PNOC 92

# ENVIRONMENTAL COMPARISON OF GEOTHERMAL AND OTHER SOURCES OF ELECTRICAL POWER PRODUCTION

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*Abstract*

*In comparing the potential environmental impacts associated with various forms of energy generation, it becomes apparent that geothermal production of energy can rank favorably. How technologies are evaluated, especially with regard to carbon dioxide emissions and impacts associated with the energy feed stock production, can result in the determination that geothermal energy is an environmentally beneficial source of energy.*

## 1.0 INTRODUCTION

Environmental considerations continue to be a factor in project development of electrical generation facilities. It can only be expected that the environmental concerns will have more influence on project design and operation. Therefore, this discussion reviews the environmental impacts of seven sources of electrical generation in a general comparative manner. The energy sources include coal, petroleum, natural gas, hydropower, nuclear, biomass, and geothermal. Other sources were not included because of their minor contribution to the overall production of electricity, or because they could be grouped in one of the above categories.

The areas of environmental review include: Land Use, Water Quality, Air Quality, Noise, Biological, Cultural, Visual and Waste Management. The rating of the environmental impacts has been divided into six numerical categories:

"0" Minimal or non-applicable
"1" Very low potential impact
"2" Low potential impact
"3" Moderate potential impact
"4" High potential impact
"5" Very high potential impact

## 2.0 DISCUSSION

The evaluation is based upon the potential environmental impacts of a typical, modern 50 megawatt facility located in the Western United States. While the coal, petroleum, natural gas, biomass and geothermal review is amenable to such an evaluation, nuclear and hydropower projects are not since their facilities are significantly much larger. Therefore, for these two energy sources, evaluations are scaled as to their potential impacts.

### 2.1 LAND USE

The land use factor is divided into four aspects. They are presented in Table 1, with the abbreviations noted, and include (R-F) raw fuel land use, (F-T) fuel processing-transportation facilities land use, (P-P) power plant land use, and (W-H) waste handling land use.

**Table** 1 - Land Use Impact Ratings

| Energy Source | R-F | F-T | P-P | W-H |
|---|---|---|---|---|
| Hydropower | 5 | 0 | 3 | 0 |
| Nuclear | 5 | 4 | 4 | 5 |
| Coal | 5 | 4 | 3 | 4 |
| Petroleum | 3 | 4 | 3 | 1 |
| Natural Gas | 3 | 3 | 2 | 0 |
| Biomass | 4 | 3 | 3 | 3 |
| Geothermal | 2 | 0 | 3 | 1 |

For hydropower projects, significant amounts of land must be surrendered in order to have the mass and height of water to produce electricity. In addition, downstream waterways, wetlands, and fisheries are often significantly impacted by fluctuating water flow quantity and quality. Therefore, the potential for environmental impact is very high. A very high potential impact must also be accorded both coal and nuclear

since significant mining is required to obtain the raw fuel. A high rating potential is given to biomass because of the quantities of land that must be reserved and harvested. This impact can be lessened if the biomass is basically wood waste or waste fiber. For petroleum, natural gas, and geothermal, the area of several drill sites can adequately to supply the energy needs of. the power plants. However, depletion of the hydrocarbon reservoir may require replacement wells during the life of the project. A properly designed and managed geothermal reservoir can sustain energy production on a long term basis. Therefore, petroleum and natural gas rate moderate potential land use impact, while geothermal development rates a low potential impact.

For fuel processing/transportation land use impacts, both hydropower and geothermal projects need to be located at the energy source, therefore, these impacts are not applicable. Biomass projects have a moderate rating because of transportation and processing requirements. Natural gas facilities require processing of the raw fuel and use an extensive network of pre-existing pipeline systems to supply fuel to a specific facility. Therefore, this energy source receives a moderate rating. Coal fired facilities are rated higher because of the need for some fuel processing and the use of railroads to supply the fuel. Although this impact can be mitigated by siting the power plant at the mine location. Petroleum and nuclear power have a similar rating to coal because of the need for extensive fuel processing facilities and transportation requirements.

For the power plant land use factor, most energy sources have been placed in the moderate range, while nuclear is higher due to needed buffer zones and natural gas is lower due to lesser equipment space requirements.

A wide range of ratings are evident in the waste handling land use factor, with nuclear having a very high impact and coal with a lower rating. Biomass comes in next with a moderate value. Petroleum and geothermal have very low waste generation rates, although there are exceptions in the case of geothermal. Waste handling land uses for hydropower facilities are generally not applicable. Although, it may become a significant issue for flood control impoundments that need to remove excessive silt build-up. For natural gas, waste handling land uses are minimal.

