Proceedings World Geothermal Congress 2026
Calgary, Canada, June 8 – 11, 2026

Developing Emergency Response Protocols for the Pico Alto Geothermal Power Plant Facing Volcanic Risk (Terceira Island, Azores, Portugal)

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Keywords: Pico Alto ORC Geothermal Power Plant, Volcanic eruption risk, Emergency planning

ABSTRACT

On June 24, 2022, a seismic-volcanic crisis began in Terceira Island (Azores, Portugal), associated with the unrest of Santa Bárbara Volcano, located 6,0 km West from the Pico Alto Geothermal Power Plant, a binary ORC system using cyclopentane as the working fluid. By the end of 2024, approximately 325 earthquakes had been felt by the local population, and the most significant event occurred on January 14, 2024, at 07:19 h, reaching a magnitude of 4,5. Following the confirmed reactivation of the Santa Bárbara Volcano, the seismic-volcanic alert level was raised to V3 (CIVISA scale, 2012) on June 24, 2024, highlighting a critical gap in the emergency response plan from the Pico Alto Geothermal Power Plant: the volcanic eruption risk. In the absence of known national and/or international guidelines specific to binary ORC geothermal facilities under volcanic eruption risk, a new emergency plan had to be developed from scratch. This process drew upon internal expertise from the multidisciplinary technical team at EDA RENOVÁVEIS (physicists, geologists, engineers, and safety professionals). From emotional and stressful days identifying critical intervention points, developing procedures, defining evacuation routes, discussions with local authorities, making logistical improvements (e.g., satellite communications, individual and collective emergency kits) to the progressive downgrade to alert level V2 on December 4, 2024.This paper, beyond recounting the technical and logistical challenges addressed in the emergency plan, pretends to raise awareness within the geothermal community about the need to establish a unified, internationally recognized set of guidelines for emergency planning in the event of seismic-volcanic risk.

1 INTRODUCTION

1.1 Geographic and Tectonic Setting of the Azores Archipelago

The Azores Archipelago is an autonomous region of Portugal made of nine inhabited volcanic islands and some islets. It is in the North Atlantic Ocean, about 1.600 km west of mainland Portugal, between latitude 37°-40° north and longitude 25°-31° west, extending over more than 600 km. The archipelago is divided into three island groups: Eastern Group (São Miguel, Santa Maria), Central Group (Terceira, Graciosa, São Jorge, Pico and Faial), and Western Group (Flores and Corvo) (Figure 1). The total land area is about 2.351 km^2. According to the 2021 census, the resident population is of 246.772 inhabitants, with São Miguel being the most populous island (SREA, 2022). Being an ultra-peripheral region of Europe, the strategic development of renewables favours the indigenous resources, bringing evident environmental, social, and economic benefits to the Region, Rangel et al. (2011).

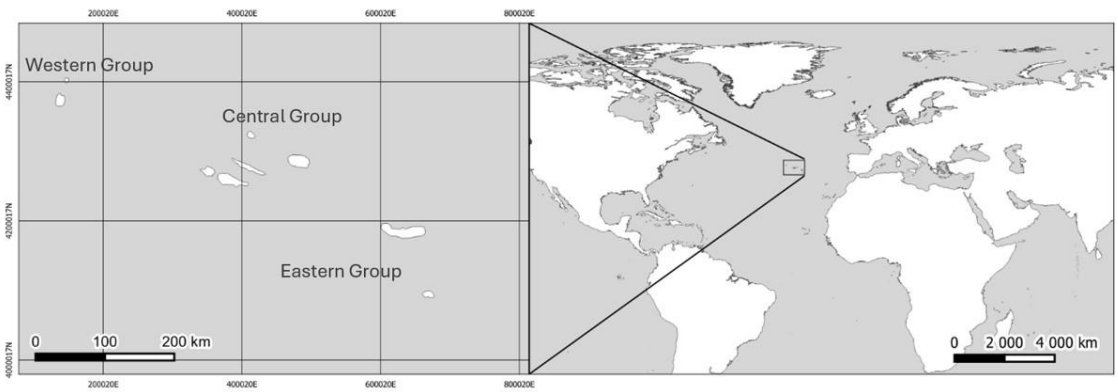


Figure 1 - Geographic location of the Azores Archipelago in the North Atlantic Ocean, showing its position relative to Europe, North America, and the main island groups.

