Proposal for the Creation of a System for Prevention of Eruptions of Volcanoes (SPEV)

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Abstract: ***This article describes a proposal of a system for prevention of eruptions of volcanoes (SPEV) based on physical models and a developed energy models of volcanoes. The obtained equations are proposed and integrated. Based on the proposed model, SPEV parameter estimates are made for super-volcanoes Yellowstone, Campi Flegrei, Long Valley and volcanoes Vesuvius, Ruapehu, Popocatépetl, Etna. The proposal includes description of business project. The proposed SPEV is a scientific and technological breakthrough that can save majority of humanity from death due to "volcanic winter" - the climate change during eruption of super-volcanoes and will prevent human casualties and material losses from the eruption of small volcanoes. This paper presents interesting information for researchers, governments, municipalities (e.g. Naples, Mexico City, etc.) and companies about creating SPEVs.***

Keywords: prevention of volcano eruptions, energy model, super-volcanoes, volcanoes

1. Introduction

Volcanic activity of the Earth is increasing and the messages below support this statement.

The European Science Foundation published a report on 08.04.2015: "Extreme Geohazards: Reducing the Disaster Risk and Increasing Resilience" in which its scientists Plag H.P., *et all* (2015) "announced that an eruption of one of its super volcanoes with VEI-7 will take place in the 21st century on the territory of the Earth; the probability of such an event is 5–10%. If such a mega hazard were to occur today, the resulting disaster impacts would be unparalleled. Exposure to geohazards has increased dramatically in recent decades and continues to do so. Extreme Geohazards such as volcanic eruptions, cause significant loss of life and property. Most of these losses occur during high-impact events and these losses are increasing as the number of people who live in areas exposed to such hazards continues to rise. Recent major geohazards are dwarfed by the largest geohazards that occurred several times during the Holocene. Consequently, VEI 7 and larger eruptions represent a severe threat for our modern society. For hazards with a potentially global extent, the provision of 'lifeboats' should be the aim for our global civilization. A first-order cost-benefit analysis shows that for a reduction in the disaster risk associated with large volcanic eruptions, humanity should be willing to invest in the order of $0.5 billion per year. Humanity faces the crucial challenge of developing in a very limited time an effective programme to reduce the risk of global disasters and catastrophes caused by natural hazards."

The Campi Flegrei volcano may be closer to an eruption than previously thought, according to new research by UCL in Naples. The authors of the article: Kilburn C.R.J., *et al.* (2017) used a new model of volcano fracturing developed at UCL to investigate whether Campi Flegrei may again be preparing to erupt. They found that the unrest since the 1950s has had a cumulative effect, causing a build-up of energy in the crust and making the volcano more susceptible to eruption. "By studying how the ground is cracking and moving at Campi Flegrei, we think it may be approaching a critical stage where further unrest will increase the possibility of an eruption, and it's imperative that the authorities are prepared for this," explained Dr C. Kilburn, Director of the UCL Hazard Centre.

"A huge super volcano at Campi Flegrei, which is under 500,000 people in Italy, can wake up and approach a critical state", scientists (Chiodini G.*et al.* (2016)) say "We use the results of physical and volatile saturation models to demonstrate that magmatic volatiles released by decompressing magmas at a critical degassing pressure (CDP) can drive volcanic unrest towards a critical state. We show that, at the CDP, the abrupt and voluminous release of H_2O-rich magmatic gases can heat hydrothermal fluids and rocks, triggering an accelerating deformation that can ultimately culminate in rock failure and eruption. We propose that magma could be approaching the CDP at Campi Flegrei, a volcano in the metropolitan area of Naples, one of the most densely inhabited areas in the world, and where accelerating deformation and heating are currently being observed." In response to this news, the Italian government raised the level of the volcano's threat from green to yellow or from silence to the required scientific monitoring.

Thus, the increased volcanic activity of the Earth during the eruption of super volcanoes threatens the existence of the greater part of mankind because of the "volcanic winter" and makes the development of technology for the prevention of volcanic eruptions and super-volcanoes extremely urgent. We propose the system for prevention of eruptions volcanoes (SPEV) in this paper on the basis of physical models and the developed energy model of a volcano. The obtained equations are proposed and integrated. Based on the proposed model, the SPEV parameters of the Yellowstone, Campi Flegrei, Long Valley super volcanoes and Vesuvius, Ruapehu, Popocatépetl and Etna volcanoes are estimated and include the business plan proposal.

2. Mechanisms for Preventing Volcanic Eruptions

To clarify the physics of the present measures and mechanisms of SPEV, in this section we will present a number of provisions of Gilat A. and Vol A. theory (Gilat A. and Vol A., 2005), (Gilat A. and Vol A., 2012). During the Earth's accretion period, primordial hydrogen and helium, comprising 98%–99% of space matter, were trapped and stored in the Earth's core and mantle as a solid and liquid solutions and chemical compounds, with help of endothermic reactions. Since the stabilization of the planet, the energy expended on the capture of H and He is quasi-continuously released by the exothermic reactions of degassing of the Earth. The resulting heat and continuous explosions produce all manifestations of magmatic activity in general and volcanic eruptions in particular. Analyses of gases from fresh lavas of Kamchatka volcanoes made by I.I. Glustchenko show that primary explosive gases uncontaminated by meteoric water and air (H2, Cl2, CO, OH, F2, Br2, H2S, CH4) comprise 10%–70% of total volcanic gases. Gases, saturated with energy, form passages for magma into magmatic chambers, break through fragile rocks and supply energy for volcanic eruptions.

Basing on the theory of Gilat A. and Vol A., we describe the proposed mechanisms for preventing volcanic eruptions, which altogether represent the system for prevention of eruptions volcanoes (SPEV).

(1st measure) The temperature of the Earth's crust and magmatic chamber has to be reduced in order to reduce the likelihood of a volcanic eruption. We propose creation of a geothermal power plant (PP) at a shallow depth. The thermal energy of the upper part of the Earth's crust is determined by the energy coming from the magmatic chamber with the help of the thermal conductivity of the crust, the thermal energy of volcanic gases (including the energy of explosive gases). Therefore, it is sufficient to use small depths for the wells of geothermal PP. For example, geothermal PP - Mammoth Geothermal Complex lifts water from a working well from a depth of 150 meters, heated to an average of 170 degrees. The waste water is pumped back through the casing to a depth of 600 meters. This is a repetitive duty cycle. Pumping heat energy from the Earth's crust, we simultaneously reduce the energy of the magma chamber and reduce the likelihood of a volcanic eruption. Thus, volcanos, the potential threat, will be able to give a clean energy and will become a national wealth of countries.

