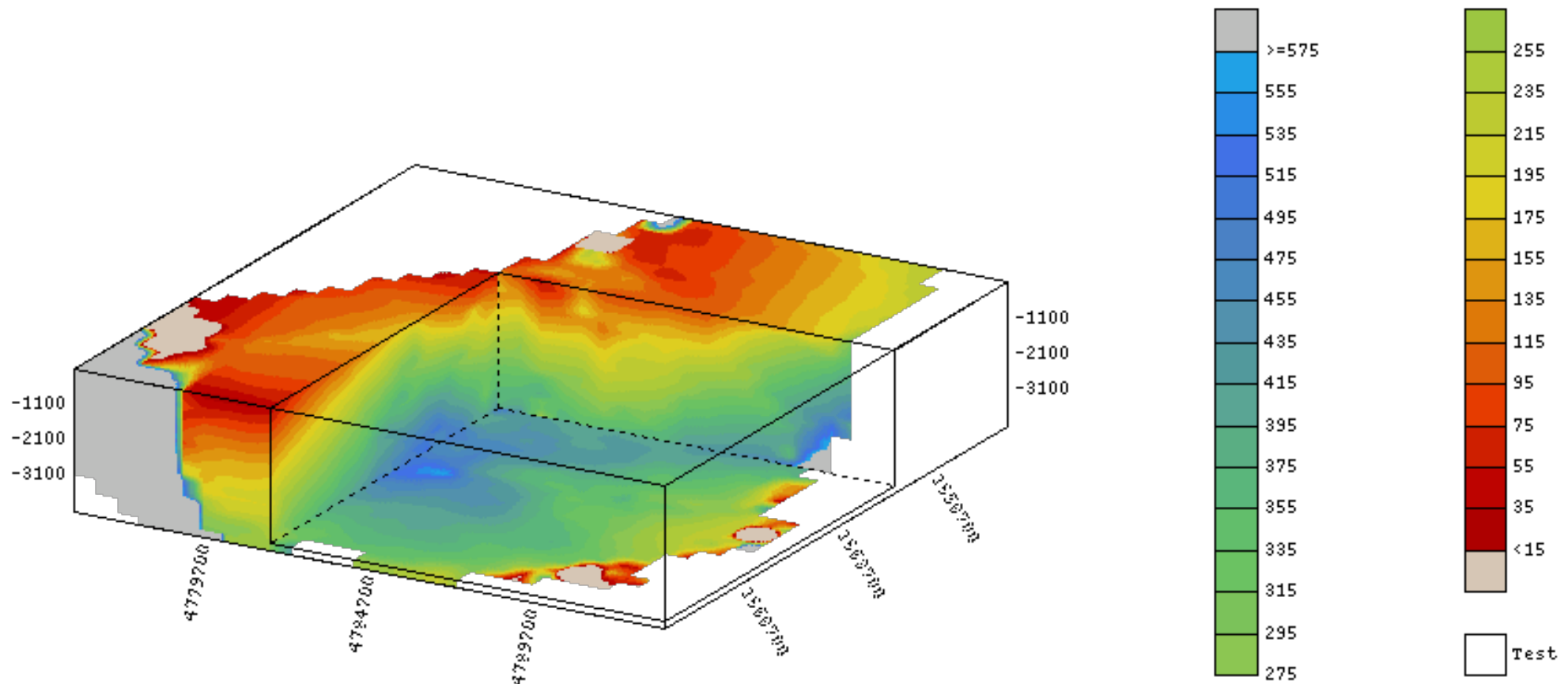
TOUGH2Path is a command line software coded in C++ running under Windows. It can compute the pathline of a particle through each block of a 3D Voronoi discretized domain using directly the output file of a TOUGH2 (Pruess et al., 1999) simulation and using the Klausen et al. (2012) method.

TOUGH2Path uses a parallel programming approach based upon OpenMP (Open Multi-Processing) to speed-up the computation.



