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ENVIRONMENTAL EVALUATION OF DIFFERENT FORMS OF ELECTRIC ENERGY GENERATION

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ABSTRACT

The development and implementation of other forms of energy generation caused local changes, where they were installed, giving rise to environmental impacts. This work presents an evaluation about different forms of electrical energy generation and the environmental impacts relative to each one of them. Five forms of electric energy generation were considered: thermoelectric, nuclear, hydroelectric, wind and solar energy. The implementation and the development of the petroleum industry in the world and in Brazil are presented. The geology of the oil, its extraction and quality improvement, besides details of the functioning of three types of thermoelectric power plants - coal, gas and oil - are also discussed. The specific as well as the environmental impacts they have in common are highlighted. The impacts originated from the deactivation of each one of them are also pointed out. Once outlined the environmental impacts from each form of electric energy generation, they were correlated and compared considering the area of the power plant implantation, the generation capacity, the efficiency, the power and the cost per kW. There is no totally clean form of electric energy generation. There is, however, generation without emission of gases responsible for the green house effect. Therefore, all forms of energy generation are important for a country; in other words, the best situation is the diversity of the energy matrix.

1. INTRODUCTION

Electric energy has an important function in the modern world; it is fundamental for progress and development. The discovery at the electricity allowed improvements in several areas: health, water and food supply, life quality and sanitary conditions, and contributed also to the establishment of the capitalist and consumption society. The oil use as an energy generation source was the impulse for the industrial revolution. Besides it, machines, motors and electrical generators developed increased the progress. This also brought the pollutant gases emission (CO_2, CO, SO_x and NO_x) and other substances that had contributed for the greenhouse effect, the ozone hole and the acid rain, modifying the balance of the planet.

Currently there is a preferential preoccupation, in all the continents, with the reduction the greenhouse effect gases, in the electric energy generation (1). The concentrate carbon dioxide (CO_2) is more rise than in all the planet life time and the expectation is what it increase goes on, causing the significant increase in the average temperature at the planet until the final of century. About of the 50% of the increase the carbon dioxide concentrate, occur at the last years due, mainly, the humans activities (2).

For compose this paper were studied five different forms at the electric energy generation (were used: thermoelectric, nuclear, hydroelectric, wind and solar energies), including its operating, as well as deactivation for the generation units correspondent. All the describe stage are associate with the impact what its can to cause for the environment. Besides, the environment questions association for the introducing, the supply and the deactivation, for the five different generation's forms, will be compare each itself.

2. ELECTRIC ENERGY GENERATION

The electric energy generation is obtained by transformation mechanic or electromagnetic energy. Can being a waterfall (hydro energy), steam produce for fossil fuel burn (thermal energy), or a wind (kinetic energy). In this case, the electricity generators operate for the electromagnetic induction principle, in other words, a conductor, like as wire, move at the magnetic field, has a different of induct power through at the its ends. It can also be produced in direct conversion process, instead of conventional mechanism of conversion of heat in movement and this in electricity. It is example energy direct conversions are solar cells and fuel cells (3).

2.1 Thermal power plant (coal, natural gas and fuel oil), environment impacts and deactivation

The thermal power plant use fuel for electric energy generation: fossil like coal, oil or natural gas; nuclear, radioactive elements (uranium, thorium and plutonium); and biomass (extract of energetically forests and the sugar cane bagasse). Generally, use water for turbine steam or combustion gas for gas turbine. The basic operation is making for fuel burn that heat the water that is in the pipe coming the boiler transformer in steam, that is to direct to a turbine and make to turn to transformer the steam in kinetic energy.

The coalfield can be to the two kinds: surface mine and the underground mine, it depends on the deposit formation, which are determinate of the geologic parameters. Only the deposit occur relatively near the surface and is used how surface mine. It is considered the deposit size, material quality and the security, health and environment aspects.

The gas thermal power plant generation causes small damages for the environment, it does not emit SO_2 and only produce one third at CO_2 when compared to emission for the power plant equal that use coal for produce energy. With the growth and the industrial development there were increases in use to fuels. This worse the air quality, cause of big emissions of SO_2 e particulate material (4). There is thermal power plant that burn diesel, it's possess a lower power and are used in access difficult locals.

