

**SAVINGS FACTORS
FOR
GEOHERMAL ENERGY UTILIZATION**

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I. TONNES OF OIL EQUIVALENT

A. 1 GWh = 3.6 TJ

B. From Lund, *et al.*, 2005

The savings of fossil fuels is estimated by using an efficiency factor of 0.35 if the competing energy is used to replace electricity and 0.70 if it is used directly to produce heat, such as in a furnace. Therefore, if the oil were used directly to produce energy by burning, these values would be reduced by half.

1. Oil equivalent to produce replacement electricity at 35% conversion efficiency:

1 TJ (in electricity produced) ~ 70.4 toe

1 GWh (in electricity produced) ~ 253.4 toe

2. Oil equivalent for ordinary burning assuming 70% efficiency to produce useful heat:

1 TJ (in heat produced) ~ 35.2 toe (e.g. in a furnace)

1 GWh (in heat produced) ~ 126.7 toe (e.g. in a furnace)

C. Estimates from the IEA*

1. Oil equivalent assuming 100% efficient combustion:

1 TJ (in heat produced) ~ 23.88 toe

1 GWh (in heat produced) ~ 85.98 toe

2. Oil equivalent of electricity produced assuming 35% conversion efficiency:

1TJ (in electricity produced) ~ 23.88 toe $\times (1/(0.35))$ ~ 68.2 toe

1 GWh (in electricity produced) ~ 85.98 toe $\times (1/(0.35))$ ~ 245.7 toe

These two results are in very good agreement with I.B.1. above (Lund *et al.* (2005)).

II. SAVING IN CARBON DIOXIDE EMISSIONS (Figures developed by Lawrence Livermore Laboratories, cited in Lund et al., 2005)

A. Carbon savings if electricity is produced (assuming 35% conversion efficiency):

14.65 tonnes/TJ for natural gas
62.6 tonnes/TJ for oil
72.7 tonnes/TJ for coal

B. Carbon dioxide emission savings if electricity is produced (assuming 35% conversion efficiency):

193 kg/MWh for natural gas
817 kg/MWh for oil
953 kg/MWh for coal

If energy is produced by burning these fuels, the carbon and CO₂ savings would be half these values.

III. COMMENT ON BERTANI'S NUMBERS SENT TO LADSI RYBACH:

A. Burning oil directly at 100% efficiency results in:

1 GWh heat ~ 85 toe (in agreement with I. C. above) and

1 toe ~ 3.18 tonnes CO₂

Therefore: 1 GWh heat ~ (85 toe) × (3.18 tonnes CO₂ /toe) ~ 270 tonnes CO₂ (100% conversion efficiency). This result is in good agreement with II.B. above (817 tonnes/GWh) when converted to 35% efficiency:

$$[270 \text{ tonnes CO}_2]/(0.35) \sim 771 \text{ tonnes CO}_2 \text{ (for 35\% efficiency)}$$

IV. CO₂ EMISSION SURVEY RESULTS (Bertani and Thain, 2001)

A. Typical CO₂ emission for fossil fuelled power plants is on the order of:

315 kg/MWh for natural gas in combined cycle power plant at 60% efficiency
760 kg/MWh for fuel oil (35% efficiency)
915 kg/MWh for coal (35% efficiency)

The results for oil and coal are in good agreement with those provided above in II.B. above.

B. Comment

The Bertani and Thain survey included 85% (i.e. 6,660 MW_e) of the total installed geothermal power plant capacity in 2001. There is a large spread in CO₂ emission from these geothermal plants, ranging from 4 kg/MWh to 740 kg/MWh. However, 73% (4,858 MW_e) of the plants surveyed were found to have a MW weighted average emission less than 150 kg/MWh, and the MW_e output weighted average CO₂ emission was 122 kg/MWh.

V. CONCLUSIONS

Based upon the above discussion, it can be concluded that:

A. The following fuel oil savings can be used assuming an efficiency factor of 35% for the production of electricity:

1 TJ (in electricity produced) ~ 70.4 toe

1 GWh (in electricity produced) ~ 253.4 toe

B. The following fuel oil savings can be used assuming 70% efficiency factor for direct burning to produce heat:

1 TJ (in heat produced) ~ 35.2 toe (e.g. in a furnace)

1 GWh (in heat produced) ~ 126.7 toe (e.g. in a furnace)

C. The following CO₂ savings can be used assuming 35% efficiency factor for production of electricity (Lund, *et al.*, 2005):

193 kg/MWh	for natural gas
817 kg/MWh	for oil
953 kg/MWh	for coal

D. The following CO₂ savings can be used assuming 70% efficiency factor for direct burning to produce heat (Lund, *et al.*, 2005):

97 kg/MWh	for natural gas
409 kg/MWh	for oil
477 kg/MWh	for coal

VI. REFERENCES

Bertani, R. and Thain, I. 2001: Geothermal Power Generating Plant CO₂Emission Survey, IGA.

Bloomfield, Moore and Neilson 2003: GRC Bulletin, 32 (March/April 2003).

Goddard and Goddar 1990: GRC Transactions, 14, Part 1 (1990), p. 649.

Lund J.W., Freeston, D.H. and Boyd, T.L. 2005: Worldwide Direct-Uses of Geothermal Energy 2005. Proc. WGC 2005, Antalya, Turkey, 24-29 April 2005.

NOTES:

* (<http://www.onlineconversion.com/energy.htm> and <http://www.iea.org/dbtw-wpd/Textbase/stats/unit.asp> The assumptions made for these calculations are not stated. The websites were sent as a reference by Carrie Pottinger, IEA; 7 January 2005 for calculation of these values). Lund (pers. comm. 13Jan05) shows these results assume 100% efficiency.

Lund et al. (2005) 1 barrel ~ 6.06 GJ

IEA: 1 toe (~6.69 barrel) ~ 0.04187 TJ ~ 0.01163 GWh