## Geostatistical analysis

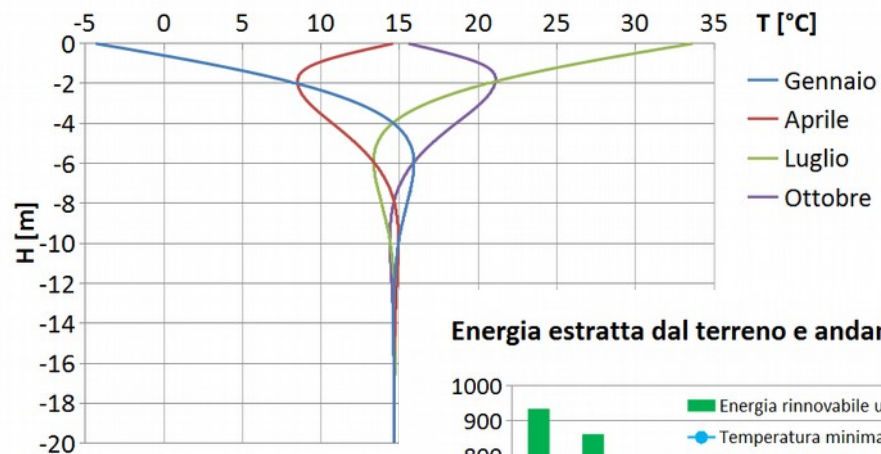
SERENGEO brings to the market cutting edge approaches for data analysis, in order to improve the accuracy of geothermal reservoir modelling.



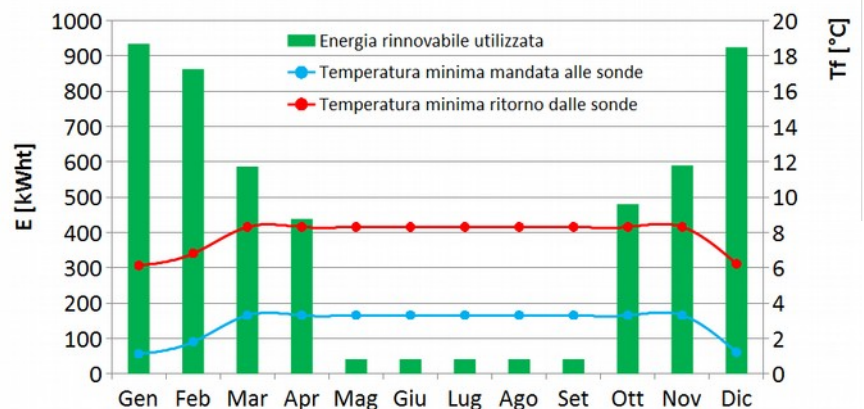
## Software for low enthalpy geothermal H&C plant technical – economic design and feasibility analysis

SERENGEIO uses in-house developed tools for geothermal plant design and investment analysis.

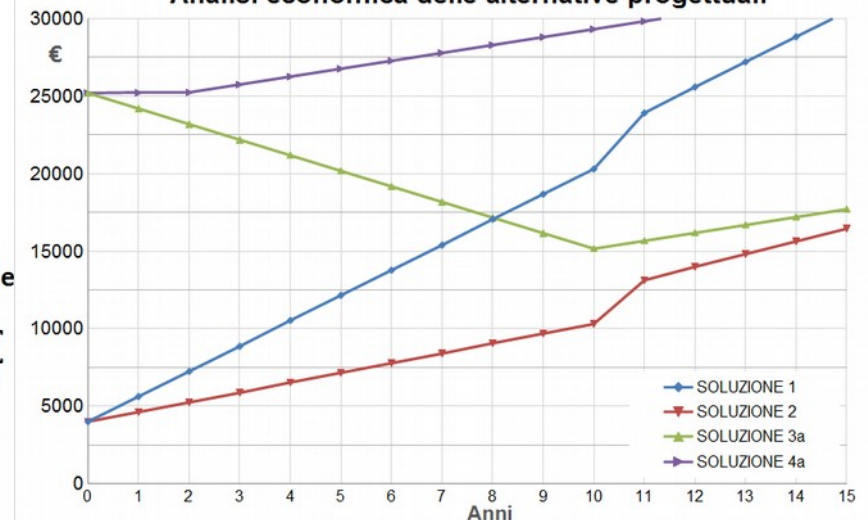
Andamento teorico della temperatura nel sottosuolo