(2nd measure) The mass of explosive gas in the Earth's crust has to be reduced in order to reduce the likelihood of a volcanic eruption. To reduce the mass of explosive gases in the Earth's crust, we recommend removing volcanic gases from water pumped back into the casing by using the System for the Removal of Volcanic Gases (SRVG) from water. The basis of SRVG can be membrane degassing of water. Industrial equipment for membrane degassing of water under the brand Liqui - Cel is manufactured by the corporation Polypore International, Inc. Thus, reducing the mass of the explosive gas with SRVG, located on the geothermal PP, ultimately reduces the likelihood of a volcanic eruption. Therefore, it is necessary to dig a second working well, and the waste water, without the explosive gases, removed by SRVG, is pumped into the Earth's crust. The resulting explosive gas can be burned in the gas PP.

Thus, we propose to use [the geothermal PP+SRVG+the gas PP] system, which we call the system for prevention of eruptions of volcanoes (SPEV). SPEV will reduce the likelihood of a volcanic eruption. We listed above the proposed mechanisms and measures to prevent volcanic eruptions, which will be used in various modifications of SPEV in the next section.

3. Using SPEV for different volcanoes

Here we will look specific volcanoes and super-volcanoes and look at the SPEV parameters that we propose to use to prevent their eruptions.

3.1. The super-volcanoes Yellowstone Caldera (USA), Campi Flegrei Caldera (Italy) and Long Valley Caldera (USA)

The following active super-volcanoes: Yellowstone Caldera (USA) (index of volcano is VEI-8), Long Valley Caldera(USA) (index of volcano is VEI-7) and Campi Flegrei Caldera (Italy) (index of volcano is VEI-7) (Volcanic Explosivity Index (2017)) present a possible danger to mankind due to the "volcanic winter". "A classic example is the Campi Flegrei caldera in southern Italy. The results provide the first quantitative evidence that Campi Flegrei is evolving towards conditions more favourable to eruption and identify field tests for predictions on how the caldera will behave during future unrest" (*Kilburn C.R.J., et all 2017*). We consider Yellowstone Caldera (USA), Campi Flegrei Caldera (Italy) and Long Valley Caldera(USA) (the using of SPEV in Long Valley Caldera has own specifics) in Chapters 5-7.

3.2. The volcanoes Vesuvius (Italy), Ruapehu (New Zealand), Popocatépetl (Mexico) and Etna (Italy)

To prevent the eruption of Vesuvius, Ruapehu, Popocatépetl and Etna we can suggest using one or more PP+SRVG. The use of SPEV for these volcanoes has its own specifics and is described in Chapters 8-11. Specifics of SPEV for these volcanoes lies in the fact that the working well and second well, through which the waste water is pumped back, are inclined wells that start from the surface of the Earth near these volcanoes and end at different depths under the vent of these volcanoes.

In the following section, we use the open energy model of the volcano and the open energy model of the super volcano, including SPEV, to evaluate the parameters of SPEV, including the calculation of the required number of PP+ SRVG and the business plan of SPEV.

4. The energy model of the volcano and the energy model of the volcano, including SPEV

We look at an open energy model of the volcano and an open energy model of the volcano with SPEV {energy passes along the path: the mantle - (magmatic chamber and Earth's crust) - the air environment}. The obtained equations for energy in the magmatic chamber and the

Earth's crust are proposed and integrated; the results allow us to understand and describe the processes of volcanic eruptions and SPEV; estimate of the parameters of the SPEV and outline a business plan, including the SPEV. The energy transfer through the Earth's crust and magmatic chamber is described using the open energy model of the super volcano, using equation (1):

$$dQ/dt=q_m-(q_h+q_e)=q_{emn}>0, \quad (1)$$

where Q is the amount of energy in the earth's crust and in the magma chamber as a function of time t; q_m is the heat flux from the mantle to the magmatic chamber; q_h is the heat flux from the Earth's surface; q_e is the energy flow in the earthquake; q_{emn} is the rate of change of thermal energy in the Earth's crust and in the magma chamber. The SPEV we propose comprises by PP+SRVG system. The energy model of the volcano and the prevention system for eruption of the volcano can be represented using equation (2):

$$dQ/dt= q_{emn}-q_{sp}=q_{es}<0, \quad (2)$$

where q_m is the heat flux from the mantle to the magmatic chamber; q_h is the heat flux from the Earth's surface; q_{sp} is the flow of energy into the energy of PP; q_{es} is the rate of change of thermal energy in the Earth's crust and in the magma chamber, if SPEV is working; q_e is the energy flow causing for earthquakes. Assuming that

$$0<q_{emn}=\text{const}, \quad (3a)$$

$$0> q_{emn}-q_{sp}= q_{es}= \text{const}, \quad (3b)$$

we obtain the function Q(t) - the amount of energy in the magmatic chamber and in the Earth's crust as a function of time t for the energy model of the super volcano:

$$Q(t)= q_{emn}(t-t_A)+Q(t_A), \text{ for } t_A<t< t_2 . \quad (4)$$

By integrating equation (2), we obtain the function Q(t) - the amount of energy in the magma chamber and in the Earth's crust as a function of time t for the energy model of the volcano and SPEV:

$$Q(t)=q_{es}(t-t_A)+Q(t_A), \text{ for } t_A<t< t_C . \quad (5)$$

The graphs show the dependence of the amount of energy in the magmatic chamber and in the Earth's crust Q(t) as a function of time t in Fig.1.: for function (4), for the energy model of the volcano is described by the line AB for ($t_A<t<t_2$) before eruption and by the line BD for ($t_2<t<t_3$) during eruption (for example t_3- t_2=15 months for Tambora eruption at 1815); for function (5) for the volcano energy model in the presence of SPEV is described by the line AC for ($t_A<t<t_C$).

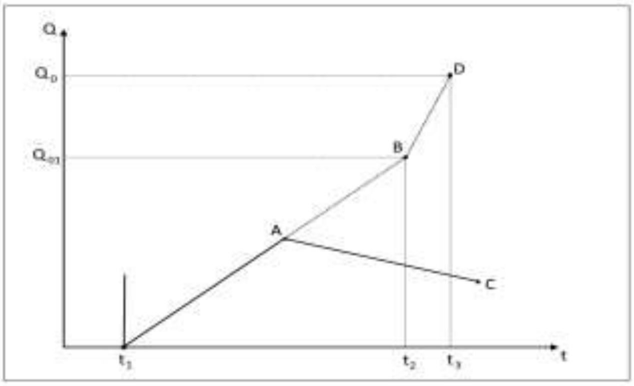

Figure 1: Graphs of the dependence of the amount of energy in the magmatic chamber and in the Earth's crust Q(t) as a function of time t: for function (4), for the energy model of the super volcano is described by the line AB for ($t_A<t<t_2$) before eruption and by the line BD for ($t_2<t<t_3$) during eruption; for function (5), for the energy model of the volcano in the presence of PP+SRVG is described by the line AC for ($t_A<t<t_C$).

