Water Pumped Storage Environmental Impact Assessment in São Miguel Island

Assessment between Freshwater Use and Seawater Use

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Abstract

The following paper consists on the study of the strategic viability on the scope of Environmental Impact Assessment (EIA) for the possible implementation of water pumped storage in São Miguel Island. The analysis and evaluation was carried out featuring the most important biophysical factors, Geology and Soil, Water Quality and Availability and Socioeconomics where the implementation of a seawater pumped storage system showed to be the most viable environmentally speaking.

Introduction

In a period of humanity where one of the biggest challenges is to guaranty a more sustainable future the implementation and exploitation of renewable energies shows to be an essential component. The exploitation of fossil fuels such as oil, coal and natural gas was one of the keys to enable the fast growth of the worldwide economy providing a better life quality particularly in western countries. Nevertheless this growing satiety led to drastic consequences like global warming.

Currently another huge challenge is the environmental protection by the Environmental Assessment. To control the human supremacy over nature, approaches were developed so the environment would be protected. These approaches can support strategic decisions like Strategic Environmental Assessment or can be an instrument which leads to identification, prevision and mitigation about environmental effects such as Environmental Impact Assessment.

The development, interconnection and application of new technologies and methodologies that secure an energetic autonomy, simultaneously with environmental appreciation, can be one of the ways to reach a better sustainable development.

Due to geographic isolation, islands are real laboratories for the development of a complex energetic network sustained by the use of existing natural renewable resources. The Azores are, due to their strategic location and wealth in natural renewable resources, the stage to the Green Island Project conceived by the MIT-Portugal with the intention to provide a path to energy autonomy.

São Miguel Island

The Azores archipelago consists of nine islands that are located on the North Atlantic Ocean between 36º55' and 39º43' N and 24º46' and 31º16' W in a subtropical area of the northern hemisphere anticyclones (Monteiro *et al*., 2008).

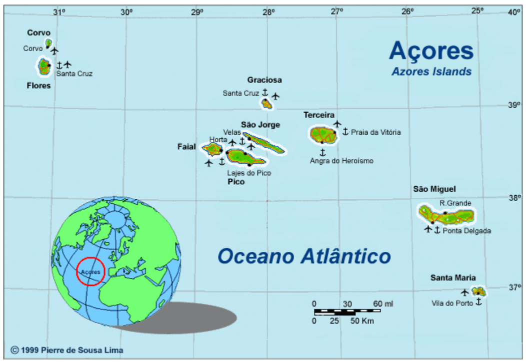
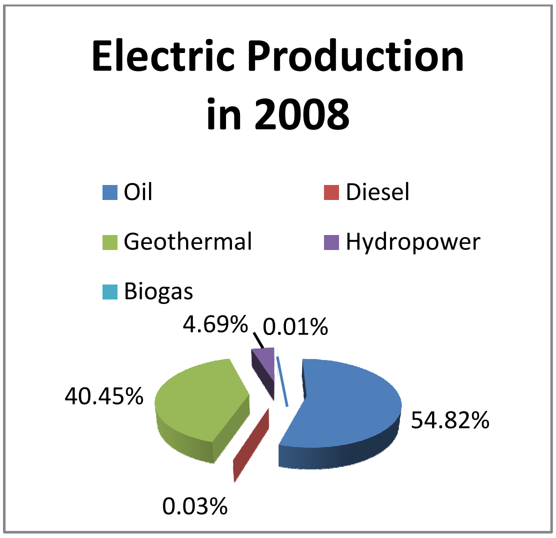


Figure 1- Azorean Archipelagos

São Miguel Island is the biggest island in the Azores with 65km long and 16km wide with a total area of 759,41km^2. It's a volcanic island composed by two basaltic mountain chain united by lowland of basaltic cones. The population is about 133 281 inhabitants and the economic distribution is: first sector 11,34%, second sector 26,85% and third sector 61,81%. In terms of electric production São Miguel Island's distribution is shown in graphic below.