Energia estratta dal terreno e andamento temperature nelle sonde



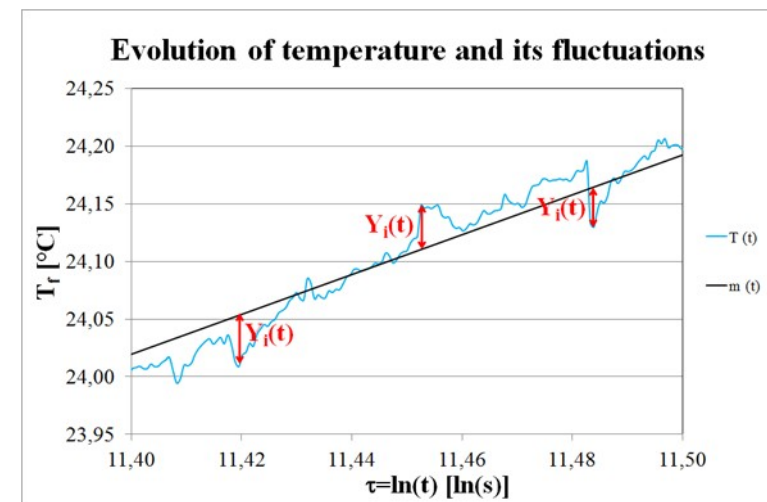
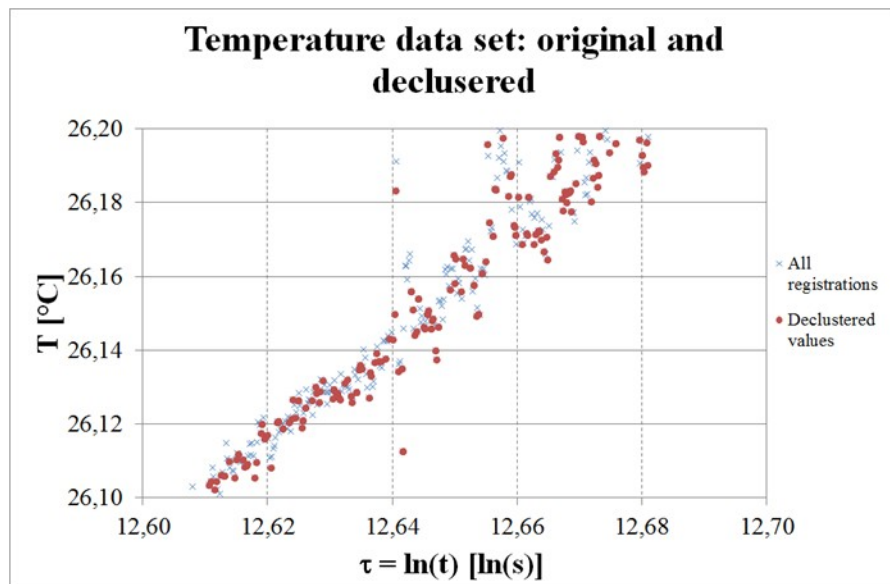
Analisi economica delle alternative progettuali





## Innovative method for TRT results analysis

SERENGEEO developed and uses an innovative geostatistical method for the interpretation of Thermal Response Test (TRT) results.



## Research activity

### Coupled wellbore-reservoir flow simulation

Determining the hydraulic properties and thermodynamic conditions of the reservoir is fundamental to assess the productive capacity of wells and predict the behavior of the reservoir subject to exploitation.

T2Well allows for the coupled simulation of transient flow in the well and in the reservoir. This simulation allows to overcome the lack of data recorded under dynamic conditions.

SERENGEO collaborates with DICAM, SAIPEM and LBNL for the application of T2Well using EWASG and EOS2 module (developed for geothermal reservoir simulation) and for the development of tools for the well-driven discretization of the investigated domain.