The formula (4) for a volcano is in accordance with the published results (Slezin, 1974): "Analysis of the flow of matter through a volcano during intervals including many eruptions has shown that the average rate of arrival of material on the Earth's surface is approximately constant during big stages of life volcano (Tokarev, 1977). The statistically established direct relationship between the eruption energy and the duration of the preceding dormant period (Tokarev 1977) suggests that the discontinuity in volcanic activity is due to the episodic (periodic) discharge of a source where matter and energy flow more or less uniformly from deeper parts of the magmatic system (Kovalev, 1971), (Kovalev, Slezin, 1974). Thermal energy in the system {earth's crust and magma chamber} increases with a rate q_{emn}, where $q_{emn}=q_m-q_h-q_e=Q_{01}/T_1<Q_0/T_1 = q_{em}$, (see Fig.1), where q_{em} is a total rate of thermal energy in the system {earth's crust and magma chamber} and potential energy of explosive gases. We estimate q_{emn} from above, with help of formula ($q_{emn}=q_{em}= Q_0/T_1$). Parameters Q_0 and T_1 we can estimate from literature information. We estimate q_{es} (3b) from above, with help of (3b). In order to cool the system {earth's crust and magmatic chamber}, we need $q_{es}=q_{em}-NM_1/E_f<0$. These formulas will be used for estimation of q_{es} for all volcanoes in the presence of SPEV in next Sections (5-12).

5. Estimation of SPEV Parameters for the Yellowstone Super-Volcano

Recently, the Yellowstone super volcano has been attracting special attention. In areas where the magma under the super volcano is located deep enough (8 km), a suggested way to prevent the eruption of this super volcano, a suggested way to establish a sufficiently large number of PPs+SRVGs (see calculation in this Section). Yellowstone super volcano has a very large area and can become a collection of many volcanoes connected by a single magmatic chamber. In this case, an eruption of a remote volcano is possible, if its magma finds a weak spot in the Earth's crust. Therefore PP+SRVG should cover the entire area of super volcano, thus, the amount of SPEV should be quite big. The Yellowstone caldera erupts roughly every T_1=640000 years. After studying the deposits, scientists established that the last eruptions were (-2.1) million years ago, (-1.3) and t_1 = -0.64 million years ago. The next eruption will occur at time t_2, which is estimated by the formula $t_2=t_1+T_1$, if SPEV is not created (see Figure 1). (Yellowstone Caldera (2017)). In this section, we formulate the requirements for the SPEV for the Yellowstone super volcano and evaluate parameters, including estimation of financial parameters. Yellowstone volcano (640000 year ago) has Volcanic Explosivity Index is equal to VEI 8; 1000 km^3 of the substance was released into the atmosphere. Volcanic Explosivity Index for Yellowstone volcano is VEI-8. The power of the eruption of the Yellowstone super-volcano is estimated at the equivalent of 1,1 10^6 the atomic-bomb equivalent. Then, the power of eruption of the Yellowstone volcano Q_0 in J is: $Q_0 = 9.24 \cdot 10^{20}$ Joules. Thermal energy in the system {earth's crust and magma chamber} increases with a rate q_{emn} , where $q_{emn}=q_m-q_h-q_e=Q_{01}/T_1<Q_0/T_1 = q_{em}$, where q_{em} is a total rate of thermal energy in the system {earth's crust and magma chamber} and potential energy of explosive gases. We estimate q_{emn} with help of q_{em}

$$q_{em}= Q_0/T_1=41.085\ \text{MW}. \qquad (6)$$

q_{em} is less than M_1/E_f = 46.66MW (where M_1 is power of PP, M_1=14 MW; we use PP from American company Raser Technologies commissioned a commercial PP Hatch Geothermal Power Plant, which was built in just 6 months and cost S_1=\$35 million, (Neville A. (2008)). Efficiency E_f of binary geothermal power plants is near E_f=0.3, see Fig. 10 in (Moon H., Zarrouk S.J., 2012). The sold capacity of all PPs equals

$$M_S=N\,M_1. \qquad (7)$$

Thermal energy in the system {earth's crust and magma chamber} with N PP increases at a rate of q_{es}.

$$q_{es}=q_{em}- M_S/ E_f <0. \qquad (8)$$

The cost of all PPs is equal to S

$$S=N\,S_1. \qquad (9)$$

Selling electricity to consumers at C_0=0.078 dollars per kW*h, the annual income for the year will be equal to

$$S_y= C_0\,N\,M_{10}\,(8760\ \text{h/year}) \qquad (10)$$

where $M_{10}=M_1$-3 MW=11 MW; 3 MW PP uses to solve its own problems. Payback period of N PPs will be equal to

$$T= S/S_y\,. \qquad (11)$$

The results of SPEV parameter calculations for three variants: 1st option (strict requirements, N=24), 2nd option (moderate requirements, N=12), 3rd option (weak requirements, N=6).

Table 1: Results of calculation of SPEV parameters for Yellowstone caldera

1	*2*	*3*	*4*	*5*	*6*	*7*
K	N	q_{es}(MW)	M_S (MW)	S_y (Million dollars/year)	S(Million dollars)	T(years)
1	24	-1079	336	180,4	840	4,66
2	12	-519	168	90,19	420	4,66
3	6	-239	84	45,09	210	4,66

In the first column of Table 1 K indicates the number of the option. The second column presents information about the number N of PPs. The third column presents information about the rate q_{es}(MW) of thermal energy in the system {Earth's crust and magma chamber}. The fourth column shows MS, which is equal to the sold capacity of all PPs. The 5th column presents S_y, which is the annual income. The 6th column shows S, which is the cost of all PPs. The 7th column presents T, which is the payback period of all PPs. Table 1 shows the results of calculations for the cost of PPs. The cost of [SRVG+the gas PP+(annual income of gas PP)] is unknown.

6. Estimation of SPEV parameters for the Campi Flegrei super volcano

In this section, we formulate the requirements for the SPEV for the Campi Flegrei super volcano and evaluate parameters, including estimation of financial parameters. The eruptions of Campi Flegrei and Tambor (1815) are comparable and attributed to eruptions with the index VEI-7. (Phlegraean Fields (2017)). Atomic-bomb the equivalent of Tambor's explosion (1815) is 200000; we assume that the atomic-bomb equivalent of the Campi Flegrei super-volcano explosion will also be 200000. Therefore, the energy of the future eruption of the Campi Flegrei volcano Q_0 in J is: $Q_0 = 1.68 \cdot 10^{20}$ Joules. The last time the super volcano erupted in t_1=1538. To carry out the estimates, we assume that the future eruption of Campi Flegrei super volcano will be in t_2 = 2028. Thus, $T_1=t_2-t_1$=490 years. Thermal energy in the system {earth's crust and magma chamber} increases at a rate of q_{em} (by analogy with (6))

$$q_{em}= Q_0/T_1=1.0874\ 10^4\ \text{MW}. \qquad (12)$$

Thermal energy in the system {Earth's crust and magma chamber} with N PPs increases at a rate of q_{es} (see (3b) and (5)). In order to cool the system {earth's crust and magmatic chamber}, we need

$$q_{es}= q_{em} -N\,M_1/E_f <0, \qquad (13)$$

where M_1 is the power of PP, we will consider M_1 = 140 MW - the power of the Olkaria IV geothermal power plant in Kenya (Ullman G. (2014)) E_f is efficiency of the PP; we assume E_f =0.15. The minimum number of PPs N_0 needed to meet the requirement (13) is equal to

$$N_0 = E_f\,Q_0/T_1M_1=12. \qquad (14)$$

The sold capacity of all PPs equals to M_S

$$M_S=N\,M_1. \qquad (15)$$

If we put the cost of one PP equal to S_1 (we will take S_1 = \$ 126 million; it is the cost of

$$S=N\,S_1. \qquad (16)$$

geothermal power plant Olkaria IV in Kenya, then the cost of all PPs is equal to Selling electricity to consumers at C_0 = 0.078 dollars per kW*h, the annual income will be equal to

$$S_y= C_0\,M_S\,(8760\ \text{h/year}). \qquad (17)$$

Payback period of N PPs will be equal to

$$T= S/S_y\,. \qquad (18)$$

Table 2: Results of calculation of SPEV parameters for Campi Flegrei super-volcano

