2009 International Nuclear Atlantic Conference - INAC 2009
Rio de Janeiro, RJ, Brazil, September27 to October 2, 2009
ASSOCIAÇÃO BRASILEIRA DE ENERGIA NUCLEAR - ABEN
***ISBN:* 978-85-99141-03-8**

ENVIRONMENTAL IMPACTS EVALUATION ASSOCIATED TO RENEWABLE SOURCES OF ENERGY

Vinícius Verna M. Ferreira[1], Ivan D. Aronne[1], Rosana A. M. Santos[1,2]

1 - CDTN - Centro de Desenvolvimento da Tecnologia Nuclear
Av. Antônio Carlos 6627, Campus UFMG
Belo Horizonte - MG - CEP: 31270-901
vvmf@cdtn.br
aroneid@cdtn.br

2 - Environmental Engineering Student –Universidade FUMEC
Rua Cobre 200, Belo Horizonte – MG – CEP 30310-190
zaninhameneses@pop.com.br

ABSTRACT

As time goes by, the need for electricity increases and creates several problems to mankind. Health and environmental problems happens wherever a power plant arises. For many people the best option for these problems is to invest in energy alternative sources, such as solar and wind. But unfortunately this sources also generates some environmental and health damages. The objective of this work is to analyze the impacts of these energy sources, to review their utilization all over the world and to discuss its relevance in the global energy market. To make a comparative evaluation, the nuclear option will also be analyzed.

1. INTRODUCTION

The permanent and growing demand for electricity in the whole planet generates a huge environmental degradation. The emissions of pollutants from thermal power plants cause several damages to the air quality and human health, among other harms. These power plants consume fossil fuels (natural gas, mineral coal or oil), that when burned liberate sulfur and nitrogen oxides, carbon monoxide and dioxide, and particulate matter, among other pollutants.

The problem is not restricted to a particular region, and happens all over the world. As example, 2.200 tons of nitrogen oxides were released by the Campo Grande thermal power plant in 2003, generating more than 4.400 tons of nitric acid, which causes acid rain. According to some estimates, the implantation of some natural gas thermal power plants foreseen by the Brazilian MME - Ministry of Mines and Energy, in the Mato Grosso do Sul State, would generate something among 1,36 and 3,93 million of tons of carbon dioxide. Also, some PETROBRAS (Brazilian Petrol S.A.) reports asseverate that there are high levels of mercury in the Bolivian natural gas, imported by Brazil and consumed in automobiles, industries and thermal power plants [1].

The acid rain in Sweden affected 18 thousand lakes, 90 thousand kilometers of rivers and 70 thousand artesian wells. Swedish and Norwegians technicians concluded that the acid rain in Scandinavia was directly linked to actions taken in Great Britain to reduce the atmospheric pollution, through the installation of higher chimneys, what took the pollutants to the Nordic

***ISBN:* 978-85-99141-03-8**

countries. In the south of Poland, the speed limit of the trains is 40 kilometers per hour due to the corrosion of the rails. In Greece the problem attacks some famous historical monuments. Corrosion experts affirm that some of the great temples of the country, like the Parthenon, deteriorated more in the last 25 years than in all 2.400 previous years [2].

Spain was the only country that was able to convince the European Community, in the last years, that a new thermal power plant was needed. However they must maintain the sulfur dioxide emissions in low levels, severely controlled. In Europe all thermal power plants that have a nominal power over 50 MW are compelled to control the emissions and to present pollutants reduction plans.

The acid rain brings serious consequences to Canada. This problem is caused by the combination of sulfur dioxide, nitrogen and water, whose mixture kill the fishes, destroy the forests, worsen the breathing diseases and corrodes the buildings, causing every year billion dollars damages. The acid rain is considered the most serious ecological problem of the country, according to public opinion researches. Canadian authorities determined that the most pollutant industries should reduce in 50% their sulfur dioxide emissions, because 43% of the 2 million lakes in Quebec and Ontario are susceptible to acidification. Also, about 10% of the rivers where the salmons are fished in New Scotia are condemned. The acid rain contributes to the destruction of important country monuments, including its tree symbol (Mapletree), used in syrups production and in typical desserts. One of the acid rain affected buildings is the Parliament, which was built with a type of calcareous stone that is very vulnerable to the acidification [2,3].