## 2.2 WATER QUALITY

Table 2 - Water Quality Impact Ratings

| Energy Source | Facility Use or Discharge | Impact of Spill or Accident | Offsite Water Impact |
|---|---|---|---|
| Hydropower | 0 | 0 | 0 |
| Nuclear | 3 | 5 | 4 |
| Coal | 3 | 1 | 4 |
| Petro1eum | 3 | 4 | 3 |
| Natural Gas | 3 | 0 | 0 |
| Biomass | 3 | 0 | 1 |
| Geothermal | 1 | 3 | 0 |

Hydropower projects are not expected to have an effect on water quality, although oxygen levels downstream of a dam are always an important design consideration. Except for geothermal, all of the other energy sources are rated at moderate impact levels for the facility use or discharge factor. This is because of the need for cooling tower water and its associated process waste water discharges. Geothermal, however, can utilize the condensed steam as make-up water for cooling purposes and reinject the wastewater along with the geothermal fluids back into the ground.

For spills or accidents, natural gas and biomass facilities are expected to have minimal impacts. Coal impacts are also low. Geothermal impacts depend on the geothermal fluid mineral quality. Thus, using a conservative view, it is given a moderate rating. Petroleum does have high impact levels from spills, however, the highest rating would go to nuclear power'becauseof the potential for longer lasting effects.

Offsite water impacts are highest for nuclear and coal power sources. Nuclear and coal bear the associated impacts due to the mining of the fuel and the potential leaching and runoff. Petroleum impacts are moderate. Generally, biomass has a very low impact, although increased erosion and runoff may be expected on harvested stands. Natural gas, geothermal, and hydropower projects would fall within the minimal level of impact.

## 2.3 AIR QUALITY

Air quality is divided into five components. As shown in Table 3, they consist of various types of emissions expected; acid gases, non-methane hydrocarbons (shown as NMHC), particulate/metals (shown as P & M), radon/radiological (shown as R & R) and carbon dioxide emissions (shown as $CO_2$).

Table 3 - Energy Source Rated by Air Emissions

| Energy Source | Acid Gases | NMHC | P & M | R & R | $CO_2$ |
|---|---|---|---|---|---|
| Hydropower | 0 | 0 | 0 | 0 | 0 |
| Nuclear | 0 | 0 | 0 | 5 | 0 |
| Coal | 4 | 4 | 4 | 2 | 4 |
| Petroleum | 4 | 4 | 2 | 1 | 4 |
| Natural Gas | 2 | 1 | 0 | 1 | 4 |
| Biomass | 3 | 2 | 3 | 0 | 4 |
| Geothermal | 1 | 0 | 1 | 1 | 1 |

Hydropower projects are not expected to have an impact on air quality.

When considering acid gas emissions, coal and petroleum have the highest rating due to their combined sulfur dioxide and nitrogen oxide emissions. While natural gas and biomass are lower because of their significantly reduced emissions of sulfur dioxide and moderate emissions of nitrogen oxides. Nuclear power is rated with a no impact level. Geothermal facilities are rated slightly higher due to the quantity of hydrogen sulfide emitted, and because hydrogen sulfide will oxidize to sulfur dioxide over time.

When methane is excluded from the hydrocarbon component of the table, both geothermal and nuclear are at the lowest rated level. In increasing levels, natural gas emissions, biomass emissions and then petroleum are greater, with coal emissions being the highest.

- Particulate/metals emissions are expected to be extremely low from natural gas or nuclear power. Geothermal emissions are

limited to metals which can be volatile at elevated temperatures, such as mercury, arsenic, and boron. Both mercury and arsenic appear at trace levels, while boron is evident in the cooling tower water. Petroleum emissions, biomass emissions and coal emissions would be progressively higher than natural gas, nuclear or geothermal.

For radon/radiological emissions, nuclear energy would be expected to have the highest value. At much lower naturally occurring levels would be coal, which contains varying concentrations of radium which will emit radon. To a lesser extent, petroleum, natural gas and geothermal contain or emit varying concentrations of naturally occurring radon and other radiological materials. Biomass is considered to be at the minimal rated level.

When considering carbon dioxide emissions and the implied green-house affect; all of the carbon based fuels have high potential impacts. The geothermal carbon dioxide emissions are a small percentage of the carbon based fuels, therefore, they are given a very low rating. Nuclear and hydropower projects have minimal potential for carbon dioxide emissions.