Graph 1 - Electric Production in 2008, São Miguel Island

Study Case – Water Pumped Storage Systems in São Miguel Island

Objective and justification

The following paper consists on the strategic viability on the scope of Environmental Impact Assessment (EIA) for the possible implementation of freshwater or seawater pumped storage in São Miguel Island in 2013. The main objectives are the evaluation of the existent possibility to transfer the energy source in the electric production, minimizing the dependence on fossil fuels and therefore providing space for an increase in the efficiency of the utilization of renewable energies such as geothermal and wind energy.

This project is based in the fact that energetic independence has to pass by the renewable energy development. In São Miguel Island this development probably has to be carried out by increasing the geothermal power installations and the construction of a wind energy park.

Nevertheless there are some objections in the renewable energies' installation, exposed in table 1.

Renewable energies	Restrictions
Water Pumped Storage	Need for an excess of electric energy from a renewable resource.
Geothermal energy capacity augment	Need to have a storage system for electric energy due to a continuous production of a large amount of energy that must be dissipated somehow in the production moment.
Wind power park	To increase the efficiency of electric use due to the uncertainty of the power generation moment and the obligation to use energy produced, at the very moment it is advisable to have a storage system.

Table 1 - Renewable Energy Restrictions

These restrictions show, in first analysis that, without a pumped storage system there will be a growth limitation in terms of geothermal and wind energy power plant capacity by the fact of existing useless energy excess in some low consumption periods.

Project Description

The water pumped storage system and seawater pumped storage are genetically identical. In the seawater case equipments have to be prepared, strengthened and specific to withstand the adverse conditions caused by water salinity, coast climate and marine fauna.

The system's constitution is made by an upper reservoir with a capacity for 98.000m^3 situated approximately 200m above the lower reservoir that will be the Atlantic Ocean if using seawater and the Furnas natural lagoon if using freshwater. The power station's location is upstream the lower reservoir with an installed capacity of 10MW providing an energy potential between 7 and 20MWh each cycle. The turbines used in the power plant are Francis turbines. This kind of turbine allows the water flow to be TURBINADA during energy production and pumped when there is an excess of energy in the electric network. These two reservoirs will be connected by underground pipelines allowing to TURBINAR at a flow of 6m^3/s and to pump at a flow of 4,33m^3/s. The seawater pumped storage project includes the construction of a seawall to protect the system from seawater fluctuation and marine fauna and flora safety.

Project and Location Alternatives

This work studies three different alternatives regarding the implementation of a pumped storage system.

The first alternative is the implementation of freshwater pumped storage using the Furnas lagoon as the lower reservoir. The unique geomorphology of the Furnas lagoon watershed is the key for the project's implementation and viability using freshwater in São Miguel Island. The watershed is characterized by the Achada plateau on the west side of the lagoon approximately 200m high. The plateau has its geological irregularities however there is a section that is flat and at a horizontal distance of 300 to 600m from the lagoon, which makes it a viable location for the underground pipelines' construction. On the lagoon's west side the shore has enough space for the construction of the hydroelectric power plant. This location for the power plant is strategic due to the necessity of the Francis turbines to work underwater.

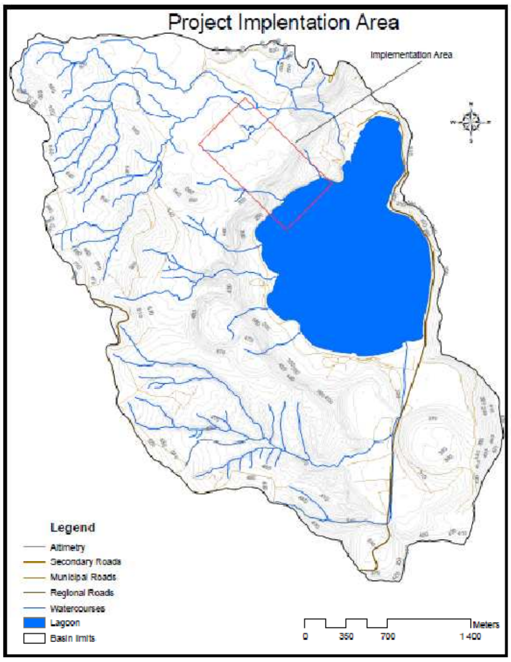


Figure 2 – Project implementation area in Furnas Lagoon Basin

The second alternative is the implementation of seawater pumped storage. Even with 227,3km of coast São Miguel Island has few places that demonstrate to be viable due to soil occupation and its irregular geomorphology. Following the exclusion of places with urbanizations, special environmental protection and dangerous zones the chosen location was in the south side of the island with a plateau contiguous to the coast with more than 200m high where the sea conditions are favorable and the wind influence is lower.