The islands follow a WNW-ESE alignment and rise above the sea level in North Atlantic from a submarine topographic high known as the Azores Plateau, which is delimited by the 2.000-meter bathymetric contour. Geodynamically, the archipelago is at the Azores Triple Junction, where the North American, Eurasian, and Nubian lithospheric plates meet (Figure 2). The area is also affected by the presence of a deep mantle plume that interacts with the Mid Atlantic Ridge and feeds the activity of the Azorean volcanoes, Gaspar et. al. (2015).

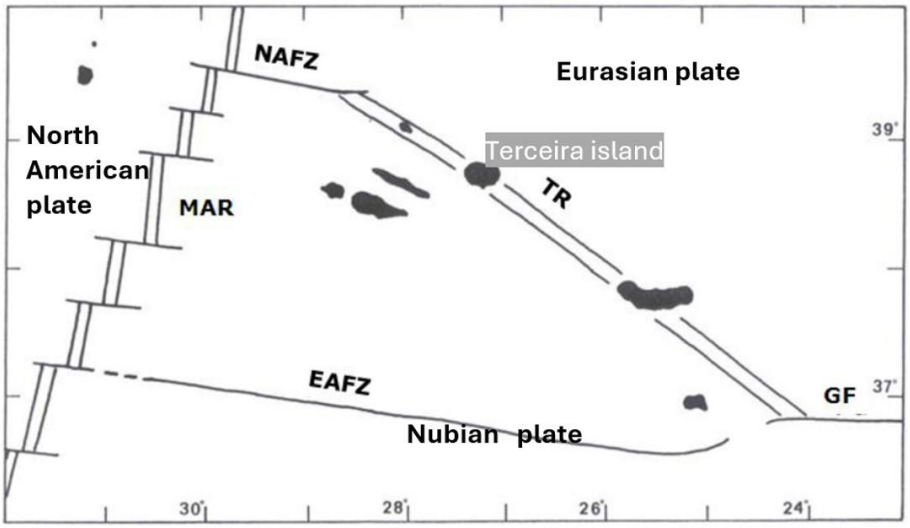


Figure 2 – Main tectonic structures in the Azores region: MAR – Mid Atlantic Ridge; NAFZ – Northen Azores Fault Zone; EAFZ – Eastern Azores Fault Zone; TR – Terceira Rift; GF - Glória Fault; Gaspar (1996).

As a result of its complex geotectonic setting, the region experiences frequent seismic and volcanic activity and, since the settlement of the islands in the 15th century, 31 destructive earthquakes and seismic crises have been recorded, and at least 28 volcanic eruptions have been registered, occurring both on land and in the sea, Gaspar et al. (2015). Subaerial volcanic eruptions ranged from Hawaiian to sub-Plinian, the latter having a hydromagmatic character when magma interacted with water from caldera lakes. In contrast, submarine events have been of Surtseyan character, sometimes giving rise to ephemeral islets that are quickly eroded by seawater, Gaspar et al. (2015).

2 TERCEIRA ISLAND

2.1 Geological Setting

Terceira Island has a diverse array of geological structures shaped by the interaction of tectonic and magmatic processes. It is influenced by the Terceira Rift, a NW-SE trending tectonic feature that marks the diffuse boundary between the Eurasian and Nubian plates, that also controls the island's dominant NW-SE to WNW-ESE structural orientation (Figure 3-a). It comprises four central volcanoes with collapse calderas—Santa Bárbara, Pico Alto, Guilherme Moniz, and Cinco Picos—alongside a WNW-ESE fissural basaltic zone (Figure 3). Cinco Picos and Guilherme Moniz are extinct, and form the eastern and southern sectors, while Pico Alto and Santa Bárbara, together with the fissural zone, remain active with eruptive activity occurring over the last millennia, e.g. Pimentel et al. (2016), Pimentel et al. (2021), Pimentel (2023), and Self (1976).

The volcanostratigraphy of the island is divided into two major groups, separated by the ~25.000-year-old Lajes-Angra Ignimbrite (LAI, Figure 3-b). The Lower Group includes older pyroclastic formations, mainly ignimbrites from Pico Alto and possibly Guilherme Moniz. The Upper Group comprises younger deposits from Santa Bárbara, Pico Alto, and the fissural basaltic zone composed of monogenetic scoria cones and lava flows, Gertisser et al. (2010), Pimentel et al. (2021), Self (1976).

Historical eruptions, that is, those occurring after the settlement of the island, have taken place both on land and offshore. The first written records of volcanic activity correspond to events in 1761 in the centre of the island (Figure 3-a), with the emplacement of trachytic lava domes (Mistérios Negros) and a Hawaiian/Strombolian eruption that produced a trachybasaltic basaltic lava flow, Pimentel et al. (2016). Two other volcanic eruptions were reported in 1867 and in 1998–2001, both along the Serreta submarine ridge, located off the west coast of Terceira, the latter of which produced lava balloons, Rodrigues (2021), Casas et al. (2018), Gaspar et al. (2003).