## 2.4 BIOLOGICAL

Biological impacts can be considered a blend of land use requirements and the specific impact to a species.

Table 4 - Biological Impact Ratings

| Energy Source | Biological Impact |
|---|---|
| Hydropower | 5 |
| Nuclear | 4 |
| Coal | 4 |
| Petroleum | 2 |
| Natural Gas | 2 |
| Biomass | 3 |
| Geothermal | 1 |

The biological impact of geothermal power is rated the lowest by referring to its low land use rating and its compatibility with the environment from a production standpoint.

The piping systems involved with production and injection exert limited demand on environmental systems. Likewise, petroleum and natural gas are evaluated similarly, but due to the higher land use rating, the overall biological rating is higher than geothermal. The biological impact of biomass power is greater due to forest disturbance, although this value could be mitigated when possible by burning only biomass waste. Nuclear and coal projects are given a high potential impact due to the large amounts of land required for development, processing and use. Hydropower is rated at a very high potential impact due also to its land requirements and the effect on fisheries.

### 2.5 NOISE

Because of the availability to easily control noise problems, all of the possible energy types can be grouped in the very low potential impact level.

### 2.6 CULTURAL

Cultural impacts are composed of diverse and often difficult to quantify entities. A major component often involves the removal and alteration of significant artifacts where they cannot be avoided. No single or group of factors can be generally used to reasonably assess cultural impact. Therefore, facilities of all types can be grouped together in a similar category, thus eliminating this variable in a general evaluation.

### 2.7 VISUAL

All of the different types of energy generation will have a visual impact. The level of impact will be dependent on site specific situations.

Visual, as with cultural and noise impacts, escapes generalization for the same basic reasons. All facilities are developed and sited with the premise that, to a sensible extent, these factors will be considered and weighed early in the development process. For the successful development of a project, the siting will take into account these impacts and balance them at a low to moderate level of impact. Therefore, for the purpose of a general evaluation, a moderate level rating will be applied for all types, but will not be included in the overall evaluation.

## 2.8 WASTE MANAGEMENT

The Table 5 lists the potential impacts due to waste generation.

Table 5 - Waste Generation Impact Ratings

| Energy Source | Waste Generation Factor |
|---|---|
| Hydropower | 0 |
| Nuclear | 5 |
| Coal | 4 |
| Petroleum | 2 |
| Natural Gas | 0 |
| Biomass | 3 |
| Geothermal | 1 |

The rating of this factor is based upon a blend of the' amount of waste generated and the toxicity of the waste. As expected, nuclear energy would be rated very high, followed by coal due to the combustion process resulting in bottom and fly ash requiring landfilling. Biomass combustion also results in bottom and fly ash which must be landfilled.

Petroleum projects are rated at the low potential mainly because of fuel processing waste generation. Geothermal is rated a reduced impact level. However, there are exceptions. When geothermal fluids exist with very high saline levels, silica can precipitate, resulting in a higher volume of waste than normal. At the minimal impact level are natural gas and hydropower projects.

## 3.0 CONCLUSIONS

Using an unweighted method of ranking the potential environmental impacts of electrical generation, with a lower number indicating lower environmental impact and a higher number indicating a greater environmental impact, the results of this study are presented below:

- Hydropower Energy Generation 13
- Geothermal Energy Generation 16
- Natural Gas Energy Generation 21

- Biomass Energy Generation 35
- Petroleum Energy Generation 39
- Nuclear Energy Generation 44
- Coal Energy Generation 50

It is obvious that some environmental impacts are more important than others. The ranking above is not designed to take this into account because the importance of the impact is often dependent on many different site specific conditions. A weighted ranking would then be expected to change the arrangement. However, the item of interest is how high geothermal energy production can rank when compared to other energy sources in a general comparative manner. The significance of this method of evaluation resides with the fact that geothermal energy obtained a lower number largely because of the minimal carbon dioxide emissions and a diminished need for land use requirements.

The importance of this ranking becomes more apparent when it is considered that the value of environmental aspects is presently being quantified and evaluated by many governmental and regulatory agencies. Hazardous waste and emissions of nitrogen and sulfur oxides from major sources are taxed in the State of California. The carbon content of hydrocarbon fuels is under consideration for an environmental tax, either in the form of "corrective taxes" or as compensatory incentives. Recognition of the value of these environmental factors can be a powerful instrument for advancing the technological and commercial development of geothermal energy resources.

If this straightforward methodology is incorporated into the environmental review or selection process, then geothermal energy production can be considered as an environmentally beneficial source of energy when compared to other energy sources.

## 4.0 REFERENCES

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