In 1998, Turkey, Azerbaijan, Turkmenistan and Tajikistan faced large scale malaria epidemics. Only in Tajikistan unofficial data estimated there were about 100.000 cases. Also, bordering countries such as Russia showed significant increases in the number of malaria cases. Experts believe that in the case of Turkey, the construction of 19 hydro power plants, 13 dams and a huge irrigation network contributed to increase these numbers [4]. In Ethiopia a study was carried out to monitor the incidence of malaria among children under 10 years of age that live in small villages close to eight micro dams. The researchers concluded that the dams increased established patterns of transmission through the year [5].

For many people, the answer to all these damages would be a solid investment in renewable sources of energy, such as wind and solar, however these sources also generate some environmental impacts and health damages.

2. MATERIALS AND METHODS

A review about the environmental damages caused by electrical energy generation in solar, geothermal, tidal and wind power plants was done, and the most significant ones were included in this paper. Some impacts of nuclear power plants were listed to compare their damages to these renewable sources Also, the energy global market, where the sources are included, was also analyzed to verify their significance and the main countries where this kind of energy is present. The growth rates for these renewable sources in these countries were calculated. The participation of these sources in Brazil was also evaluated to check their importance for the country, and their participation in the national energy matrix.

***ISBN:* 978-85-99141-03-8**

3. SOLAR ENERGY

Solar energy is the designation given to any type of energy reception originating from the Sun, and its subsequent transformation to some usable form by the man, directly for water heating, as electrical or mechanical energy. This can be obtained through photovoltaic panels.

In Brazil, only one photovoltaic power plant is connected to the EPS - Eletrical Power System. Located in the municipality of Nova Mamoré, in Rondônia State, the Araras plant has a nominal power of 20,48 MW [6]. However, a significant number of solar collectors assist to several applications in the whole Brazilian national territory. They are used in urban and rural residences, and also in independent photovoltaic systems that feed the Ecological Station of Juréia-SP, the Ecological Park of Porto Sauípe-BA, remote stations of telecommunications in Bonfim-MG, several schools, Federal Police and bank agencies, indigenous communities, fish culture stations, irrigation, public telephony and pumping systems, among others.

Table 1 shows some data containing the installed photovoltaic solar capacity at the end of 2007, considering IEA PVPS main countries members - International Energy Agency/ Photovoltaic Power Systems Programme, and its growth rate in the period 2006/2007. In all these countries, a signification fraction of the installed capacity is not interconnected to the national EPS.

Table 1. Installed capacity and growth rates – photovoltaic solar energy [7]

Country	Total installed at the end of 2006 (MW)	Total installed at the end of 2007 (MW)	Growth rate 2006/2007 (%)
Germany	2.863.000	3.971.000	28,58
Australia	70.301	82.501	17,35
Austria	25.585	27.685	7,58
Canada	20.484	25.784	20,55
South Korea	34.733	77.633	55,26
Spain	118.200	630.200	81,24
United States	624.000	830.500	24,86
France	49.933	75.233	41,60
Holland	52.705	54.305	2,95
Italy	50.000	120.200	58,40
Japan	1.708.499	1.918.899	10,96
Czech Republic	29.700	36.200	17,95

The solar energy also generates some environmental impacts, and some of the main problems associated to this source of energy are [8]:

- emissions and other impacts associated to the production of the necessary energy for the processes of production, transport, installation, operation, maintenance and decommissioning of the systems;

***ISBN:* 978-85-99141-03-8**

- emissions of poisonous products during the obtaining process of the prime matter for the production of the modules and some peripheral components, such as acids and cancerous products, besides CO_2, SO_2, NO_X, and particulate matter;
- visual impacts, that can be minimized in function of no-sensitive areas choice;
- occupation of areas for the project implementation and possible loss of natural habitats (critical just in special areas);
- risks associated to the poisonous materials used in the photovoltaic modules (arsenic, gallium and cadmium) and other components;
- risks associated to the sulfuric acid of the batteries (fire, acid spilling, contact with sensitive parts of the body);
- need to displace and recycle the batteries correctly (usually acid lead type, that endures four or five years), other poisonous materials contained in the photovoltaic modules and others electrical and electronic components. These components average life is 20-30 years;
- the operation of decentralized facilities generates a danger, like fire risks, associated to the installation, maintenance and removal of photovoltaic systems from roofs.