Seismicity in the Central Group includes moderate events and swarms, but sometimes, major tectonic destructive events of larger magnitude occur. The most destructive was the 1980 event (M 7.2), which caused major damage and significant loss of life.

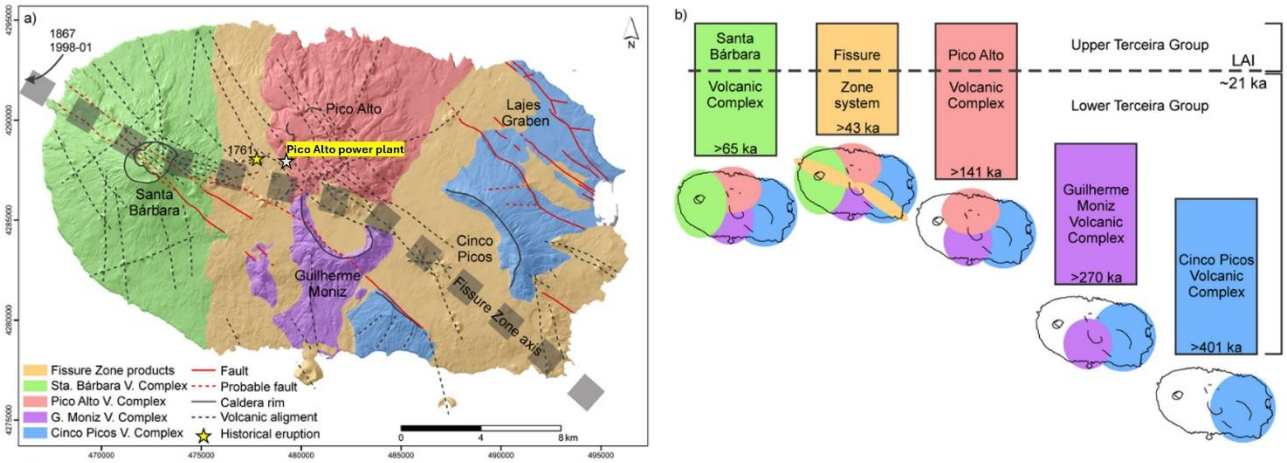


Figure 3 - a) Simplified geological map of Terceira Island with the location of the Pico Alto power plant (modified from Madeira, 2005 in Pimentel et.al, 2016); UTM coordinates, zone 26S. b) Stratigraphic scheme and reconstruction of the different phases of evolution of Terceira (LAI -Lajes-Angra Ignimbrite Formation). Ages from Calvert et al. (2006), Gertisser et al. (2010) and Hildenbrand et al. (2014) in Pimentel et al. (2016).

2.2 Santa Bárbara Volcano

Since late June 2022, the Santa Bárbara Volcano has shown activity levels (seismicity and deformation) above the reference background, resulting from a deep magmatic intrusion (CIVISA alert report, December 2024). This activity has occasionally extended eastward along the western part of the Fissural Volcanic System, specifically along the axis where the 1761 volcanic eruption occurred (CIVISA alert report, June 2023). A summary of the crisis events up to May 2024 is presented in Table 1 and in figure 4, as an example, an epicentral map of the events located with precision during September of 2024.

The seismic activity recorded during this crisis has been mostly concentrated within the perimeter of the Santa Bárbara Volcano and has been characterized primarily as micro-seismicity. Until October 2025, the most energetic event occurred on January 14, 2024, at 07:19 a.m. (local time), reaching a magnitude of 4,5 on the Richter scale (ML). Its epicentre was located approximately 1 km east of Serreta, and it was felt with a maximum intensity of VI on the Modified Mercalli Intensity (MMI) Scale in the western sector of the island. On that occasion, some cracks were reported in buildings with low seismic resistance, along with the collapse of dry-stone walls, damage to certain roads, and landslides both inland and along coastal cliffs, SRPCBA (2024).

Table 1 – Summary of the main events from the Santa Bárbara Volcano seismic crisis, occurring in Terceira and the surrounding marine area, Silva et al. (2023, 2024, 2025).