1	*2*	*3*	*4*	*5*	*6*	*7*
K	N	q_{es} (MW)	M_S (MW)	S_y (billion dollars/year)	S(billion dollars)	T (years)
1	18	- 5926	2520	1.550	2.268	1.46
2	15	- 3126	2100	1.291	1.890	1.46
3	12	- 326	1680	1.033	1.512	1.46

Thus, all the SPEV parameters depend on the N. The results of SPEV parameter calculations for three variants: 1st option (strict requirements, N=18), 2nd option (moderate requirements, N=15), 3rd option (weak requirements,

$N=N_0=12$) are presented in Table 2. The cost of [SRVG+the gas PP+(annual income of gas PP)] is unknown.

7. Estimation of SPEV parameters for the Long Valley Caldera

In this section, we formulate the requirements for the SPEV for the Long Valley Caldera and evaluate parameters, including estimation of the financial parameters. We assumed, that the energy of the future eruption of the Long Valley Caldera in J is: $Q_0 = 5.88 \cdot 10^{20}$ Joules. The last time the super volcano erupted T_1=100000 years ago. (Long Valley (2018)). To carry out the estimates, we assume, as a first approximation, that the future eruption of Long Valley Caldera will be at $t_2 = 2020$ (according to the forecasts of geologists). We will correct this value of t_2 in this Chapter. Thermal energy in the system {Earth's crust and magma chamber} increases at a rate of q_{em} (by analogy with (6))

$$q_{em}= Q_0/T_1=186.4\,\mathrm{MW}. \qquad (19)$$

In Long Valley Caldera a complex of geothermal power plants Mammoth Geothermal Complex is working with a power of

$$M_{esm}=29\ \mathrm{MW}. \qquad (20)$$

The energy is produced by three separate power plants, using hot water from the same source. The three facilities are: G1 (MP1) with 6 MW generating capacity, G2 (MPII) with 11 MW and G3 (PLES-1) with 12 MW generating capacity. The first power plant, G1 (MP1), started operations in 1984 and G2 (MPII) and G-3 (PLES-1) came life in 1990 in Mammoth Geothermal Complex. Efficiency of binary geothermal power plants is near E_f=0.3, (see Fig. 10 in (Moon H., Zarrouk S.J., 2012)). The module of rate of thermal energy due to Mammoth Geothermal Complex equals

$$q_{esm} = M_{esm}/E_f = 96.7\ \mathrm{MW} < q_{em}. \qquad (21)$$

Therefore, Mammoth Geothermal Complex cannot cool Long Valley Caldera, but can only reduce the total heating rate of Caldera. This fact allows us to make a second approximation for estimating the eruption time t_2. If geologists predicted the eruption time t_2.= 2020, then we calculate the new eruption time t_{2n}. Proceeding from the idea that the eruption will take place when the energy of the system{Earth's crust and magma chamber} reaches the value equal to Q_0, we write equation

$$q_{em}(2020\text{-}1984)\mathrm{year}=(q_{em}\text{-}6\mathrm{MW}/E_f)6\mathrm{year} + (q_{em}\text{-}29\mathrm{MW}/E_f)(t_{2n}\text{-}1990\ \mathrm{year}). \qquad (22)$$

Solving equation (22), we obtain the eruption time t_{2n}, which increased due to the work of Mammoth Geothermal Complex:

$$t_{2n}= \{q_{em}(2020\text{-}1984)\mathrm{year}\text{-}(q_{em}\text{-}6\mathrm{MW}/E_f)6\ \mathrm{year} +(q_{em}\text{-}29\mathrm{MW}/E_f)(1990\ \mathrm{year})\}/$$

$$(q_{em}\text{-}29\mathrm{MW}/E_f)= 2053{,}7\ \mathrm{year}. \qquad (23)$$

Thus, the value of the eruption time found was increased by 33.7 years, which gives enough time to prevent the eruption by creating SPEV for Long Valley Caldera. We will estimate the number of new PPs that need to be created. Thermal energy in the system {Earth's crust and magma chamber} with N PPs should decrease at a rate of q_{es} (see (3b) and (5)). In order to cool the system {Earth's crust and magmatic chamber}, we need

$$q_{es}= q_{em} - q_{esm} - N\, M_1/E_f<0, \qquad (24)$$

where q_{esm} = 29 MW/E_f ; M_1 is power of one new PP, we will consider M_1 = 14 MW - the power of the commercial PP Hatch Geothermal Power Plant from American company Raser Technologies commissioned, which was built in just 6 months and cost S1=\$35 million, (Neville A. (2008)). The minimum number of PPs N_0 needed to meet the requirement (24) is equal to

$$N_0 = E_f\,(Q_0/T_1 - q_{esm})M_1=2. \qquad (25)$$

The sold capacity of all PPs equals to M_S

$$M_S=N\,(M_1\text{-}3\ \mathrm{MW}). \qquad (26)$$

Power Plant uses 3 MW for its own purposes, so in (26) we write (M_1-3 MW). If we put the cost of one PP equal to S_1 (we will take S_1 = \$35 million; S_1 is cost of one PP of the commercial PP Hatch Geothermal Power Plant), then the cost of all PPs is equal to

$$S=N\,S_1. \qquad (27)$$

Selling electricity to consumers at C_0=0.078 dollars per kW*h, the income for the year will be equal to

$$S_y= C_0\, M_S\ (8760\ \mathrm{h/year}). \qquad (28)$$

Payback period of N PPs will be equal to

$$T= S/S_y. \qquad (29)$$

Thus, all the SPEV parameters depend on the N. The results of SPEV parameter calculations for three variants: 1st option (strict requirements, N=24), 2nd option (moderate requirements, N=12), 3rd option (weak requirements, $N=N_0=2$) are presented in Table 3. The cost of [SRVG+the gas PP+(annual income of gas PP)] is unknown.