4. WIND ENERGY

Wind energy is the kinetic energy contained in the masses of air in movement. Its use happens with the help of wind turbines, also denominated aero generators, for the generation of electricity, or windmills and mills for mechanical works as water pumping.

In Brazil 17 wind power plants are in operation, generating 0,25% of the total energy produced. Other 16 power plants are under construction, and 61 enterprises were granted in the last 10 years, however their construction works did not begin until the moment [6].

Table 2 shows some data of the main generating countries of electrical energy from wind turbines. The ten countries of the table are responsible for 86% of the generated wind energy total, and for 90% of the investments in the sector in the period 2006/2007.

Table 2 – Installed capacity and growth rates – wind energy [9]

Country	Total installed at the end of 2006 (MW)	Total installed at the end of 2007 (MW)	Growth rate 2006/2007 (%)
China	2.604	5.906	55,91
Denmark	3.136	3.125	-0.35
France	1.567	2.454	36,14
Germany	20.622	22.247	7,3
India	6.270	7.845	20,07
Italy	2.123	2.726	22,12
Portugal	1.716	2.150	20,19
Spain	11.615	15.145	23,30
United Kingdom	1.963	2.389	17,83
United States	11.603	16.818	31,01

***ISBN:* 978-85-99141-03-8**

Some of the more relevant environmental problems associated to the energy generation through the winds are [10]:

- noises generated by the wind turbines (originated from the gear box and the aerodynamics shovels). To reduce the noise level the wind industry has been developing gears boxes with sound encapsulation, doing the pieces isolation that suffer vibration and even manufacturing wind generators without gear boxes, compensated by multipolar stators. There is also a legal obligation regarding the maximum level of noise to be noticed by the population. As example, the German government, to stimulate the manufacturers to reduce the noise level, introduced in the subsidies concession formula, a factor that allows to increase the subsidies as minor is the level of produced noise;
- interference in electromagnetic communication systems in some areas due to signs reflection;
- modification in the air standard circulation due to the turbines, what can affect the local climate and generate micro climates;
- movement of the shadows caused by the helixes - this aspect should be considered if the turbines will be located close to inhabited areas;
- the reflection of the solar light in the shovels and tower on the people's eyes (this problem has been solved through opaque painting in the shovels and in the towers);
- illnesses and alterations in the dairy cattle productivity (fact verified due to the wind turbines vibration in 1991, North Carolina).

The presence of wind turbines in the hills, valleys and seacoast divides the population opinion when the matters are the visual impacts. Sometimes this subject has been considered an aesthetic question not so important. Nevertheless, in some countries, the manufacturers have been accomplishing improvements in the design of the towers and shovels and recommended less aggressive configurations for the facilities visual.

Another relevant subject related to the wind energy environmental impacts refer to the migrations of birds. It is recommended not to install wind parks in bird migration and reproduction areas, and places of environmental protection. A serious case of bird's collision in wind turbines happened in city of Tarifa, Spain. At the end of 1993, 269 wind turbines were installed (the total projected were 2.000 turbines), located in the main routes of birds migration in Western Europe. Many birds of countless threatened species of extinction died in collisions with the turbines [11].

Out of the migration routes, the wind turbines rarely disturb the birds. Studies with radars in Tjaereborg, Denmark, show that in the place where a 2 MW wind turbine with a 60-meter diameter was installed, the birds tend to change their flight route, going over or around the turbine, in safe distances. That behavior was observed during the night as during the day.

5. GEOTHERMAL ENERGY

The geothermal energy comes from the heat found in the center of the earth, which can be verified by the eruption of the volcanos, geysers and thermal sources of fresh water. It is a source of energy still little used for generation of electricity, because there are a lot of difficulties for its implantation, its cost is considered high and its efficiency is not satisfactory. In Brazil there is no geothermal power plant.

***ISBN:* 978-85-99141-03-8**

The first effort to generate electricity from geothermal sources happened in 1904 in Lardarello, Toscania, Italy. In 1913 a 250 kW power plant was built with success and about 30 years later, 100 MW were being generated, however the installation was destroyed during the Second World War [12].

