

Economic and environmental impact of geothermal production electricity in São Miguel, Açores

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Abstract

Localized on the Central Mountain of the Atlantic, on the junction of three tectonic platforms, São Miguel Island, in Açores, has an enormous geothermal potential which has been tapped during the three last decades, to produce electricity through modern geothermal power plants.

The industrial exploration of high enthalpy geothermal fluids to produce electricity has been part of the regional governmental renewable energy programs during the last three decades.

The primary objective of these different programs is to reduce the use of oil products used in the production of electricity and the consequently minimize the expense associated with the importation of fossil energy as well as its environmental impact.

Renewable electricity production is extremely important in small spaces, such as on this tourism oriented island, with its limited endogenous economic resources and high levels of energy dependency and its significant distance from the European and American continents.

These endeavors and economic considerations represent the main support for its sustainable development.

In this paper we will quantify the monetary savings that can accrue due to reduced oil importation for the production of electricity, together with environmental benefits that result from the utilization of geothermal electricity production.

Key words: geothermic, electricity, island, impact, economic, environmental

Introduction

São Miguel Island, part of the Portuguese Atlantic archipelago of Açores, is an ultra-peripheric European region.

It includes specific characteristics due to its location, system of transports, climate, limited natural resources, economy and industry development and limited population.

Among the islands in the archipelago, S. Miguel is the biggest in area and human resources and the most developed.

It consistently attracts people from other islands and from the mainland, and it has an increasingly high level of urbanization near the capital.

As with all locations with similar characteristics, São Miguel has a high level of energy dependency that results from its paucity of natural resources.

It must therefore import fuel products, which represents a negative factor relative to its economic and social development.

During the last two decades - although the experimental phase began in the 1980's - an important public program to develop industrial geothermic electricity production represents the possible of a lower degree of energy dependency.



Fig. 1. Açores and São Miguel island map

The electricity production through two geothermal power plants located in the island near the mountain of Lagoa do Fogo volcanic system permits a reduction in the quantity of oil products acquired and consequently the associated.

This facilitates equilibrium on the regional commerce balance of Açores.

We estimated that during the last year of 2008, total regional electricity production, which serves about a quarter of a million habitants, was about 821.4 GWh, which represents an increase of about 2.0% compared to 2007. It also represents an annual increase rate of 5.8% during the period 1990 to 2008.

São Miguel Island - the most populated and economically developed island in the archipelago – presents, during the last year, an electricity production of about 441.0 GWh, last year (2008) representing 53.7% of total regional production.

Together with electricity production derived from small hydro electricity systems, representing about 4.4% of the island’s total production in 2008 (19.4 GWh), total renewable energy on the island represents about 43.0% of all production.

In 2008, 38.6% (about 170.3 GWh) of all island electricity production was produced through renewable geothermal energy systems.

The level of renewable electricity production in São Miguel, a value higher than the share of electricity from renewable sources in the mainland of Portugal, is in accordance with the target established for the country by the European Community states, which must be 39.0% in 2010.

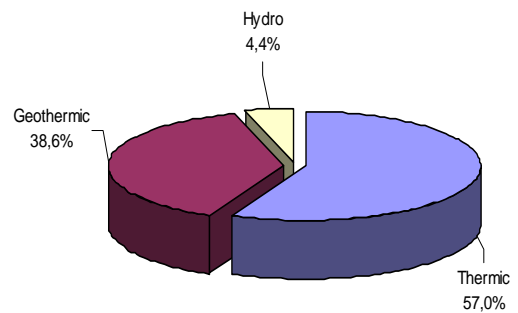


Fig. 2. Total electricity production by origin in S. Miguel, 2008

During the period 1990 to 2008 several phases (Fig. 3.) were involved in the program that focuses on geothermal electricity production:

- the first was from to the period that extended until the mid-1990s. This was comprised of the development of drilling and power plant installation program, with a limited production of electricity.
- the second, representing the initial phase of industrial production, began in 1995 and ended in 2001. At that time production achieved 105.2 GWh, which represented 34.6% of all of the island’s electricity production. This was an increase of about 214.9% during the period.
- the third phase, after the peak production of 2001, was similar to the first phase of drilling the wells, but the presence of silica and calcite concentration became problematic.

Because of this there was a decline in production (about 70.7 GWh, in 2005), resulting in a decrease in electricity production of about 49.0%.

- Finally a new phase solved the main problems with the wells and established a higher level of production. This increase was about 111.7%, from 2005 to the present, presenting a total production of electricity of about 170.3 GWh, in 2008.