Table 3: Results of calculation of SPEV parameters for Long Valley Caldera

1	2	3	4	5	6	7
K	N	q_{es} (MW)	M_S (MW)	S_y (million dollars/year)	S (million dollars)	T (years)
1	24	- 1030,3	264	180.4	840	4,66
2	12	- 470.3	132	90.2	420	4,66
3	2	- 3.6	22	15.03	70	4,66

8. Estimation of SPEV parameters for the volcano Vesuvius

The thermal energy of the upper part of the Earth's crust under the mouth of volcano Vesuvius is determined by the energy coming from the magmatic chamber with the help of the thermal conductivity of the crust, the thermal energy of volcanic gases (including the energy of explosive gases). We propose creation of a geothermal power plant (PP) at a shallow depth. Therefore, it is sufficient to use small depths for the PP. For example, PP (Mammoth Geothermal Complex) lifts water from a working well from a depth of 150 meters, heated to an average of 170 degrees. The waste water is pumped back through the casing to a depth of 600 meters. This is a repetitive duty cycle. Pumping heat energy from the Earth's crust, we simultaneously reduce the energy of the magma chamber and reduce the likelihood of a volcanic eruption.

Specifics of SPEV for volcano Vesuvius lies in the fact that the working well and the second well, through which the waste water is pumped back, are inclined wells that start from the surface of the earth near volcano Vesuvius and end at different depths under the vent of volcano Vesuvius. The index of volcano Vesuvius is VEI-5. We will assume that the atomic-bomb equivalent of the eruption of volcano Vesuvius will be 4.

In this section, we formulate the requirements for the SPEV for Vesuvius volcano and evaluate parameters, including estimation of financial parameters. We assumed, that the energy of the future eruption of the Vesuvius volcano in J is: $Q_0 = 33.6 \cdot 10^{14}$ Joules. The last time the volcano erupted at t_1 = 1944 years ago. (Visuvius (2018)) To carry out the estimates, we assume, as a first approximation, that the future eruption of Vesuvius volcano will be at t_2 = 2018 thus T_1=74. Thermal energy in the system {Earth's crust and magma chamber} increases at a rate of q_{em} (by analogy with (6))

$$q_{em}=q_m-q_h-q_e=Q_0/T_1=1.43\ \text{MW}. \qquad (30)$$

Efficiency of binary geothermal power plants is near E_f=0.3, see Fig. 10 in (Moon H., Zarrouk S.J., 2012). We will estimate the number of new PPs that need to be created. Thermal energy in the system {earth's crust and magma chamber} with N PPs should decrease at a rate of q_{es} (see (3b) and (5)). In order to cool the system {earth's crust and magmatic chamber}, we need

$$q_{es}= q_{em} -N\ M_1/E_f<0, \qquad (31)$$

where; M_1 is power of one new PP, we will consider M_1 = 14 MW - the power of the commercial PP Hatch Geothermal Power Plant from American company Raser Technologies commissioned, which was built in just 6 months and cost S1=$35 million, (Neville A. (2008)). The sold capacity of all PPs equals to M_S

$$M_S=N\ (M_1-3\ \text{MW}). \qquad (32)$$

Power Plant uses 3 MW for its own purposes, so in (32) we write (M_1-3 MW). If we put the cost of one PP equal to S_1 (we will take S_1 = $35millions; S_1 is cost of one PP of the commercial PP Hatch Geothermal Power Plant), then the cost of all PPs is equal to

$$S=N\ S_1. \qquad (33)$$

Selling electricity to consumers at C_0 = 0.078 dollars per kW*h, the annual income will be equal to

$$S_y= C_0\ M_S\ (8760\ \text{h/year}). \qquad (34)$$

Payback period of N PPs will be equal to

$$T= S/S_y . \qquad (35)$$

Thus, all the SPEV parameters depend on the N. The results of SPEV parameter calculations for two variants: 1st option (moderate requirements, N=1), 2nd option (strict requirements, N=2) are presented in Table 4. The cost of [SRVG+the gas PP+(annual income of gas PP)] is unknown.

Table 4: Results of calculation of SPEV parameters for Vesuvius volcano

1	*2*	*3*	*4*	*5*	*6*	*7*
K	N	q_{es} (MW)	M_S (MW)	S_y (million dollars/year)	S(million dollars)	T (years)
1	1	- 45.2	11	7.516	33	4.39
2	2	-91.9	22	15.032	66	4.39

9. Estimation of SPEV parameters for the Ruapehu volcano

In this section, we formulate the requirements for the SPEV for the Ruapehu volcano. Mount Ruapehu, also known simply as Ruapehu, the largest active volcano in New Zealand, is the highest point on the North Island and has three major peaks: Tahurangi (2,797m), Te Heuheu (2,755m) and Paretetaitonga (2,751m). The deep, active crater is between the peaks and fills with Crater Lake between major eruptions. Major eruptions have been about 50 years apart, in 1895, 1945 and 1995–1996. Minor eruptions are frequent, with at least 60 since 1945. Some of the minor eruptions in the 1970s generated small ash falls and lahars. Ruapehu erupted at 4 October 2006. The small eruption created a volcanic earthquake at a magnitude of 2.8, sending a water plume 200 m into the air. At 25 September 2007, a hydrothermal eruption occurred without warning. A GeoNet New Zealand Bulletin was released on 21 July 2008 stating that "the current phase of volcano unrest appears to be over, however Ruapehu remains an active volcano. Future eruptions may occur without warning." On 5 April 2011, 16 November 2012 warnings and 29 April 2016 Geonet changed Mount Ruapehu's Volcanic Aviation Colour Code from Green to Yellow (elevated unrest above the known background). (Mount Ruapehu (2017)). Volcanic

Explosivity Index (VEI) of Ruapehu is VEI =2. We assume that the future eruption of Ruapehu volcano will have T_1=1 year and the atomic-bomb equivalent of the Ruapehu volcano will be 0,1. Specifics of SPEV for volcano Ruapehu lies in the fact that the working well and the second well, through which the waste water is pumped back, are inclined wells that start from the surface of the earth near volcano Ruapehu and end at different depths under the vent of volcano Ruapehu. Thermal energy in the system {earth's crust and magma chamber} increases at a rate of q_{em} (by analogy with (6))

$$q_{em}= Q_0/T_1=2.66\ \text{MW}. \qquad (36)$$

Thermal energy in the system {Earth's crust and magma chamber} with N PPs increases at a rate of q_{es} (see (3b) and (5)). In order to cool the system {earth's crust and magmatic chamber}, we need

$$q_{es}= q_{em} - N\, M_1/E_f < 0, \qquad (37)$$

where M_1 is the power of PP, we will consider M_1 = 14 MW - the power of the (where M_1 is power of PP, M_1=14 MW; we use PP from American company Raser Technologies commissioned a commercial PP Hatch Geothermal Power Plant, which was built in just 6 months and cost S_1=$35 million, (Neville A. (2008)). Efficiency E_f of binary geothermal power plants is near E_f=0.3, see Fig. 10 in (Moon H., Zarrouk S.J., 2012). The sold capacity of all PPs equals to M_S