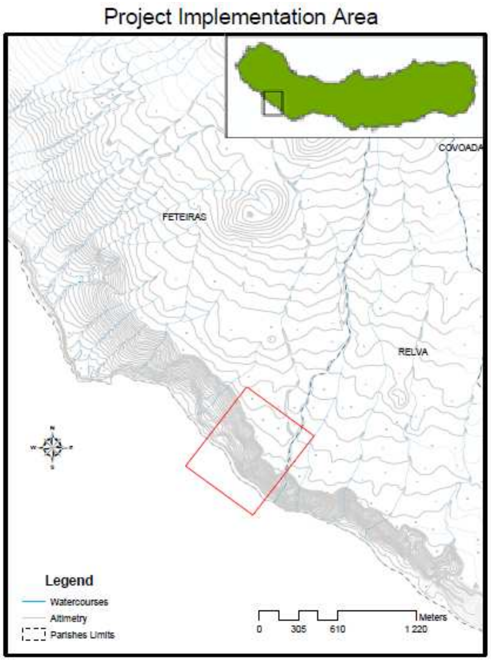


Figure 3 - Project implementation area on the coast

The last alternative focuses in the non implementation of freshwater or seawater pumped storage. The necessity of this alternative comes with the indispensable understanding of the environmental evolution without the project and also to understand the island's energetic evolution in terms of contributions to reduce global warming.

Environmental Evaluation

The environmental evaluation of the three alternatives focuses on the most relevant biophysical aspects: Geology and Soil, Water Quality and Availability and Socioeconomics.

Geology and Soil

In terms of geology, the analysis and evaluation encountered several environmental impacts susceptible to induce geological changes in both alternatives of implementing pumped storage. In relation to the construction of the upper reservoir the impacts are very similar between freshwater and seawater pumped storage where the main identified risks were the landslides and the compression of the less dense geological layers like the layers composed of projection materials. These impacts can lead to the instability of the upper reservoir foundations with possible devastating consequences like the collapse of the reservoir and therefore the collapse of the escarpments or sea cliffs that would modify drastically the geomorphology and consequently the human and natural activities.

Relatively to the underground pipelines, the environmental impacts that could occur during the construction and exploration phase are likely to be equal for the project using freshwater and seawater. The biggest environmental concern is the emergence of joints due to vibrations caused by drilling and water movement during the exploration. These joints may lead to the breakdown of the igneous rocks and thus promoting geological instability with the increasing possibility of landslides.

Nevertheless one of the biggest concerns is related to the project using freshwater from the Furnas lagoon due to its proximity to volcanic activity. If by hazard there are some changes, although unexpected, harsh consequences such as an increase in the intensity of volcanic activity would jeopardize the safety of inhabitants and the region’s biodiversity.

In relation to landslides, the possibility of occurrence can be minimized with the obligation to strengthen the escarpments in the Furnas lagoon by natural means and the sea cliffs in the coast by artificial means trying therefore to conciliate with the existing Spatial Plans. In the project using seawater the construction of a seawall will be a benefit to geological stability of Rocha das Feteiras slowing the coastal erosion.

If the project is not implemented the natural geological degradation can be minimized by actions defined in the Spatial Plan of the Furnas Lagoon Basin like the forestation. However the Spatial Plan that includes the location in the coast does not have a plan to save the sea cliffs from natural phenomenon jeopardizing human activities.

As for the soil, the main negative environmental impacts in both alternatives that implement a pumped storage system are associated to the destruction of the soil’s physical and chemical characteristics and therefore a higher risk of erosion and soil contamination. These two impacts may occur during the upper reservoir and underground pipelines construction phase due to the large area needed to perform the works. However these rich agricultural soils can be moved to other areas thereby minimizing the loss of soil.