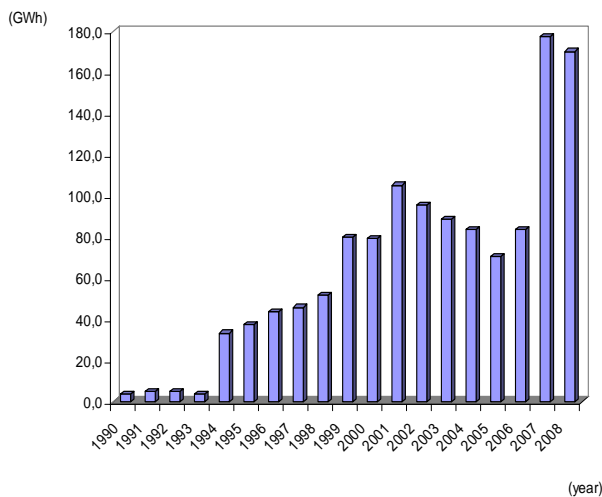


Fig. 3. Geothermal electricity production in São Miguel Island, 1990-2008

With the high level of energy dependency from imported fossil import energy, the thermal electricity production in 1990 represented 90.0% of all production. In 2008 the dependency perceptual value decreased to about 57.0%.

This was not only because of the high level of investments on renewable energy during this period, but also because a very good result in accordance with the previously establish drilling and power plant program.

As seen in fig. 4. it is possible to confirm that throughout the period, thermal energy had a reduction on its representation in all electricity production, concurrent with the hydroelectric systems, while geothermal has increased its participation in electricity production on the island.

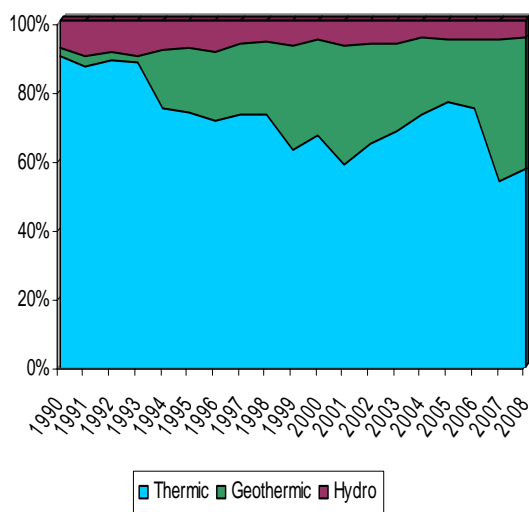


Fig. 4. Electricity production by origin in S. Miguel – 2008

As we can assume through the graph the period of reduced geothermal electricity production corresponds to a high level of fossil fuel production, which corresponding further to a high level of imports. These clearly affected the economy and the commercial exchange balance equilibrium with foreign countries and contributed to greater environmental impact.

TABLE I. - Electricity Production in São Miguel (GWh)

Year	Thermic	Geothermic	Hydro	Total
1990	143.3	3.7	12.2	159.2
1991	149.7	5.1	17.7	172.6
1992	162.4	5.0	16.0	183.5
1993	166.2	3.9	19.1	189.2
1994	145.6	33.4	16.5	195.5
1995	151.3	37.5	16.4	205.2
1996	151.9	43.6	18.5	214.1
1997	162.4	46.0	14.4	222.8
1998	177.4	52.1	14.0	243.5
1999	162.9	80.0	18.1	261.0
2000	187.3	79.6	14.1	281.0
2001	178.5	105.3	20.8	304.6
2002	214.1	95.7	20.8	330.6
2003	241.5	88.9	23.4	353.8
2004	274.2	84.0	17.4	375.5
2005	306.9	70.7	21.8	399.4
2006	307.1	83.8	21.6	412.6
2007	228.4	177.5	23.0	428.9
2008	251.2	170.3	19.5	441.0

An immediate consequence of geothermal production of electricity, for the Region of Açores as has been indicated previously is the annual savings realized by reductions in importation of fossil fuel.

We estimate a savings, from the beginning of geothermal production until last year, of about 10.9 million euros, which corresponds to an average of about half a million euros *per year*.

Clearly, this amount of money saved, is not only directly proportional to the amount of annual geothermal electricity production, but it also increases considerably in periods of energy crises, such as that which has taken place during the last two years, compounded by the high volatility of fossil fuel prices.

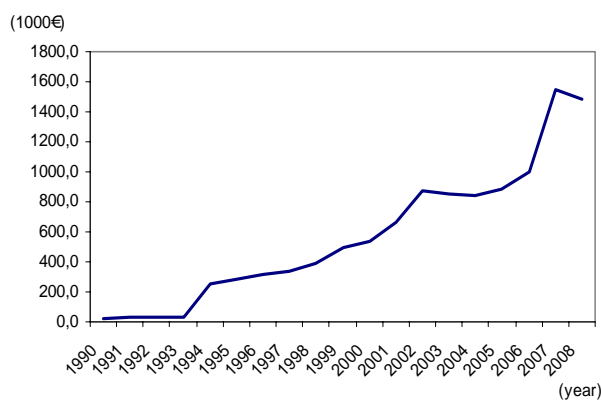


Fig. 5. Annual estimate amount not spent in the acquisition of fossil fuels in the period

Another consequence, as we mentioned before, result from reduced utilization of fossil products for electricity production. This reduces the negative impact on the environment.

For an island on which tourism represents the main economic activity, the quality of air and landscape must be protected. Geothermal electricity production is a green energy includes very small chances for environmental impact.

It is important to consider that not only the production of electricity through renewable systems contributes to reducing environmental impact, but this can be seen as its most important aspect.