$$M_S=N\,(M_1-3 \text{ MW}). \qquad (38)$$

Power Plant uses 3 MW for its own purposes, so in (38) we write (M_1-3 MW). If we put the cost of one PP equal to S_1 (we will take S_1 = $35millions; S_1 is cost of one PP of the commercial PP Hatch Geothermal Power Plant), then the cost of all PPs is equal to

$$S=N\, S_1. \qquad (39)$$

The PP+SRVG will obviously cost more. Selling electricity to consumers at C_0 = 0.078 dollars per kW*h, the annual income will be equal to

$$S_y= C_0\, M_S\, (8760 \text{ h/year}). \qquad (40)$$

Payback period of N PPs will be equal to

$$T= S/S_y\,. \qquad (41)$$

Thus, all the SPEV parameters depend on the N. The results of SPEV parameter calculations for two variants: 1st option (strict requirements, N=2), 2nd option (moderate requirements, N=1) are presented in Table 5. The cost of [SRVG+the gas PP+(annual income of gas PP)] is unknown.

Table 5: Results of calculation of SPEV parameters for Ruapehu volcano

1	2	3	4	5	6	7
K	N	q_{es} (MW)	M_S (MW)	S_y (million dollars/year)	S(million dollars)	T (years)
1	2	- 90.7	22	15.03216	70	4.66
2	1	- 44.	11	7.51608	35	4.66

10. Volcano Popocatépetl

10.1. Information about volcano Popocatépetl

Volcán Popocatépetl towers to 5426 m 70 km SE of Mexico City to form North America's 2nd-highest volcano. Popocatépetl is the most active volcano in Mexico, having had more than 15 major eruptions since the arrival of the Spanish in 1519. A violent VEI-6 (Volcanic Explosivity Index) eruption in the mid-to late first century CE. A major eruption occurred in 1947. On December 21, 1994, the volcano spewed gas and ash, which was carried as far as 25 km away by prevailing winds. The activity prompted the evacuation of nearby towns and scientists to begin monitoring for an eruption. In December 2000, tens of thousands of people were evacuated by the government, based on the warnings of scientists. On December 25, 2005, the volcano's crater produced an explosion which ejected a large column of smoke and ash about 3 km into the atmosphere and expulsion of lava. In January and February 2012, scientists observed increased volcanic activity at Popocatépetl. On January 25, 2012, an ash explosion occurred on the mountain, causing much dust and ash to contaminate the atmosphere around it. On April 19, 2012, there were reports of superheated rock fragments being hurled into the air by the volcano. Ash and water vapor plumes were reported 15 times over 24 hours. On Wednesday May 8, 2013, Popocatépetl erupted again with a high amplitude tremor that lasted and was recorded for 3.5 hours. It began with plumes of ash that rose 3 km into the air and began drifting west at first, but later began to drift east-southeast, covering areas of the villages of San Juan Tianguismanalco, San Pedro Benito Juárez and the City of Puebla in smoke and ash. Explosions from the volcano itself subsequently ejected fragments of fiery volcanic rock to distances of 700 m from the crater.

On July 4, 2013, due to several eruptions of steam and ash for at least 24 hours, at least six U.S. airlines canceled more than 40 flights into and out of Mexico City and Toluca airports that day. During 27 August–September 2014, CENAPRED reported explosions, accompanied by steam-and-gas emissions with minor ash and ash plumes that rose 800-3,000 m above Popocatépetl's crater and drifted west, southwest, and west-southwest. On most nights incandescence was observed, increasing during times with larger emissions. On 1 September partial visibility due to cloud cover was reported. On 29 and 31 August the Washington Volcanic Ash Advisory Center (VAAC) reported discrete ash emissions. On January 7, 2015, CENAPRED reported that ash from recent explosions coats the snow on the volcano's upper slopes. On March 28, 2016, an ash column 2,000 metres high was released, prompting the establishment of a 12-kilometer "security ring" around the summit. On 3 April 2016, Popocatépetl erupted, spewing lava, ash and rock. Eruptions continued in August 2016, with four discrete blasts on August 2017 and on November 10, 2017 (Popocatépetl (2017)).

10.2. Estimation of SPEV parameters for the volcano Popocatépetl

The thermal energy of the upper part of the Earth's crust under the mouth of volcano Popocatépetl is determined by the energy coming from the magmatic chamber with the help of the thermal conductivity of the crust, the thermal energy of volcanic gases (including the energy of explosive gases). We propose the creation of a power plant (PP) at a shallow depth. Therefore, it is sufficient to use small depths for the PP. For example, PP (Mammoth Geothermal Complex) lifts water from a working well from a depth of 150 meters, heated to an average of 170 degrees. The waste water is pumped back through the casing to a depth of 600 meters. This is a repetitive duty cycle. Pumping heat energy from the earth's crust, we simultaneously reduce the energy of the magma chamber and reduce the likelihood of a volcanic eruption. Specifics of SPEV for volcano Popocatépetl lies in the fact that the working well and second well, through which the waste water is pumped back, are inclined wells that start from the surface of the earth near volcano Popocatépetl and end at different depths under and near the vent of volcano Popocatépetl. The index of volcano Popocatépetl is VEI-5. We will assume that the atomic-bomb equivalent of the eruption of volcano Popocatépetl will be 4. In this section, we formulate the requirements for the SPEV for the Popocatépetl volcano and evaluate parameters, including financial parameters. We assumed, that the energy of the future eruption of the Popocatépetl volcano in J is: Q_0 = 33.6•10^{14} Joules. Last eruptions of Popocatépetl in Mexico 2005 to 2017 (ongoing), therefore, the last time the super volcano erupted at t_1 = 2017 year. To carry out the estimates, we assume, as a

First approximation, that the future eruption of

Popocatépetl_will be at t_2 = 2018 thus T_1=1. We based on SPEV in our estimates of SPEV parameters. Thermal energy in the system {earth's crust and magma chamber} increases at a rate (see (6) in of q_{em} (by analogy with (6))

$$q_{em}=Q_0/T_1=106.53\text{ MW}. \qquad (42)$$

Efficiency of binary geothermal power plants is near E_f=0.3, see Fig. 10 in (Moon H., Zarrouk S.J., 2012**)**. We will estimate the number of new PPs that need to be created. Thermal energy in the system {earth's crust and magma chamber} with N PPs should decrease at a rate of q_{es} (see (8)). In order to cool the system {earth's crust and magmatic chamber}, we need

$$q_{es}= q_{em} -N\ M_1/E_f<0, \qquad (43)$$

where; M_1 is power of one new PP, we will consider M_1 = 14 MW - the power of the commercial PP Hatch Geothermal Power Plant from American company Raser Technologies commissioned, which was built in just 6 months and cost S1=$35 million, (Neville A. (2008)). The power of all PPs equals to M_S

$$M_S=N\ (M_1\text{-3 MW}). \qquad (44)$$

Power Plant uses 3 MW for its own purposes, so in (44) we write (M_1-3 MW). If we put the cost of one PP equal to S_1 (we will take S_1 = $35 millions; S_1 is cost of one PP of the commercial PP Hatch Geothermal Power Plant), then the cost of all PPs is equal to

$$S=N\ S_1. \qquad (45)$$

The cost of PP+SRVG will obviously be more. Selling electricity to consumers at C_0 = 0.078 dollars per kW*h, the income for the year will be equal to

$$S_y= C_0\ M_S\ (8760\text{ h/year}). \qquad (46)$$

Table 6: Results of calculation of SPEV parameters for Popocatépetl volcano

1	2	3	4	5	6	7
K	N	q_{es} (MW)	M_S (MW)	S_y (million dollars/year)	S(million dollars)	T (years)
1	N_0=3	- 33,45	33	22.55	105	4.66
2	4	- 80.11	44	30.06	140	4.66
3	*5*	*-126,77*	*55*	*37.58*	*175*	4.66