Dates	Main events
Jun-Nov 2022	24-06-2024: beginning of the seismic crisis and the volcanic alert is increased to V2. All events are reported as having tectonic origin Events: - 1.790 with an average magnitude <1,5 (7 events felt by the inhabitants) - Maximum magnitude and intensity: 2,5 ML / IV (MMI)
Dec 2022 – May 2023	1 event reported as volcano-tectonic Events: - 3.523 with average magnitude <3,0 (28 felt) - Maximum magnitude and intensity: 3,6 ML / V (MMI)
Jun 2023 – May 2024	June 2023: Volcanic alert for the Fissural System increased to V1 (activity was occasionally extended eastward along the Fissural System, specifically along the axis where the 1761 volcanic eruption occurred). February 2024: 5 seismic events could be related to volcanic activity.

	Events: -13.074 with average magnitude <2,0 (156 felt) - Maximum magnitude and intensity: 4,5 ML / VI (MMI)
Jun 2024 – May 2025	June 2024: Volcanic alert to Santa Barbara Vulcano raised to V3. December 2024: Volcanic alert to Santa Barbara Vulcano decreased to V2 15 seismic events could be related to volcanic activity. Events: - 18.685 with average magnitude <2,0 (140 felt) - Maximum magnitude and intensity: 4,4 ML / VI (MMI)

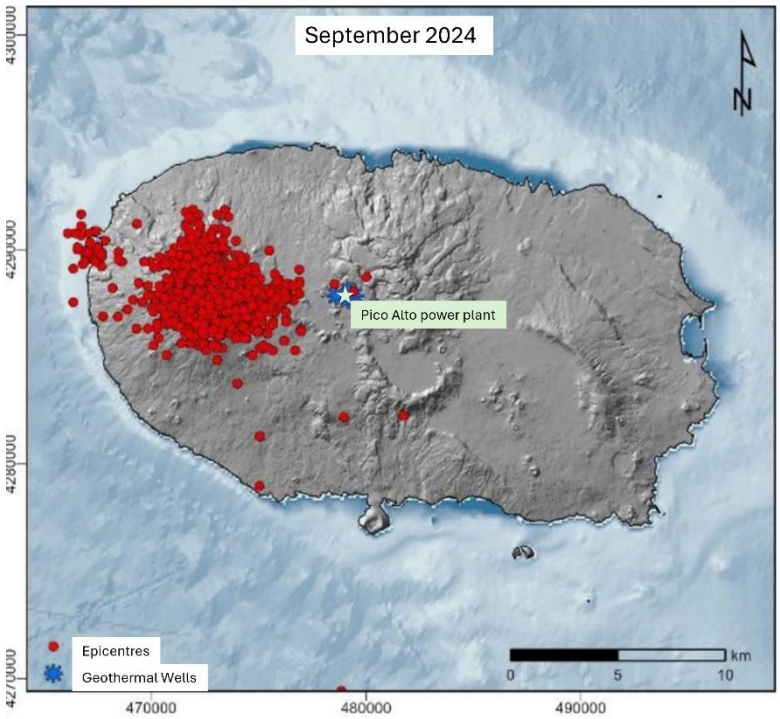


Figure 4 - Epicentral map of the precisely located events on Terceira Island and surrounding region in September of 2024, Silva, R. et al. (2025).

By the end of October 2025, the situation of unrest persists, with seismic-volcanic activity remaining slightly above normal (V2 to Santa Barbára Volcano and the Fissural System).

2.3 Pico Alto Geothermal Project

At the surface, the Pico Alto Geothermal Field (PAGF) encompasses mostly the Pico Alto volcano and the Fissural Basaltic Zone formations, but at depth the geothermal system develops in the Pico Alto, Guilherme Moniz, and Santa Bárbara central volcanoes geological formations, in a complex volcanological and tectonic setting. It is a high-enthalpy system, reaching maximum temperature of about 300ºC. An update of the conceptual model of the Pico Alto geothermal system is underway considering the data gathered from the 2020-2023 drilling and testing campaigns (figure 5).

Operated by EDA RENOVÁVEIS, S.A. (EDAR), the Pico Alto Geothermal Plant it is a 3,5 MW_{net} Organic Rankine Cycle binary pilot power plant, that uses cyclopentane as working fluid. It was designed and constructed by the consortium EXERGY-CME and started operation in August 2017. The resource is provided by the two-phase fluid from 3 production wells (PA2, PA3, PA4) and everything is reinjected back to the reservoir in one well (PA8) (figure 6). Reinjection is made by gravity. The wells intersect a liquid-dominated reservoir, with maximum temperature of about 300ºC. The top of the reservoir is very shallow, near 400-500 m depth, and the depth of the geothermal well's ranges from 1,1 to 2,4 km. Since 2017, the annual production at Pico Alto has guaranteed 4% to 12% of the electricity needs of Terceira Island.