During the exploration phase the soil contamination continues to be one of the environmental problems that could occur due to water leakage from the upper reservoir and the pipelines. The soil contamination in the coast alternative could lead to soil salinity causing soils to be unfit for agricultural purposes. This problem can be minimized by soil treatments with plaster. The soil in the surroundings of the project in the Furnas lagoon could profit from the abundance of nutrients in the water like phosphate and nitrogen, but in high concentrations these nutrients can function as pollutants and in combined with water toxins from eutrophication problems can make the soil unfit for agriculture use. The power plants in both alternatives related to the implementation of a pumped storage can provide a decrease of the soil's erosion due to the necessity of strengthening the escarpments and sea cliffs.

During the search of the locations for the project it was taken into account the existence of road accesses which leads to less territorial fragmentation and therefore less soil compression and degradation.

In relation to the construction of a seawall for the seawater pumped storage project in first instance could lead to the destruction of underwater soil but in a future perspective it can avoid sea erosion and create a new niche for water life.

Water Quality and Availability

The implementation of this type of project in São Miguel Island will always have some consequences in water quality and availability since the water resources are split all over the island with hundreds of watercourses, dozens of lagoons and numerous drainage basins.

In the two alternatives for implementing the project there is a high probability of superposition between the upper reservoir and a watercourse. This situation can lead to an increase of solid particles in the watercourse and lead to pollution coming from oil and fuel leakage reducing the water quality and therefore reducing the lagoon or sea water quality. During the exploitation phase, leakage from the upper reservoir or underground pipelines can lead to another type of contamination decreasing water quality: salinity intrusion for the alternative in the coast and an excess of nutrients and toxins for the alternative using the Furnas lagoon. One more impact that could occur is the upper reservoir functioning like a blockade for the natural water stream.

In terms of the underground pipelines the major environmental danger in relation to water could be the emergence of impacts in the groundwater for both alternatives of implementation of a pumped storage system. During the perforations, contamination of these waters can happen by leakage of industrial fluids due to the need of cooling the drills. Once the pipelines are built the lack of knowledge in relation to the size and characteristics of the groundwater flows can affect the availability of the water that will reach the water spring and it also can lead to some contaminations from the water that flows in the pipelines if there is some leakage. Groundwater contamination will make it impossible for human and agriculture consume.

Regarding the power plant, the water movement caused by the Francis turbines will provide a higher oxygenation of the water. This action could help on the one hand the decrease of the Furnas lagoon's eutrophication together with the guidelines defined by the lagoon's Spatial Plan on reducing the nutrient flow that reaches the lagoon. On the other hand, in the coast, oxygenation can lead to an increasing of the marine life potential near the seawall. However it is important to stress out that during the construction there will be an increase of water turbidity and unintentional discharge of some pollutants in the lagoon water or sea temporarily reducing its quality.

It is also important to note that the possibility of occurring geological structure changes in each of the two pumped storage project alternatives can have impacts on water quality and availability. If sizeable joints appear one of the consequences is the intrusion of seawater or eutrophic water endangering groundwater quality. These sizeable joints could also change the direction of the water flow decreasing the quantity of water reaching the water springs.

If the project is implemented, whether in the Furnas lagoon or the coast, the fact that there are already accesses means less work and therefore a possibility of decreasing adverse effects on the water quality and availability.

If the freshwater or seawater pumped storage project is not carried forward, negative water quality and availability impacts are less probable to happen. The existing Spatial Plans for the Furnas lagoon and the coast integrate the responsibility to safeguard the water resources aiming for the regional sustainable development.

Socioeconomics

The socioeconomic impacts rely in three principal aspects: territory, population and regional economy.

The fact that the pipelines are built underground for both pumped storage alternatives could be an asset in order to preserve the natural landscape of São Miguel Island. In relation to the power station in the Furnas alternative it could be an obstacle to the panoramic path next to the lagoon which could destroy the site's natural beauty. Nevertheless the power station in the coast alternative will provide a reinforcement of the accesses making it safe in rough winter conditions. In terms of the upper reservoir in the Furnas alternative it will interfere with the panoramic path and viewpoints destroying the local natural and rural aspect. Thereby not doing the project in the Furnas location makes it possible to keep a landscape with unique characteristics and unmistakable splendor.