Payback period of N PPs will be equal to

$$T= S/S_y\,. \qquad (47)$$

Minimum number of N PPs will be equal to

$$N_0= Q_0\ E_f\ /\ M_1\ T_1=3. \qquad (48)$$

Thus, all the SPEV parameters depend on the N. The results of SPEV parameter calculations for three variants: 1st option (strict requirements, N=5), 2nd option (moderate requirements, N=4), 3rd option (weak requirements, N=3). The cost of [SRVG+the gas PP+(annual income of gas PP)] is unknown.

11. Etna Volcano

11.1. Information about Etna volcano

Mount Etna is an active stratovolcano on the east coast of Sicily, Italy, in the Metropolitan City of Catania, between the cities of Messina and Catania. It lies above the convergent plate margin between the African Plate and the Eurasian Plate. It is the tallest active volcano in Europe outside the Caucasus. It is currently 3,329 m high. It is the highest peak in Italy south of the Alps. Etna covers an area of 1,190 km^2. This makes it by far the largest of the three active volcanoes in Italy, being about two and a half times the height of the next largest, Mount Vesuvius. Eruptions of Etna follow a variety of patterns. Most occur at the summit, where there are currently (as of 2008) five distinct craters — the Northeast Crater, the Voragine, the Bocca Nuova, and the Southeast Crater Complex (2). Other eruptions occur on the flanks, which have more than 300 vents ranging in size from small holes in the ground to large craters hundreds of metres across. Summit eruptions can be highly explosive and spectacular, but rarely threaten the inhabited areas around the volcano. In contrast, flank eruptions can occur down to a few hundred metres altitude, close to or even well within the inhabited areas. Numerous villages and small towns lie around or on cones of past flank eruptions. Since the year AD 1600, at least 60 flank eruptions and countless summit eruptions have occurred; nearly half of these have happened since the start of the 20th century. Since 2000, Etna has had four flank eruptions — in 2001, 2002–2003, 2004–2005, and 2008–2009. Summit eruptions occurred in 2006, 2007–2008, January–April 2012, and again in July–October 2012. (Mount Etna (2017)).

Through January 2011 to February 2012, the summit craters of Etna were the site of intense activity. The July 2011 episode also endangered the Sapienza Refuge, the main tourist hub on the volcano, but the lava flow was successfully diverted. In 2014, a flank eruption started involving lava flows and strombolian eruptions. On 3 December 2015, an eruption occurred. The Voragine crater exhibited a lava fountain which reached 1km in height, with an ash plume which reached 3 km in height. The activity continued on the following days, with an ash plume that reached 7km in height. An eruption on 16 March

Table 7: Volcanic explosivity index for Mount Etna's eruptions since January 1955

1	2	3
K	VEI	Number of eruptions (total=49)
1	VEI 0	1
2	VEI 1	17
3	VEI 2	24
4	VEI 3	7
5	VEI 4	1

2017 injured 10 people, including a BBC News television crew, after magma exploded upon contact with snow. (Mount Etna (2017)). The volcano Etna wanders unusually in its slopes and seldom remains in one place for the reason that the soil is unstable and gradually "falls through" to the ground, according to an article published by (Acocella V. (2016)). The Global Volcanism has assigned a volcanic explosivity index (VEI) (Volcanic Explosivity Index (2017)) to all of Mount Etna's eruptions since January 1955.

11.2. Estimation of SPEV parameters for Etna volcano

The eruption of Etna 2017 is the one from which we calculate t_1=2017. We assume, that eruption of Etna will be VEI 3 at t_2=2018. Thus, $T_1= t_2 - t_1 =1$. We assume, that the power of the eruption of the Etna volcano is estimated at the equivalent of Q_0=0,05 the atomic-bomb equivalent. Thermal energy in the system {Earth's crust under the mouth of volcano Etna and magma chamber} increases at a rate (see (6)) of q_{em} (by analogy with (6))

$$q_{em}=Q_0/T_1=1{,}33 \text{ MW}. \tag{49}$$

The company's unique rapid deployment strategy utilizes UTC power generating units that are manufactured off-site and shipped to the project ready to be hooked up and operated. The 14-MW facility combined 50 modular (PP uses 4 MW to solve its own problems), low-temperature Pure Cycle power units from UTC Power, allowing power plant construction to be completed in just a few months. These turbine-generator modules function as small individual power plants. Thermo is the first commercial-scale project to use the UTC units and will act as a template for developing a number of cookie-cutter 14-MW projects in a rapid deployment fashion. The binary geothermal power plants combined 50 modular, low-temperature PureCycle power units from UTC Power. Neville A. (2008). Thus, one of the binary geothermal power plant (PP) has the gross electric power M_{1S}

$$M_{1S}=14 \text{ MW}/50=0{,}28 \text{ MW}. \tag{50}$$

Efficiency E_f of binary geothermal power plants is near E_f=0.3, see Fig. 10 in (Moon H., Zarrouk S.J., 2012). Thermal energy in the system {earth's crust and magma chamber} with N PPs should decrease at a rate of q_{es} (see (3b) and (5)). In order to cool the system {earth's crust and magmatic chamber}, we need

$$q_{es}=q_{em}- NM_{1S}/50E_f = <0, \tag{51}$$

To satisfy (51), min (N) = 2, then

$$q_{es}(N=2)=-0{,}537 \text{ MW}, \tag{52}$$

The area of Etna is gigantic and includes a large number of volcanoes. We assume that the number of all active volcanoes equals to N_v. Volcanoes, located at a great distance from each other, can erupt independently; then, to prevent volcanic eruptions with high probability, we must install modules under each volcano. To prevent volcanic eruptions with high probability, we will install 2 modules under each volcano, then we will need minimum N_{SV} = 2 Nv modules. The cost of all PPs is equal to S

$$S= N_{SV}\, S_1,$$

where S_1=(35 Million dollars)/50=0,7 Million dollars (53)

Selling electricity to consumers at C_0=0.078 dollars per kW*h, the income for the year will be equal to

$$S_v= C_0\, M_{SS}\, (8760 \text{ h/year}). \tag{54}$$

where $M_{SS}=N_{SV}\, M_{10}$, M_{10}= 10 MW/50=0,2 MW.