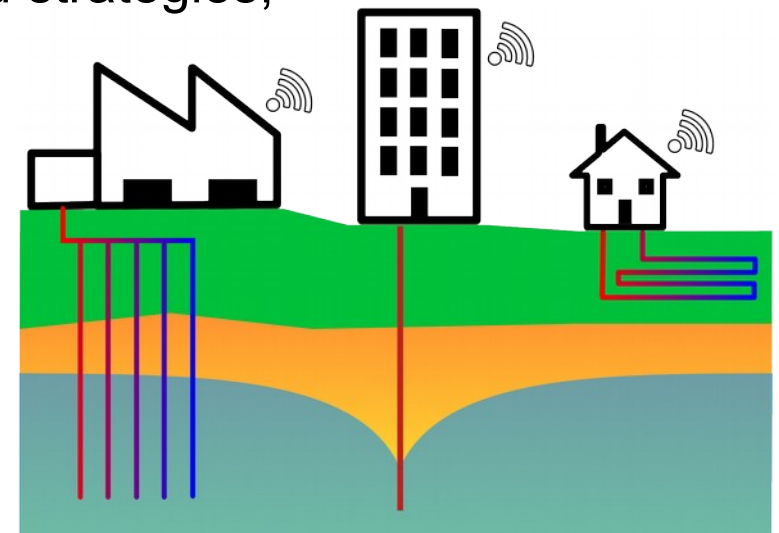
## Research activity

### Expert system for geothermal resources and plants management and control

The proposed geothermal monitoring system is an expert system to facilitate the optimal use of geothermal resources, with particular attention to applications in densely populated contexts.

The expert system will:

- provide a decision support tool for Energy Plans and strategies;
- help decreasing the investment risk due to a more accurate design;
- provide a tool for locating the most suitable areas for geothermal energy use;
- help preventing the risk of geothermal resource depletion.



## Research activity

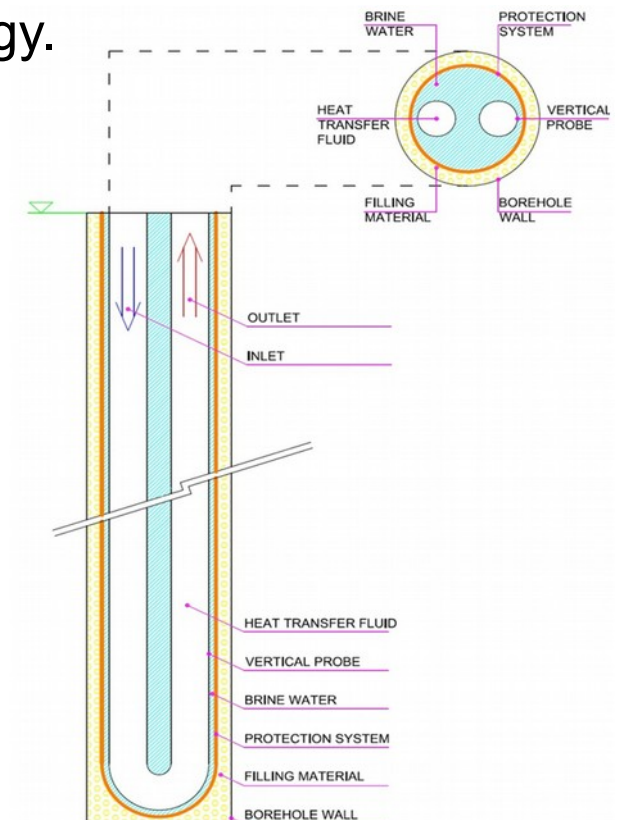
### Innovative configuration of shallow geothermal systems based on a patented technology

The study is aimed to assess the efficiency of a new configuration of shallow geothermal systems, based on a patented technology.

The patent reference is PCT/IB2013/053034 and the inventors are Sara Focaccia and Francesco Tinti, respectively associate and collaborator of SERENGEEO.