Table 3 shows some data related to the main generating countries of energy through the geothermal source.

Table 3 – Installed capacity and growth rate – geothermal energy [13]

Country	Total installed at the end of 2000 (MW)	Total installed at the end of 2005 (MW)	Growth rate 2000/2005 (%)
United States	2.228	2.544	12,42
Philippines	1.909	1.931	1,13
Mexico	755	953	20,78
Indonesia	589,5	797	26,03
Italy	785	790	0,63
Japan	546,9	535	-
New Zealand	437	435	-
Iceland	170	322	47,20
Costa Rica	142,5	163	12,58
El Salvador	161	151	-

The main environmental impacts associated to the geothermal power are [14,15];

- usually the geothermal flow contains dissolved gases, which are released for the atmosphere, with the water steam. Most of the time these are sulfurous gases, like H_2S, with unpleasant odor, corrosives and with noxious properties to the human health;
- a human being can detect concentrations of H_2S in a few minutes, being 0,030 ppm the normal threshold. In some cases the concentration of H_2S in the place of the geothermal power plant can be close or even bigger then 1 ppm;
- benzene emissions, toxin associated to anemia and leukemia were detected in the emissions of geothermal fluids in the USA, Mexico and Italy;
- The contamination of rivers and lakes that are near a geothermal power plant is a possibility, due to arsenic, mercury or boron emissions, in significant environmental amounts of such fluids. As example, researchers proved an increase of 39 μg/l in the arsenic concentrations in the River Waikito, in New Zealand, due to the Wairakei geothermal power plants discharges;
- the geothermal sources perforation tests are noisy operations, generating noise pollution. In consequence, usually the geothermal areas are distant from the urban ones;
- the exploration of the place can take the geothermal field to the exhaustion;
- the geothermal power plants heat lost causes an temperature increase close to the plant;

***ISBN:* 978-85-99141-03-8**

- when a great amount of fluid is removed from the soil, there is always a chance to happen a disturbance, and in those places water should be injected to avoid the landslide;
- the most drastic landslide example in a geothermal power plant is in Wairakei, New Zealand. The maximum rift was in 7,6 m and was increasing 0,4 m each year. It is believed that the problem can be attenuated with reinjection.

6. TIDAL ENERGY

The waves of the sea have kinetic energy due to the water movement and potential energy due to its height. Electric power can be obtained if the oscillatory movement of the waves is used. In the high tide the water fills the reservoir, passing through a turbine and producing electrical energy, in the low tide the water empties the reservoir, passing again through the turbine in the opposite way, also producing electrical energy.

In France a headquarters of tidal energy production was built in La Rance. In this place the tidal width is 13 meters. It is operating since 1966 and produces about 550 GWh annually. Also, there are another two tidal power plants in operation, one in the Bay of Fundy, Nova Scotia – Canada, and the Barents Sea at Kislaya Guba in Russia. But the utilization of the sea waves to generate energy is being developed in Japan, Denmark, Australia, India and China. The first electric power generator from the sea waves is ready to arrive to the market energy. The Pelamis is installed in the Sea Energy European Center, in the coast of Great Britain. Despite of being a prototype, it possesses commercial scale and it is already integrated to the electrical power system of the country. The project shows 40 machines working together, occupying an area of just a square kilometer and generating 300 MW of energy [16].

In Brazil, COPPE/UFRJ is studying the energy generation capacity of the whole national coast. Some preliminary data indicate that the potential of the Brazilian coast is enough to supply 15% of the electric power consumed at the country [17].

The main environmental impacts associated to the tidal energy are [18, 19]:

- the marine currents will change with the variation of the tide levels, and could cause alterations in the temperatures of the superficial and deep waters;
- with the increase of the tide levels the speed of the current would increase and this would cause a larger agitation, mixing the superficial and deep waters, equaling its temperature that usually possessed a larger differential;
- faster currents can also cause more erosion along the coast;
- areas among tides (those that are flooded alternately by the tides) as the swamps, possesses complex ecosystems that maybe will not adapt to the changes in the areas of the tides limits;
- if some dikes were built to stop the floods, the swamps can be totally destroyed;
- in areas more sensitive to the tidal variation, a increase of floods can happen;
- there is the possibility to disturb the marine navigation and recreational boating in places where already certain difficulty exists;
- the construction of those dams can interfere with the migration of some species of fish;
- toxic releases from leaks or accidental spills of liquids used in those systems with working hydraulic fluids can happen;

***ISBN:* 978-85-99141-03-8**

- visual and noise impacts (device-specific, with considerable variability in visible freeboard height and noise generation above and below the water surface).