The surface mine cause, immediately, visual impact, changing the local landscape. This occur associate with erosion, dust generation, noise, vibration problems and the emission gases of detonation and reject and sterile deposits. It can to happening impacts in the water table, generation of the conflicts at soil use, worker health damage, and surface water pollution besides particulate material. It can to occur also the acid draining, sedimentation, chemical pollutants for trace metals and suspend or dissolve solids.

Underground mine has smaller impacts, however significant, such as: slope failure, underground mining roof collapse, hydrological changes with the water tables lower, generation of the vibrations cause of the detonation of explosive, dust, gases and methane

liberation came to the underground, sterile deposition and rejects on the surface. The remove of the material can to cause earthquake and collapse small. The methane concentration high is responsible for explode occur at underground mines (5). The bigger risk accident the natural gas is mainly in the extraction stages (exploration, perforation, yields) and due the possible leak in the distribution net generally can to happen explosion (6). In this process, the combustion is the main responsible for the emission pollutant.

The main gas emission at the thermal power plant is the nitrogen oxides (NO_x) from among nitrogen dioxide (NO_2) responsible for smog effect, and the nitrous oxide (N_2O), cause the acid rain. It has negative effects about the vegetation and the human health. Its also emits the carbon monoxide (CO), hydro-carbon (C_xH_y), smoke and particulate material. The main oil emission is the carbon monoxide (CO), nitrogen oxide (NO_x), hydro carbon not burned or partially burned (C_xH_y), sulphur oxides, particulate material and radioactive material (Salvarli, 2006). This emissions are related the fuel quality, motor (relation air-fuel) and combustion organization (3).

The acid deposition is cause mainly for the sulphur oxide (SO_2), nitrogen oxide (NO_x) e ammonia (NH_3). At the atmospheric emission, the arsenic, cadmium, lead and mercury are responsible for the damage for human health (7).There is also, the emission carbon dioxide (CO_2) and methane (CH_4) that contribution for greenhouse effect and the nitrous oxide that cause the acid rain. These pollutants are harmful for many flora and fauna species near the poser plants, affect also workers health and the local population.

The liquid effluent can to affect physic or chemically the soil, also the surface and underground water. The effluent launching contend nitrogen and phosphorus, can contribution for the growth aquatic plants (benthic algae and phytoplankton), changing the reproduction and the growing the aquatic organism and water eutrophication. A 100 MW pulverized coal-fired power plant emit up to 6-8 megatons of CO_2 annually; an oil-fired power plant emit about 25% less; and a natural gas combined cycle power plant can emit about half of the CO_2 emissions that come from coal powered plants (8).

This deactivation is similar an industry, can to contaminated the soil, it has disassemble installations e eventually demolition the building for land reutilization.

2.2 Nuclear power plants, environment impacts and deactivation (decommissioning)

The yields the energy for the nuclear power plants is base on the cooling reactor nucleus, using the close primary circuit (with pressure water) for removal the heat that was generation for the nuclear fission, that reach high temperatures. The secondary circuit is responsible for the cooling the water the primary circuit. The liquid at the secondary circuit make turn on the turbine that generate the electric energy. The tertiary circuit makes the cooling at the secondary circuit; the water use is catch at the external search, like as rivers, seas or lake.The reactor nucleus is involved for a steel, lead and concrete covering. In the nucleus stay the control rods and the fuel elements where is the uranium. The control rods are important for stabilise the reaction, for control the fission speed.

The first impact is a mining, where worker's health are seriously affect. Its cost of operation, functioning and monitoring have to be constants why its environment security against radioactive. The storage at the radioactive waste must have local, security and monitoring adjusted. This is a problem why still won't search a final destination. In many countries a

possibility of the reprocess, this use it's in another generation process. But this and anothers alternatives are being studied. The nuclear power plants not emit either greenhouse gases or acid rain.