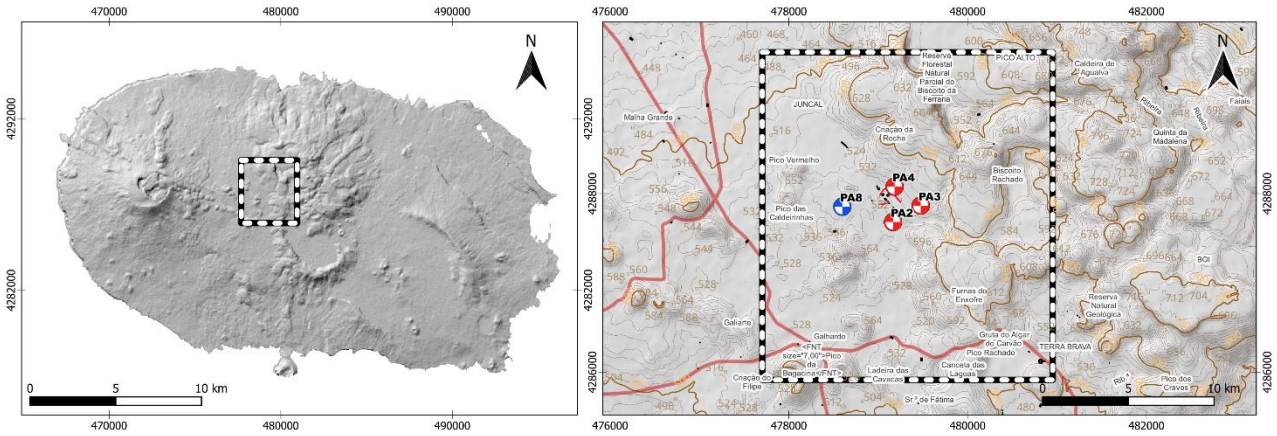


Figure 5 – Pico Alto Geothermal Fiel concession area.

3 EMERGENCY PLANNING

In June 2024 the volcanic alert to Santa Bárbara Vulcano was raised to V3 in the CIVISA volcanic alert scale. The V3 level is described as follows (translated from Portuguese from CIVISA website, 2025):

Volcanic system in a reactivation phase *– Elevated activity, clearly above reference levels, with evidence suggesting or confirming magmatic influence. At any moment, activity may intensify in terms of seismicity, degassing patterns may change, and/or slope movements, lahars, steam explosions, or phreatic eruptions may occur. Although less common, tsunamis may also be generated. The situation may escalate to a pre-eruptive state, and under extreme conditions, it may not be possible to issue timely warnings of an impending volcanic eruption*.

Following the confirmed reactivation of the Santa Bárbara Volcano, a critical gap in the existing emergency response plan from the Pico Alto Geothermal Power Plant was found: the volcanic eruption risk was identified in the plan, but the response actions to be implemented in case of an eruption were not detailed as needed.



Figure 6 – Photography of the Pico Alto Geothermal Project highlighting the location of Santa Bárbara and the scoria cones from 1761 eruptions. Arrows indicate the direction of the lava flows (Photography taken by António Araújo to EDA RENOVÁVEIS).

Local authorities and volcanology experts were unable to determine the expected eruptive style, which could range from low-intensity Hawaiian or Strombolian activity. Additionally, special attention was given to the Fissural Volcanic System, considering that, in 1761 the eruption started with the extrusion of lava domes at the Mistérios Negros site, located on the eastern flank of the Santa Bárbara Volcano and, 4 days later, the activity shifted to the Fissural Volcanic System, and formed the scoria cones of Pico das Caldeirinhas, Pico do Fogo and Pico Vermelho, and it was followed by effusive trachybasalt lava flows towards 3 different direction following the topography, Pimentel et al. (2016). Drummond, a Portuguese chronicler who witnessed the 1761 eruptions, described the eruption that gave rise to the Picos do Fogo, Vermelho, and Caldeirinhas as follows: **"Hurling into the air, with a horrible roar, stones of extraordinary size, and dense showers of sand and ash that spread across the entire island.",** Jorge, B. (2012). The scoria cones are located around 1,5 km west from the Pico Alto power plant (figure 6).