At the population level with or without the project there may not be a great negative effect although urbanizations near the coast location could suffer from some noise and vibrations during the construction phase and project exploitation.

Concerning the economy, the impacts depend on which sector is been analyzed. In the primary sector the impact of doing the project will be the diminution of the agriculture area of the island that suffers already a decrease due to abandonment of these activities by the younger generation.

The secondary sector on the other hand will benefit from the project mainly in the construction area which will see its activity growing and could benefit from the acquired knowledge in future project in the Azores. The electric area will be a beneficiary due to the decrease of fossil fuel dependence and consumption.

If the project is not done and efforts are made in a energetic efficiency policy, particularly in the domestic sector, the total production of electric energy could be decreased in 5,15% in 2013. This reduction will allow less oil consumption reducing annually in 10,5% the CO_2 emissions equivalent to 139373,2 tons of CO_2 in 2013. Nevertheless the non existence of an energetic storage system will make it impossible to raise the geothermal capacity of the island due to the impossibility of having excess of geothermal energy without using it in the moment. Therefore the increase of geothermal capacity would be directly dependent of the consumption evolution. It is yet important to demonstrate that wind power would be less profitable in energetic terms.

If the project is implemented, in the Furnas location or the coast location, the scenario could be different. With the existence of an energetic storage system there is the possibility of using energy that is produced in excess by storing it and than using it during consumption peaks. With this project it will be possible at first to profit more from the wind energy park and secondly it will be possible to increase the geothermal capacity that will also provide an excess of energy that will be stored. In environmental terms, this project will make it possible for energy resource transfer in the electric production where renewable energies will be responsible for 72% of the production and just 28% will come from burning fossil fuels. The estimation with this project for 2013 is a reducing of 25% in CO_2 emissions equivalent to 116716 tons of CO_2. This way the project will make it possible to have a more important reduction in CO_2 emission and will make it possible for increasing the geothermal capacity and make the wind power park more energetically profitable.

The third sector will be affected in relation to the tourism area if the project is implemented in the Furnas lagoon by the fact that this particular lagoon is one of the most visited sites in the island. If the project is implemented in the coast the scenario could be different. The chosen location is not famous for its landscape and with the project the location could be transformed into science and technology tourism site since this type of project only exists in another place in the world, in Okinawa Island, Japan.

Conclusions

São Miguel Island is the most influent island of the Azores in a socioeconomic way and consequently has been suffering more pressure in terms of environmental preservation but without reaching a critical state. The environmental preservation is becoming more and more a government and population priority. For this reason a project like this requires special attention due to the possible environmental changes not only in the specific locations but in the entire island.

The study demonstrates in a short period of time that the project could be an environmental asset providing the transfer of energetic sources in the electric network production with a huge decrease on fossil fuels that can reduce 25% of CO2 emissions. In a medium and long period of time the project could allow the increase of renewable energies that have a huge potential in São Miguel Island due to its unique geographic characteristics in particular the geothermal energy, wind energy and probably wave energy.

Nevertheless it was demonstrated that the implementation of this project could have direct impacts on the environment. The Furnas alternative could be easier to implement in terms of technology in comparison to the coast alternative due to saltwater problems. However this location in the Furnas lagoon that gathers all physical necessary conditions entails a range of worrying environmental objections. The reason is the fact that there are some impacts that are unpredictable in terms of their magnitude such as the collapse of escarpments with 200m high or the uncertainty of volcanic activity changes. The full range of environmental impacts demonstrates that the project could jeopardize the beauty and harmony of this special place.

Finally, the study shows that the location of pumped storage using seawater may be the most viable option. There are few negative environmental impacts with relevance in terms of seawater effects on the geology, soil and water quality. But the different knowledge gathered by the pilot project in Okinawa, Japan could be very usefully to avoid environmental problems. It is equally relevant to say that this project could be a good investment in terms of scientific and environmental tourism.

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