The decommissioning at the nuclear power plant is making for three different levels or stages: to take apart, decontamination and restoration. It has a procedures that are adopted for the International Atomic Energy Agency (9): 1 - No action, implying maintenance of the shutdown situation; 2 - Long term or 'safe' storage, which entails modifying the installation in order to establish a structure that will safely contain the radioactive material for a prolonged period; 3 - Immediate dismantling, consisting of the dismantling of the facility in the short term, leaving the site free for unconditional use after a short waiting period (3 to 10 years) during which it is subject to surveillance (10).

2.3 Hydro power plant, environment impacts and deactivation

The hydro power plant uses the gravitational power energy the dammed water and transformer in rotation kinetic energy, for use to advantage the hydraulic power. The water is catch in reservoir through force conduits until the hydraulic turbine where this work is change in kinetic energy, that goes to generator for be to change in electric energy and thus distributed for the consumers centers. The reservoirs are responsible for disable for fertile soil, flooding cities and forests areas emitting methane gas, lost archaeology sites, water pH alteration, change the fish's cycle reproduction and the increase the nutrients concentrate. It's possible the soil collapse, provoking small tremors. It can to happen a serious accident like as disruption of the dam, which destroyed everything that find in the front.

The deactivation at the hydro power plant is caused for: project errors, show the security problems; bad operations conditions; natural's disasters and; operation, maintenance and recovery high costs.

2.4 Wind power plant, environment impacts and deactivation

The wind make turn on the helix to generate the kinetic energy focusing it's conversion in electric energy. Batteries are used to storage the energy. The tower has to be tall because the wind is stronger as the height increase. The turbines can to have its axle at two kinds: vertical and horizontal. It is a renewable and clean energy because don't generation any kind of pollutant material. However, the storage is a problem, because batteries contain toxic metals like lead, cadmium, zinc, manganese, nickel, lithium, mercury and copper. The turbine noise can cause stress in peoples and fauna which live near the wind power plant. Besides, when the wind power plant is in the route of migratory birds, can provoke mortal injuries (12). The material used in the wind power plant when to take tower apart, the material is considered scrap, however can to be recycled don't polluting the environment. In the place where the wind power plant was, can to be used for another destination.

2.5 Solar power plant, environment impacts and deactivation

The solar power plant can to be constituted for solar cell or photoelectric cell. Both use the solar radiation how sources the energy. The solar power plant uses the renewable and clear sources. However, this equipments are restrict an areas with big sunny. Its can to be constitute by silicon that is a good conductor.

The main impacts from solar cells are the shade that its panel made. The kind the energy storage, its use the battery like as wind power plant. And the any kinds the solar cell use dangerous materials, like as hydrogen selenium and solvents (12). For produce the solar cell, the material used is high pollutant. The destruction the solar panels can to contaminate the environment, however this effect can to minimize if get rid material is recycle (12).

3. RESULTS AND CONCLUSIONS

It was adopted how standard unit a power plant with 1.300 MW at power, that is the same power at nuclear power plant Angra II. For this, will use the power plants: TPP Candiota, coal thermal power plant; TPP Governador Leonel Brizola, gas thermal power plant; TPP Breitener, fuel oil thermal power plant; NPP Angra II, nuclear power plant; HPP Serra da Mesa, hydro power plant; WPP La Sierra de El Perdón, wind power plant (wasn't used a brazilian wind power plant, because its existing can low power installed); and SPP in Espenhain, solar power plant (this was used for there aren't in Brazil for comparison).

Table 1. Power plants used for the comparison at environment performance, with power at 1300 MW, build area, total area for power at 1300MW and relation power/area

Kind of generation	Power plant	Local	Area (m^2)	Power (MW)	Total area (m^2)	Power/area (MW/m^2)
Coal thermal power plant	TPP Candiota	Candiota – RS, Brazil	200,000	445	600,000	2.17
Gas thermal power plant	TPP Governador Leonel Brizola	Duque de Caxias – RJ, Brazil	120,000	1040	120,000	10.83
Fuel oil thermal power plant	TPP Breitener	Maracaú – CE, Brazil	120,000	166	120,000(1)	10.83
Nuclear thermal power plant	NPP Usina de Angra 2	Angra dos Reis – RJ, Brazil	100,000	1300	100,000	13
Hydro power plant	HPP Serra da Mesa	Minaçu – GO, Brazil	1,784,000,000	1275	1,784,000,000	0.00073
Wind power plant	WPP La Sierra de El Perdón	Spain	46,000	20	2,990,000	0.43
Solar power plant	SPP Espenhain	Germany	200,000	5	52,000,000	0.025