3.1 Main Actions

A few months before the volcano alert level was raised to V3, an annual fire drill was conducted in the Pico Alto power plant in collaboration with the Fire Department from the municipality of Angra do Heroísmo. The risks associated with the seismic-volcanic crisis were also discussed, namely the resources available in the power plant to respond in the event of a major earthquake or volcanic eruption. Given the remote location of the power plant (away from inhabited areas) and the limited civil protection resources on the island, the authorities emphasized that it was essential for the power plant to be as self-sufficient as possible. In the event of a significant seismic or volcanic event, priority response efforts would focus on the most densely populated areas. Additionally, there is a high probability that roads could be blocked due to rockfalls.

It was only when the alert level increased that the full extent of the necessary preparedness measures became evident, both in terms of protecting personnel and safeguarding infrastructure.

The first action taken was the acquisition of a satellite phone. In today's context, where mobile phones are ubiquitous, it is often ignored that both landlines and mobile networks may become inoperative during a major disaster. The satellite phone ensures that EDAR can maintain communication with the Fire Department, Civil Protection, and other EDAR or EDA locations, including other islands (EDA - Electricidade dos Açores, S.A., is the power utility of the region, which holds 99.68% of EDAR).

Workers were encouraged to share the satellite phone number with their closest family members and to develop a comprehensive family emergency safety plan. Providing workers support, and clear and concise information, strictly based on official communications from local authorities, helped to counteract the spread of misinformation, which was amplified through social networks.

The primary decision by EDA RENOVÁVEIS Board of Directors was that the Pico Alto power plant did not constitute a critical facility for the island's electrical grid. Influencing this decision was the small power generation capacity (3,5 MW_{net}), and the fact that the Pico Alto power plant is the most remote power plant on the island, and the one closest to the Santa Bárbara Volcano. Its non-critical status implied that, in the event of a volcanic eruption of Santa Bárbara, the facility could be evacuated following the implementation of predefined safety protocols. Considering the potential for an event with Strombolian characteristics, this resolution provided considerable relief to all personnel, contributing for the improvement of the workplace atmosphere by mitigating the levels of stress and anxiety among staff.

3.1 Emergency Plan

In the absence of known national and/or international guidelines specific to binary ORC geothermal facilities under volcanic eruption risk, the detailed emergency plan was developed from scratch. This process involved internal experts from the multidisciplinary technical team at EDA RENOVÁVEIS (physicists, geologists, engineers, and health & safety professionals).

The pre-eruption procedures in case of a volcanic eruption were proceeded by a set of preparedness and self-protection measures that, among others, included: 1) Provision of updated information to all workers regarding the alerts issued by Civil Protection and official entities; 2) keeping the satellite phone and the radio that gives direct connection to the grid manager charged, including the spare batteries (it was decided to keep both equipment accessible and available in the power plant control room); 3) Making available for all workers individual and collective emergency kits, including a set for the service providers (all kits were equipped with the standard items recommended by the authorities; the collective emergency kit included a portable FM radio with spare batteries); 5) It was recommended to all workers to carry a valid identification while on duty. Lastly, it was defined to check the evacuation routes every week, recording their conditions, considering that there is only one

paved road access to the power plant, and the alternative routes that were identified needed a 4X4 vehicle since they correspond to old rural roads, without regular use or maintenance.

For the operational approach in the event of a volcanic eruption, two action plans were defined: 1) occurrence outside working hours, when only one operator and one security guard are present on site, or 2) occurrence during working hours (08:30 to 17:00). The next subchapters resume the main actions.

3.1.1 Outside normal working hours

In the event of a volcanic eruption occurring outside normal working hours, the operator must immediately shut down the power plant following the detailed instructions made available in the control room. The operator then proceeds to the designated Meeting Point, confirms the presence of all individuals, and initiates search and rescue if anyone is missing, if it is safe to do so. Emergency kits are distributed, the best evacuation route is assessed, and the nearest evacuation site on the island is identified according to official guidance received by the Civil Protection Authorities.

Once evacuation is deemed necessary, the operator, acting as the Safety Delegate, contacts the designated Safety Responsible (Member of the Board of Directors) using the satellite phone. The Safety Delegate must remain with personnel throughout the evacuation and in direct contact with the Safety Responsible. This ensures coordination and communication with the Civil Protection emergency services and authorities. The operator leads the evacuation process, ensuring all safety protocols are followed and that personnel are equipped and guided effectively to safety.

3.1.2 Normal working hours

During normal working hours, the Safety Delegate is the highest-ranking person on site. He assesses the situation and, if necessary, orders the shutdown of the plant following the detailed instructions made available in the control room while promptly, if possible, informing the Safety Responsible (Member of EDA Renováveis Board). If feasible, the water supply system to the fire tank should be activated, with the water well submersible pump configured to continuously fill the tank manually. Additionally, and if conditions allow leave the sprinklers left on to mitigate fire risk.

