Supplementary Materials: The Integration of 3D Modeling and Simulation to Determine the Energy Potential of Low-Temperature Geothermal Systems in the Pisa (Italy) Sedimentary Plain

Alessandro Sbrana[1*], Paola Marianelli[1], Giuseppe Pasquini[1], Paolo Costantini[1], Francesco Palmieri[2], Valentina Ciani[3] and Michele Sbrana[3]

Table S1: Initial conditions and parameters for TOUGH2 simulation.

Unit	Density (kg/m³)	Porosity	Permeability (mD)	Wet heat conductivity (W/(m·k))	Specific heat (J/(kg·K))
RAC	2253[a]	0.40 [1]	1.00 [2]	1.8[b]	1050 [3]
SGU-1	2261[a]	0.25 [1]	6.8×10^{3}[b]	2[b]	960 [3]
Clay1	2273[a]	0.45 [1]	0.10 [2]	1.8[b]	1050 [3]
SGU-2	2288[a]	0.25 [1]	6.8×10^{3}[b]	2[b]	960 [3]
CSU	2360[a]	0.40 [1]	0.10 [2]	1.9[b]	1050 [3]
BEDROCK	2663[a]	0.10 [1]	10.00 [2]	3.3[a]	920 [3]

Pressurefunction, $P = 1.013 \times 10^{5}$ Pa + 9810.0 z.

Temperature function, T = 16°C + 0.056 z.

[a] P. Costantini, unpublished data.

[b] Experimental data.

Table S2: Geothermal energy calculation (Balke, 1977, Muffler and Cataldi, 1978).

	Volume (m³)	Density (kg·m⁻³)	Specific heat (J·kg⁻¹·K⁻¹)	Volumetric heat capacity (kJ·g⁻¹·K⁻¹)	Temperature reduction (K)	Geothermal energy (kJ)
SGU–water	1.82×10^{9}[a]	997[b]	4200[b]	4187.4	5	3.81×10^{13}
SGU–sediments	5.45×10^{9}[a]	2200[c]	960 [3]	2112.0	5	5.76×10^{13}

[a] Considering the porosity of SGU is 0.25 and the volume of SGU is 7.27×10^{9} m³.

[b] German engineering guideline, VDI 4640/1 (2000). Considering the temperature of water is 20°C.

[c] P. Costantini, unpublished data.

Table 3: Parameters for the standard vertical BHE.

Parameter	Value
Minimum temperature of the heat carrier fluid (T_{lim}, °C)	5
Length of the pipes (L, m)	100
Borehole radius (rb, m)	0.1
Operating time of the system (t_s, years)	50
Borehole thermal resistance (Rb, m·KW^{-1})	0.11
Double U-pipe BHE (n, number of pipes)	4
Pipes radius (r_p, m)	0.016
Thermal conductivity of grout (λ_{bf}, W·m^{-1}·K^{-1})	1.8

Table S4: Bedrock geothermal potential calculation (Balke, 1977, Muffler and Cataldi, 1978).

	Volume (m^3)	Density ($kg·m^{-3}$)	Specific heat ($J·kg^{-1}·K^{-1}$)	Volumetric heat capacity ($kJ·g^{-1}·K^{-1}$)	Temperature reduction (K)	Geothermal energy (kJ)
Water	1.06×10^{9}[a]	987[b]	4182[b]	4127.6	30	1.31×10^{14}
Rock	9.51×10^{9}[a]	2663[c]	920 [3]	2450.0	30	6.99×10^{14}
Rock and water						8.30×10^{14}

[a] Considering the porosity of bedrock limestones is 0.10 and the volume of high gravimetric bedrock is 1.06×10^{10} m^3.

[b] German engineering guideline, VDI 4640/1 (2000). Considering the temperature of water is 50°C.

[c] P. Costantini, unpublished data.

References

1. Celico, P. *Prospezioni Idrogeologiche*; Liguori Editore: Napoli, Italy, 1986; Volume 2. (In Italian)
2. Freeze, R.A.; Cherry, J.A. *Groundwater*; Prentice-Hall: Englewood Cliffs, NJ, USA, 1979; 604p.
3. Baietto, A.; Pochettino, M.; Salvatici, E. *Progettazione di Impianti Geotermici—Sonde Verticali e Pozzi d'Acqua*; Flaccovio, D., Ed.; Tipografia Priulla: Palermo, Italy, 2010; 159p, ISBN 978-8-85-790058-2. (In Italian)