Table 4 shows some tidal power schemes that are being considered all around the world.

Table 4 – Several tidal power schemes in consideration [19]

Country	**Place**	**Mean tidal range (m)**	**Area of basin (km^2)**	**Maximum capacity (MW)**
Argentina	San Jose	5.9	INA	6800
Australia	Secury Bay	10.9	INA	Not decided yet
Canada	Cobequid	12.4	240	5338
	Cumberland	10.9	90	1400
	Shepody	10	115	1800
	Passamaquoddy	5.5	INA	Not decided yet
India	Kutch	5.3	170	900
	Cambay	6.8	1970	7000
South Korea	Garolim	4.7	100	480
	Cheonsu	4.5	INA	INA
Mexico	Rio Colorado	6.7	INA	Not decided yet
	Tiburon	-	INA	Not decided yet
United Kingdom and Channel Islands	Severn River	7.8	450	860
	Mersey River	6.5	61	700
	Strangford Lough	-	INA	INA
	Conwy	5.2	5.5	33
	Alderney	9.6	N/A	3000
United States	Passamaquoddy, Maine	5.5	INA	Not decided yet
	Knik Arm, Alaska	7.5	INA	2900
	Turnagain Arm, Alaska	7.5	INA	6501
	Golden Gate, California	Not decided yet	INA	Not decided yet
Russia	Mezen	9.1	2300	19200
	Tugur	INA	INA	8000
	Penzhinskaya Bay	6	20500	87000
South Africa	Mozambique Channel	Not decided yet	Not decided yet	Not decided yet
New Zealand	Kaipara Harbour	2.1	947	200+

INA = Information Not Available

7. NUCLEAR ENERGY IMPACTS

As any other source of energy, the nuclear one also generates some environmental damages. Nuclear plants can release small amounts of airborne radioactive gases, such as carbon-14 and iodine-131. Nuclear plants that rely upon water for once-through cooling systems require two-and-a-half times as much water as fossil fuel plants. Also, the nuclear sector require

***ISBN:* 978-85-99141-03-8**

larger capital cost because of emergency, containment, radioactive waste and storage systems, besides the potential nuclear proliferation issue.

Uranium mining techniques used for coal and similar issues of toxic contamination of local land and water resources arise -- as do unique radioactive contamination hazards to mine workers and nearby populations. Abandoned mines contaminated with high-level radioactive waste can continue to pose radioactive risks for as long as 250,000 years after closure.

Some of the most serious impacts linked to the generation of electricity on land can also be attributed to nuclear plants. Whereas the amount of solid wastes generated at nuclear plants is relatively small, these radioactive wastes have health risks that exceed any other source of electricity. It is quite possible that these radioactive wastes will be stored for a century or more at existing nuclear plant sites, a prospect that may preclude any future re-uses of these contaminated lands [20].

8. DISCUSSION

According to IEA – International Energy Agency, the participation of the renewable sources like geothermal, solar, wind, tidal and others in the total of energy generated is still very small, only 2,3%. But in 1973 this value was only 0,6 % [7].

Although the global role of the geothermal energy is very limited, it can play an important role in some countries like El Salvador, where it accounts for 25% of all electricity generation. In the Philippines and Kenya approximately 20% of electricity is generated from geothermal sources. Among industrialized economies it is significant in Iceland (around 20% of total electricity generation) and New Zealand (7% of total electricity generation).

Six underwater turbines are being installed in New York's East River. Each can capture up to 35 kilowatts of power from the river's tidal currents. Also, a tidal project can arise on the coasts of Northern Ireland and Scotland. If the tests are successful, the tidal turbines should be able to supply power for up to 40.000 homes. But tidal projects like these ones in operation are still exceptions, what keeps the real use of this source almost inexistent all over the world.