In the event of evacuation, the Safety Delegate gives the order and activates the alarm. All personnel, except for the members of emergency brigades, must proceed to the Meeting Point. The designated Evacuation Team is responsible for identifying and guiding individuals to the Meeting Point, confirming attendance, and initiating search and rescue operations if anyone is missing (if it is safe to do so). They must also gather and distribute emergency kits and determine the safest evacuation route to ensure a coordinated and secure departure from the facility.

3.1.3 Further information included in the emergency plan

If evacuation is not possible, the Safety Delegate must designate a safe location within the facility for the workers and remain in close coordination with the Azores Regional Civil Protection, the Fire Department, and the EDA Renováveis management. Personnel should try to stay calm and wait for further instructions, remaining prepared for a potential evacuation. If possible and safe, measures must be taken to prevent ash infiltration by sealing openings with damp cloths, turning off non-essential equipment, and regularly cleaning machinery and surfaces to avoid damage from abrasive ash and lapilli. Roofs and fuel tanks should be monitored and cleared of ash accumulation, especially since wet ash increases structural load and risk of collapse. All actions must be performed with proper protective gear (respiratory masks, safety goggles, and long-sleeved clothing). The Safety Delegate must be informed of the effectiveness of these measures, and if needed, personnel may use the thermal blanket from emergency kits to signal aerial evacuation units.

The end of the emergency is declared by the Safety Delegate, following a joint assessment with the Azores Regional Civil Protection. Once conditions are deemed safe, the Safety Delegate coordinates the return to normal operations. This includes instructing employees to resume their duties, restoring energy production, cleaning the facility, inventorying and separating damaged materials, and replenishing and cleaning all intervention resources. A detailed report should be prepared for the Board of Directors of EDA Renováveis. The start of the power plant only proceeds once all technical and safety conditions for electricity production and supply are confirmed.

3.1.4 Cyclopentane

In addition to ensuring the safety of personnel, one of the main concerns throughout the process was the presence of cyclopentane at the plant, stored in a tank that serves as a reserve and drainage point for the system during interventions. Risk analysis concluded that the fall of hot volcanic material over this tank would pose a high risk of explosion. The most effective mitigation strategy identified was the acquisition of an ISO tank, mounted on a trailer, equipped with a system to allow the rapid emptying of the existing tank and the plant's circuit, followed by transport to a safe location on the island. Given the impossibility of timely implementation of this measure, highlighting the need for permanent structural solutions to mitigate this risk, the solution found was, if conditions allow, to the leave the tank sprinklers on to mitigate fire/explosion risk.

4 DISCUSSION

The seismic-volcanic crisis associated with the Santa Bárbara Volcano led to revision of the emergency plan from the Pico Alto Power Plant to include the detailed actions to undertake under volcanic eruption scenario. The first steps included the acquisition of essential communication tools such as a satellite phone, individual and collective emergency kits, and the establishment of evacuation routes. Strategically, the decision by EDA Renováveis Board of Directors to classify the Pico Alto power plant as a non-critical facility for the island's electrical grid allowed for a clear protocol of evacuation in case of eruption, prioritizing human safety.

Seismic-volcanic hazards can seriously endanger the integrity of geothermal infrastructures and result in long term operational outages. For example, lava flows can cause irreversible damage to surface installations, including pipelines, control units, and electrical systems, ashfall, depending on its thickness and moisture content, may lead to roof collapse, clogging of air filters, abrasion of mechanical components, and contamination of sensitive equipment and pyroclastic products, such as volcanic bombs, can directly impact structural elements, causing mechanical failure or fire hazards, especially in facilities using flammable working fluids, like Pico Alto power plant that uses cyclopentane. On the other hand, seismic activity may compromise the structural integrity of well casings, reinjection systems, and surface facilities.

In addition to surface infrastructure risks, the seismic-volcanic activity may also impact the geothermal resource itself. Potential damages include the loss of production and reinjection wells, as well as the destruction of surface facilities essential for resource exploitation. More critically, changes in subsurface conditions caused by seismicity or magmatic intrusion(s) could alter the gas content in the geothermal fluids, the permeability, the pressure, or the temperature of the geothermal reservoir, affecting its productivity and long-term viability.

The Pico Alto power plant a pilot facility that requires future expansion to ensure its economic viability. A significant impact on the existing infrastructures or in the subsurface conditions of the resource could jeopardize the entire project because it may not only halt operations but also compromise the technical feasibility of future expansion and the economic sustainability of the project.