The innovative configuration can be used with several types of geoexchangers (spirals, single/double U, baskets, etc.) and allows for:

- improving the efficiency of shallow geothermal systems;
- reducing the investment risk and maintenance costs;
- easy technologic system update.



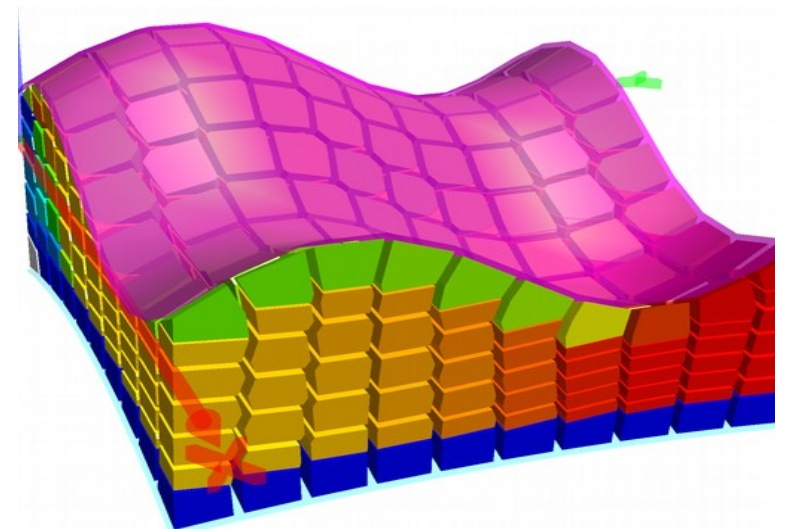
## Research activity

### 3D Voronoi spatial discretization

The Integral Finite Differences Method (IFDM), used by TOUGH2, requires some geometrical conditions to be met when performing spatial discretization (in particular the orthonormality between the segment connecting two grid nodes and the plane containing the common boundary surface). This condition is satisfied by Voronoi tessellation, that has been adopted within TOUGH2GIS.

In order to improve numerical model accuracy, 3D Voronoi discretization is required (Voronoi polyhedron). Such grids are very difficult to generate and manage, but can greatly improve simulation performance while working with complex geological settings and directional wells.

SERENGEO collaborates with DICAM, SAIPEM and LBNL to the development of innovative tools for the creation of 3D Voronoi grids.



# Portfolio | Publications



Bonduà S., Tinti F., Vasini E.M., Lusetti D., Battistelli A., Bortolotti V. (2018). " Pathline computation in geothermal applications using TOUGH2 and TOUGH2Path". In: Proceedings of the TOUGH Symposium 2018. Lawrence Berkeley National Laboratory, BERKELEY, CALIFORNIA, in press.

Focaccia, S., Tinti, F., Barbaresi, A. (2018) "Simulation of Observed Temperature Field below a Building" Environmental Geotechnics, p. 1-39, doi: 10.1680/jenge.17.00105

Cazorla-Marín, A., Montagud, C., Corberán, J. M., Tinti, F., Focaccia, S. (2018) "Upgrade of the B2G dynamic geothermal heat exchanger model: Optimal location of the ground nodes" IGSHPA Conference and Expo, vol. 48

Vasini, E.M., Battistelli, A., Berry, P., Bonduà, S., Bortolotti, V., Cormio, C., Pan, L. (2018) "Interpretation of production tests in geothermal wells with T2Well-EWASG" Geothermics, Vol. 734, May 2018, pp. 158-167, DOI: 10.1016/j.geothermics.2017.06.005

Bonduà, S., Battistelli, A., Berry, P., Bortolotti, V., Consonni, A., Cormio, C., Geloni, C., Vasini, E.M.(2017) "3D Voronoi grid dedicated software for modeling gas migration in deep layered sedimentary formations with TOUGH2-TMGAS" Computer & Geoscience, DOI: 10.1016/j.cageo.2017.03.008

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Focaccia, S., Tinti, F., Monti, F., Amidei, S., Bruno, R. (2016) "Shallow geothermal energy for industrial applications: A case study" Sustainable Energy Technologies and Assessments, p. 93-105, doi: 10.1016/j.seta.2016.05.003