It is a fact that some damages exist in the process of energy generation from photovoltaic and wind power plants, but the benefits of their use are also a reality for many experts. As example, their use avoids the emissions of Greenhouse Gases. A 600 kW turbine, depending on the wind regime and the capacity factor, can avoid the emission of 20.000 to 36.000 tons of CO_2 that would be generated in a thermal power plant, considering its useful life as 20 years. Also the wind farms in general occupy 0,06 to 0,08 km^2/MW (or 12-16MW/km^2), and the area are can also be used for other activities such as agriculture [11].

Although the environmental damages generated by the wind and solar power plants are considered not so significant as those ones linked to thermal and hydro power plants, the participation of these sources in the global energy market are very limited. As example, Germany has 27,8% of the world-installed capacity for generating electrical energy by wind power plants. However, this corresponds to only 6,4%of the country's total [21].

***ISBN:* 978-85-99141-03-8**

9 - CONCLUSIONS

The electrical energy generation by renewable sources generate some environmental damages that cannot be forgotten in the environmental impacts studies. Nevertheless, their participation in the global energy market is still very small. Local governments should motivate their utilization all over the world. The growth rates in some countries show that some investments are being done, mainly in Europe, North America and some Asian countries. However, their fraction in the world energy balance is very limited.

REFERENCES

1. HESS, S. "As Usinas Termelétricas do Mato Grosso do Sul e a Saúde Pública." http://www.redeaguape.org.br/desc_artigo.php?cod=69
2. http://www.pick-upau.org.br/mundo/termeletrica_energia/termeletrica.htm
3. Environment Canada: The green lane: acid rain and the facts. http://www.ec.gc.ca/acidrain/acidfact.html
4. Radio Netherlands – Malaria back in Europe. http://www.radionetherlands.nl/features/science/malaria_back_in_europe.html. (1999)
5. GHEBREYESUS et al, *Incidence of malaria among children living near dams in Northern Ethiopia: community based incidence survey*. *British Medical Journal*. **Vol 319**: 663 – 666. (1999).
6. ANEEL – Agência Nacional de Energia Elétrica. www.annel.gov.br
7. IEA – International Energy Agency – www.iea.org
8. TOLMASQUIM, MAURÍCIO T. *Alternativas Energéticas Sustentáveis no Brasil*. Editora Relume Dumará. Rio de Janeiro. (2004).
9. GLOBAL WIND ENERGY COUNCIL - http://www.gwec.net/
10. INATOMI, T. A. H. & UDAETA, M. E. M. *Análise dos Impactos Ambientais na Produção de Energia dentro do Planejamento Integrado de Recursos*. www.cori.rei.unicamp.br/BrasilJapao3/Trabalhos2005/Trabalhos%20Completos/Analise%20dos%20impactos%20ambientais%20na%20producao%20de%20energia%20den.pdf.
11. WORLD ENERGY COUNCIL – www.worldenergy.org
12. THAIN, I. A. A Brief history of Wairakei Geothermal Power Project. GHC Bulletin. http://geoheat.oit.edu/bulletin/bull19-3/art1.pdf. 1998.
13. IGA – International Geothermal Association – Geothermal in the world. http://iga.igg.cnr.it/geoworld/geoworld.php?sub=elgen
14. Ambiente Brasil – Portal Ambiental. Energia Geotérmica. http://www.ambientebrasil.com.br/composer.php3?base=./energia/index.html&conteudo=./energia/geotermica.html
15. FREITAS, V. R & FREITAS, T. R. Aproveitamento de Energia Geotérmica http://www.fem.unicamp.br/~em313/paginas/geoter/geoter.html
16. Queensland Energy Museum –Electricity fact sheet: Tidal and Wave Energy - http://www.energymuseum.com.au/06_education/TidalandWaveEnergy.htm
17. Planeta COPPE - http://www.planeta.coppe.ufrj.br/artigo.php?artigo=637
18. http://www.fem.unicamp.br/~em313/paginas/mar/mar.html
19. Tidal power – Wikipedia, free encyclopedia. http://en.wikipedia.org/wiki/Tidal_power
20. http://www.powerscorecard.org/tech_detail.cfm?resource_id=7
21. Ministério Alemão de Meio Ambiente, Proteção à Natureza e Segurança de Reatores http://www.erneuerbare-energien.de/inhalt/36356/