Volcanic eruptions in active geothermal zones can have contrasting effects on energy production, as demonstrated by the cases of Krafla (1975–1984), Kīlauea (2018), and Reykjanes (2023–2024). In Krafla, Iceland, the eruptive activity coincided with the development of the geothermal field causing the increase of the non-condensable gases content in the geothermal fluid but without discontinuing production; on the contrary, it fostered technical and scientific advancements. In contrast, the Kīlauea eruption in Hawaii caused a complete shutdown of the Puna Geothermal Venture for over two years, following the destruction of wells and infrastructure, and required emergency measures and reconstruction. More recently, in the Reykjanes Peninsula, also in Iceland, eruptions disrupted hot water supply and damaged energy infrastructure, highlighting the vulnerability of geothermal systems in areas of increasing volcanic activity. Even with these examples, there is a tendency to underestimate the potential impact of volcanic activity on geothermal projects, often creating a false sense of security; "it will never happen". However, the reality is that most high-enthalpy geothermal projects are in volcanic active zones, and the risk is real. In the case of Terceira Island, the greatest concern lies in the type of volcanism, as the possibility of explosive volcanism cannot be ruled out.

During the preparation of the safety plan, it was not possible to identify any international guide with specific safety procedures for geothermal power plants under volcanic risk. It should be noted that this does not mean such a guide does not exist, only that it could not be found, which already demonstrates that, if it does exist, its dissemination among operators is insufficient. As a result, the summarized steps described in the previous section were based on common sense and the internal know-how of EDA Renováveis multidisciplinary team, including physicists, geologists, engineers, and health & safety professionals. However, despite our efforts, our experience and judgment are largely shaped by the local conditions and knowledge, which may introduce bias and lead to the underestimation of critical aspects (or overestimation of noncritical aspects). It is therefore

essential to raise awareness within the geothermal community about the importance of developing internationally recognized emergency planning guidelines for geothermal installations exposed to seismic-volcanic hazards.

Based on such guidelines, it may be necessary to revise how geothermal plants are designed and built, including aspects such as the way inflammable working fluids are stored. Improving containment systems, relocating storage tanks to safer zones, and reinforcing protective barriers could be essential steps to mitigate risks associated with explosive volcanic activity and ensure the resilience of future geothermal infrastructures.

5 CONCLUSIONS

The Azores Archipelago is in a complex geodynamic setting, dominated by the Azores Triple Junction and the presence of a deep mantle plume that interacts with the Mid-Atlantic Ridge and feeds the Azorean volcanoes. Triggered by this complex setting, a seismic-volcanic crisis began in June 2022, associated with the Santa Bárbara Volcano on Terceira Island.

The elevation of the alert level to V3 in June 2024, confirming that the volcanic system was in a reactivation phase, revealed critical gaps in the emergency plan of the Pico Alto Pilot Geothermal Power Plant, a binary ORC power plant using cyclopentane as working fluid. This led to the revision of the safety plan and the implementation of a detailed preparedness and response measures in case of a volcanic eruption.

Priority actions included the acquisition of a satellite phone, the provision of individual and collective emergency kits, the definition of evacuation routes, and the decision by EDA Renováveis Board of Directors that the facility was not critical to the island electrical system, balancing its limited contribution to the grid and its proximity to Santa Bárbara volcano.

This paper, beyond recounting the technical and logistical challenges addressed in the emergency plan, aims to raise awareness within the geothermal community about the need to establish a unified, internationally recognized set of guidelines for emergency planning in the event of volcanic hazard. Additionally, it highlights the necessity of re-evaluating market-available construction solutions to better withstand explosive volcanic events and protect critical infrastructure from thermal and mechanical impacts.

After 7 months, in December 2024 the seismic-volcanic activity decreased, and the alert level was downgraded to V2. In the scenario described, the most challenging feature was the management of our own personal emotions together with power plant workers emotions, which can be summarized as high levels of stress and anxiety, particularly in the first couple of months. Providing emotional support to the workers, being available to listen to their concerns, taking time to deconstruct false beliefs and provide clear and concise information, strictly based on official communications from local authorities, helped counteract the spread of misinformation and minimize stress and anxiety levels at work.

Acknowledgements

The authors appreciate EDA RENOVÁVEIS, S.A. for authorizing and supporting the preparation of this paper. Special thanks are extended to Tiago Guimarães for the execution of the maps and to Ricardo Peixoto for his valuable safety-related insights.

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