Also changes in the fuel mix (as was the case in São Miguel during the period, changing from diesel to fuel oil products, 0.01% and 99.9%, respectively, in 2008) together with efficiency of electricity production, contribute to this result.

Considering the production of electricity as a significant source of air pollution and greenhouse gas emissions we can calculate the amount of carbon dioxide (CO₂), nitrogen oxide (NO_x) and sulphur dioxide (SO₂) that has not been produced as a result of geothermal production.

In order to quantify the emissions we will use the emissions factors considered in the following table

TABLE II. – Emission Indicators (tons)

	SO ₂	NO _x	CO ₂
Fueloil	0.06999	0.0101	3.117
Diesel	0.00602	0.00433	3.153

Using the annual values of geothermal production during the period and the emission indicators

for the two types of fossil products used to produce electricity it was possible to estimate the amount of emissions that do not produce an adverse affect on the environment (table 3).

TABLE III. – Reduction on emissions due to geothermal electricity production (tons)

Year	CO ₂	NO _x	SO ₂
1990	11.52	3.66	0.26
1991	16.03	5.13	0.36
1992	15.68	494	0.34
1993	12.29	3.93	0.27
1994	104.23	33.38	2.33
1995	116.96	37.51	2.62
1996	135.98	43.60	3.05
1997	143.45	45.94	3.21
1998	162.42	51.92	3.63
1999	249.35	79.87	5.58
2000	248.12	79.27	5.54
2001	328.20	104.90	7.33
2002	298.36	95.63	6.68
2003	277.01	88.85	6.21
2004	261.73	83.95	5.87
2005	220.34	70.67	4.94
2006	261.34	83.82	5.86
2007	553.00	177.44	12.40
2008	531.60	170.44	11.91

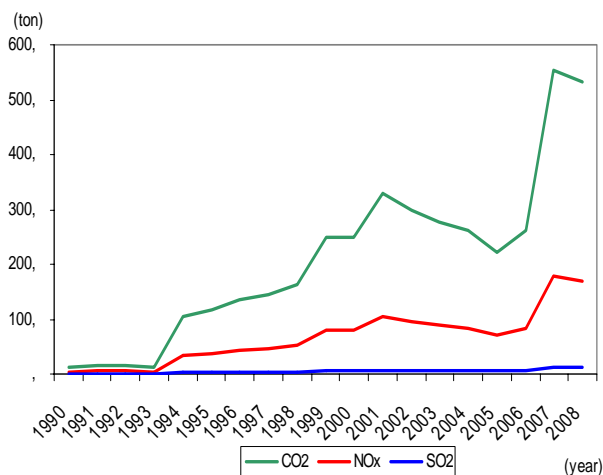


Fig. 6. Total emission reduction in CO₂, NO_x and SO₂

As was expected the highest environmental impact results from carbon dioxide (CO₂), with 531,6 tons, followed by nitrogen oxide (NO_x) and sulphur dioxide (SO₂) at 170,4 and 11,9 tons of emissions, respectively, in 2008.

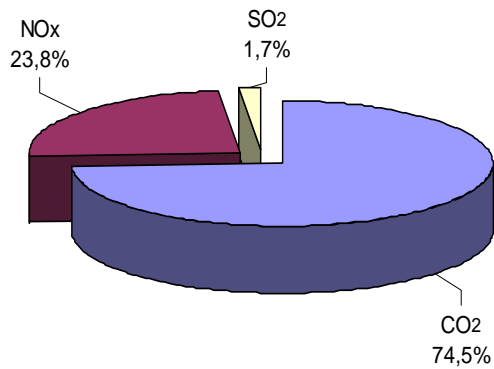


Fig. 7. Emission reduction in 2008

Conclusion

Following the political objectives defined through the European Community relative to electricity production, São Miguel Island and Azores region have been substantially reducing over the last decades, their economic dependency and the resultant environmental impacts that results from energy production, principally related to the production of electricity.

As consequence of the increase on the electricity demand and the need for of a high level of production, as well as resulting from it's the process of development during the last three decades, the regional government authorities have been dedicating substantial amounts of money for investments into their programs for renewable energy.

On São Miguel Island most electricity production investments in renewable energy were made on geothermic systems followed by small hydroelectric endeavours.

Additional investments into wind systems for electrical production are planned to commence construction in the present year, indicating a future higher level of independence from fossil energy and a consequent reduction in environmental impact.

The results show that the resources mentioned are used efficiently to supply almost the majority part of electricity to the island.

São Miguel Island is in fact a very good example of how to reduce dependency and use with renewable energy efficiently. It has received support for the latest governmental decisions on regional electricity program relative to developing the use of geothermal systems on other islands. This will begin in the present year in Terceira, the second most important island in the archipelago.

In the near future it is likely that not only São Miguel and Terceira islands will become “Zero Energy Islands” (ZEI), which assessment is in accordance with Bagci’s (2009) conclusions about alternative energy resources in Peng Chau Island, Hong Kong, in which he developed this new concept using an analogy with the term “Zero Energy Building”.

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