Payback period of N PPs will be equal to

$$T= S/S_v. \tag{55}$$

The results of SPEV parameter calculations for two variants: 1st option (moderate requirements, N_V =55), 2nd option (strict requirements, N_V =300). The cost of SRVG+the gas PP+(annual income of gas PP) is unknown.

Table 8: Results of calculation of SPEV parameters for volcano Etna

1	*2*	*3*	*4*	*5*	*6*	*7*
K	N_V	N_{SV}	M_{SS}(MW)	S_y(Millions dollars/year)	S(Millions dollars)	T(years)
1	55	110	1100	15,03	77	5,12
2	300	600	6000	81,99	420	5,12

12. Discussion

12.1. Let us compare the level of danger of the state of three super volcanoes, based on the calculations presented in the article: Long Valley Caldera poses the least dangerous super volcano: (1) the work of Mammoth Geothermal Complex in Long Valley Caldera contributed to this relatively safe state, for example the value of the eruption time was increased by 33.7 years; (2) the minimum amount of work required to create SPEV; (3) financial costs are minimal. Campi Flegrei volcano presents the greatest danger by comparison with other super volcanoes; (1) there is a shortage of time for the construction of SPEVs, because the amount of work required is the greatest; (2) the financial costs are the highest compared to the projected financial costs for other super-volcanoes.

12.2. The author was asked in a conversation: "all the processes in the magmatic chamber are giant in magnitude; $Q_0 = 9.24 \cdot 10^{20}$ Joules for Yellowstone super volcano. What is the physics of SPEV, which allows you to prevent eruptions of volcanoes and to cool the magmatic chamber at a depth of 8 km, if you have only PPs with wells at a depth of several hundred meters?"

The physics of the process is as follows: First, the Earth's crust and magmatic chamber are connected due to thermal conductivity and volcanic gases. Therefore, it is sufficient to use small depths for the PP. Secondly: thermal energy Q in the system (Earth's crust and magma chamber) increases at a rate of q_{em} = 41.085 MW, (see (6)), which is substantially less than M_1/E_f = 46,7 MW that allows to cool the magmatic chamber and Earth's crust (see Table 1 and Fig. 1), and to prevent eruptions of volcanoes.

12.3. The geological record suggests that summit eruptions are somewhat more probable than flank in Etna. However, both summit and flank eruptions are likely to produce lava flows, and these are the greatest hazard posed by Etna to inhabited areas (Negro C.D. (2013)). Therefore, the density of the SPEVs should be larger in summit than in flank in Etna.

13. Conclusions

13.1) Based on physical models, the mechanisms for a volcanic eruption prevention system (SPEV) are proposed as: [the geothermal PP+SRVG+the gas PP] system. Thus, the proposed SPEV is to create a this system with a small depth of wells (which will result in a relatively small cost).

13.2) An open energy model of super volcano and SPEV was developed. The obtained equations are proposed and integrated; Based on the proposed model, SPEV parameter estimates of the Yellowstone, Campi Flegrei, Long Valley super volcanoes and Vesuvius, Ruapehu, Popocatépetl and Etna volcanoes are made and include a business plan proposal (see Chapters 5-11; Tables 1-8).

13.3) The density of SPEV over the area of the super volcano should be maximum in the area of the maximum level of heat release, but the entire area of the super volcano should be served by SPEV, so that an autonomous volcano does not occur on the outskirts. The natural system of energy removal through geysers cannot be destroyed.

13.4) The proposed SPEV is a scientific and technological breakthrough that can save humanity from death due to "volcano winter" - the climate change during the eruption of super volcanoes and will prevent human casualties and material losses from the eruption of small volcanoes. This paper will be informative for researchers; and should also be of interest to governments, municipalities (e.g. Naples, Mexico City, etc.) and companies to create SPEVs for protecting the population from the most terrible danger for humanity.

13.5) Currently, geothermal power engineering is developing at an accelerated pace. This development is promoted by governmental programs adopted in many countries in the world, that support this direction of development. The amount of thermal energy produced in the bowels of the planet exceeds the amount of energy removed, which results in overheating of the Earth. The thermal energy of the planet releases during the eruption of volcanoes, which restores thermal equilibrium of the planet. The reports presented in Introduction section of this article show that the volcanic activity of the Earth is increasing at the present time, and this threatens the existence of the greater part of humanity due to the "volcanic winter". Thus, if we want to prevent volcanic eruptions, then we simply have to build a large number of SPEV, which, firstly, will constantly remove some of the heat energy from the Earth to generate electricity, and secondly, will gradually reduce the remaining heat in the system {magmatic camera and crust}, not allowing thermal energy to escape in the form of volcanic eruptions. This remaining energy in the system of the magmatic chamber and the Earth's crust will be a national treasure, as it will supply energy to PPs, instead of destructive volcanic eruptions. Thus, the proposal and rationale for SPEV in this article should give a powerful incentive for the development of geothermal power engineering, because there is simply no other alternative to prevent volcanic eruptions.

13.6) Eruption of Campi Flegrei super volcano will cause a climatic catastrophe of a planetary scale as super volcano with the index VEI-7 (due to the "volcanic winter"), and ashes will cover Europe and North Africa. This makes Campi Flegrei super volcano the problem for Europe. The calculations presented in the article show: (1) Campi Flegrei volcano presents the greatest danger by comparison with other super volcanoes; (2) there is a shortage of time for the construction of SPEVs, because the amount of work required is the greatest; (3) the financial costs are the highest compared to the projected financial costs for other super-volcanoes. The author hopes that the European Union, governments, IMF and other Foundations will be able to finance companies in creating SPEVs to protect the population from the most terrible danger for humanity.

13.7) The work of Mammoth Geothermal Complex in Long Valley Caldera cannot cool Long Valley Caldera, but can only reduce the total heating rate of Caldera; thus, the value of the eruption time found was increased by 33.7 years, which gives enough time to prevent the eruption by creating SPEV in Long Valley Caldera.

13.8) The proposed SPEV is a scientific and technological breakthrough that can save most of humanity from death due to "volcano winter"- the climate change during the eruption of super volcanoes. SPEV allows to generate clean electricity. SPEV promotes the removal of volcanic gases (in Long Valley Caldera) by using the Systems for the Removal of Volcanic Gases (SRVG) from water, which is located in PPs; thus, SPEV contributes to the solution of environmental problems too.

13.9) The European Science Foundation and some professors predict (see 1.1-1.3 in the Introduction of this article) that eruption of one of the super volcanoes will kill most of the homo sapience due to global climate changes. The author agrees with this forecast only provided that the SPEVs will not widely used. The author hopes that governments, IMF and other Foundations will be able to finance companies in creating SPEVs to protect the population from the most terrible danger for humanity.

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