Geloni, C., Consonni, A., Della Rosa, M., Battistelli, A., Bortolotti, V., Bonduà, S., Vasini, E.M., Cormio, C. (2016) "Non-hydrocarbon Migration Model in Petroleum System Analysis – An Integrated Procedure for Accurate Risk Assessment" Proceedings of 78th EAGE Conference & Exhibition 2016, Vienna

Al-Khoury, R., Focaccia, S. (2016) "A spectral model for transient heat flow in a double U-tube geothermal heat pump system", Renewable Energy, vol. 85, p.195-205, doi:10.1016/j.renene.2015.06.031

Bruno, Tinti, Focaccia (2016) "Estimating Thermal Response Test Coefficients: Choosing Coordinate Space of The Random Function", Mathematical Geoscience, p. 1-21, DOI 10.1007/s11004-015-9612-z

# Portfolio | Publications



Tinti, Focaccia, Bruno (2015) "Thermal response test for shallow geothermal applications: a probabilistic analysis approach", Geothermal Energy, vol.3, issue 6, doi:10.1186/s40517-015-0025-5

Battistelli, A., Berry, P., Bonduà, S., Bortolotti, V., Consonni, A., Cormio, C., Geloni, C., Vasini, E.M. (2015) "Thermodynamics related processes during the migration of acid gases and methane in deep sedimentary formations" Proceedings of the TOUGH Symposium 2015. Lawrence Berkeley National Laboratory, California, pp. 14-21. Focaccia, Tinti, Monti, Amidei, Bruno (2016) "Shallow geothermal energy for industrial applications: A case study" Sustainable Energy Technologies and Assessments, p. 93-105, doi: 10.1016/j.seta.2016.05.003

Berry, P., Bonduà, S., Bortolotti, V., Cormio, C., Vasini, E.M. (2014). "A GIS-based open source pre-processor for georesources numerical modelling". Environmental Modeling & Software, vol. 62, December 2014, pp 52-64.

Tinti, Barbaresi, Benni et al. (2014) "Experimental analysis of shallow underground temperature for the assessment of energy efficiency potential of underground wine cellars" , Energy and Buildings, vol. 80, p. 451-460, DOI: 10.1016/j.enbuild.2014.06.002

Giambastiani, Tinti, Mendrinòs, Mastrocicco (2014) "Energy performance strategies for the large scale introduction of geothermal energy in residential and industrial buildings: The GEO.POWER project", Energy Policy, Volume 65, February 2014, Pages 315-322 M

Focaccia, Bruno, Tinti (2013) "A software tool for Geostatistical Analysis of Thermal Response Test data: GA-TRT", Computer and Geoscience, vol. 59, p. 163-170, ISSN: 0098-3004

Focaccia (2013) "Thermal response test numerical modeling by using a dynamic simulator", Geothermal Energy, vol. 1, p. 3-14, ISSN: 2195-9706

Focaccia, Tinti (2013) "An innovative Borehole Heat Exchanger configuration with improved heat transfer", Geothermics, vol. 48, p. 93-100, ISSN: 0375-6505

Cormio C., Berry P., Bonduà S., Bortolotti V. (2012). "Innovative tools for continuum discretization, better management of TOUGH2 input data and analysis of the numerical simulation results". In: Proceedings of the TOUGH Symposium 2012. Lawrence Berkeley National Laboratory, BERKELEY, CALIFORNIA, pp. 52- 59.

Bonduà, S., Berry, P., Bortolotti, V., Cormio, C. (2012). "TOUGH2Viewer: A post-processing tool for interactive 3D visualization of locally refined unstructured grids for TOUGH2". COMPUTERS & GEOSCIENCES, issue 46, pp. 107-118, doi: 10.1016/j.cageo.2012.04.008, ISSN 0098-300

# Contacts

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SERENGEO Srl

Via U. Terracini 28, 40131 Bologna, Italy



[www.serengeo.com](http://www.serengeo.com)



[serengeo@serengeo.com](mailto:serengeo@serengeo.com)



+39 051 4843504