Analysing the generation power and built area, the bigger yields or energy per m^2 is the nuclear energy. The gas and fuel oil power plant show values near for nuclear energy. The environment impact encloses: 1- the soil use: getting/extraction, processing and conversion at the fuel in electricity; 2- air, soil and water pollution associate the conversion; 3- radiation and/or pollutants emission during the normal operation or in accident case; 4- occupational factors health associate each stage; and 5- solids waste storage. Besides, the risks in deactivation at the power plants generation.

The fossil fuel substitution in the electric energy generation and as fuel of automotive vehicles is important, because it can be economized for noblemen uses in chemical e druggist industry. Its necessary the improvement the materials, methods and technologies for generation electric energy, for save the environment.

If considered the greenhouse gases, the quantity of electric energy generation and the nearly consumers centers, can to see that the nuclear energy is more viable in detriment anothers. The nuclear energy is in search of news technologies to improve their income. The more expensive energy is that we haven't.

REFERENCES

1. P. D. C. WIJAYATUNGA; W. J. L. S.FERNANDO; R. M. SHRESTHA. **"**Impact of distributed and independent power generation on greenhouse gas emissions: Sri Lanka". *Energy Conversion & Management*, **Nº 45**, pp. 3193-3206 (2004).
2. T. M. YEGULALP; K.S. LACKNER; H.J.ZIOCK. "Ini. J. Surf. min. Reclam. Environ". **Nº 15**, pp. 52-68 (2001).
3. R. A. HINRICHS; M. KLEINBACH. "Energia e Meio Ambiente". Pioneira Thomson. São Paulo (2003).
4. J. L. LOPEZ; C. MANDUJANO. "Estimation of the impact in the air quality by the use of clean fuels (fuel oil versus natural gas)". *Catalysis Today*. **Nº 106,** (2005).
5. S. HIRSCHBERG; P. BURGHERR; G. SPIEKERMAN; R. DONES. "Severe accidents in the energy sector: comparative perspective". *Journal of Hazardous Materials*, **Nº 111**, pp. 57-65, (2004).
6. S. M. RASHAD; F. H. HAMMAD. "Nuclear power and environment: comparative assessment of environment and health impacts of electricity-generating systems. Applied Energy", **Nº 65**, pp. 211-229, (2000).
7. H. H. KHOO; R. B. H. TAN. "Environmental impact evaluation of conventional fossil fuel yields (oil and natural gas) and enhanced resource recovery with potential CO_2 sequestration". *Energy & Fuel*, **Nº 20**, pp. 1914-1924 (2006).
8. H. J. HERZOG; D. GOLOMB. "Carbon Capture and storage from fossil fuel use". *Encyclopedia of Energy*, **Vol.1**. (2004).
9. INTERNATIONAL ATOMIC ENERGY AGENCY – IAEA. "Decommissioning of nuclear facilities: decontamination, desassembly and waste management". *Technical Report Series*, **Nº 230.** Vienna: International Atomic Energy Agency. (1983).
10. A. BOND; J. PALERM; P. HAIGH. "Public participation in EIA of nuclear power plant decommissioning projects: a case study analysis". *Environmental Impact Assessment Review*. **Nº 24**, pp. 617-641, (2004).
11. M. S. M. DE ARAÚJO; M. A. V. DE FREITAS. "Acceptance of renewable energy innovation in Brazil – case study of wind energy". *Renewable & sustainable energy reviews* (2006).
12. L. B. REIS. "Geração de energia elétrica: Tecnologia, inserção ambiental, planejamento, operação e análise de viabilidade". Ed. Manole. São Paulo (2003).