

# GEOTHERMAL ENERGY USE COMPARED TO OTHER RENEWABLES

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Renewable energy, which includes production from geothermal, wind, solar, biomass, hydroelectric and wave/ocean/tides, is gaining interest from politicians and developers due to global warming predictions and the high cost of oil. Development is also stimulated by the establishment in many states of Renewable Portfolio Standards (RPS) that are to be implemented over the next 10 to 30 years. We in the geothermal industry tend to look only at our resource, but putting geothermal energy production in perspective with the other renewables, helps to understand their place in the market along with strengths and weaknesses. Thus, this article is an attempt to compare the development of all renewable energy types. Data on renewables are available for the world from the International Energy Agency (IEA), but, unfortunately the latest data are from 2004 with some estimates for 2005 (IEA, 2006). The following tables are based on data from the IEA publication, supplemented by several other sources.

World energy is described in terms of Total Primary Energy Supply (TPES), which is all energy consumed by end users, excluding electricity but including the energy consumed at electric utilities to generate electricity. (In estimating energy expenditures, there are no fuel-associated expenditures for hydroelectric power, geothermal energy, solar energy, or wind energy, and the quantifiable expenditures for process fuel and intermediate products are excluded.)

To put fossil fuels and nuclear in context with renewables, the world TPES was 11,059 Mtoe (million tonnes of oil equivalent; one Mtoe =  $4.1868 \times 10^4$  TJ =  $3.968 \times 10^7$  MBtu = 11,630 GWh), of which 13.1% or 1,448 Mtoe was produced from renewable energy sources in 2004. This is equivalent to 463.4 million TJ (128.7 million GWh) and 60.6 million TJ (16.8 million GWh) respectively. The various shares of energy are as follows:

Table 1. 2004 Fuel shares in World Total Primary Energy Supply.

Fuel	Percentage	Mtoe	10 <sup>6</sup> TJ	10 <sup>6</sup> GWh
Oil	34.3	3,793	158.8	44.1
Coal	25.1	2,776	116.2	32.3
Natural Gas	20.9	2,311	96.8	26.9
Nuclear	6.5	719	30.1	8.4
Non-Renew. Waste	0.2	22	0.9	0.2
Renewables	13.1	1,448	60.6	16.8

Looking at renewables in more detail, we find that renewable combustibles and wastes (including solid biomass/charcoal, liquid biomass, renewable municipal

waste, and gas from biomass – referred to as biomass in this paper) accounts for 79.4% of the total as shown in the following table.

Table 2. 2004 product shares in world renewable energy supply.

Renewable	Percentage	Mtoe	10 <sup>6</sup> TJ	10 <sup>6</sup> GWh
Biomass	79.4	1,150	48.1	13.4
Hydro	16.7	242	10.1	2.81
Geothermal	3.2	46.3	1.94	0.549
Wind	0.5	7.24	0.303	0.084
Solar/Tide/Ocean	0.3	4.34	0.182	0.067

If we just consider electricity production, then the relationship between renewables and other fuel types are shown in Table 3.

Table 3. Fuel shares in world electricity production in 2004.

Fuel	Percentage	Mtoe	10 <sup>6</sup> GWh
Coal	39.8	705	8.20
Gas	19.6	347	4.04
Nuclear	15.7	278	3.23
Oil	6.7	119	1.38
Non-Renew. Waste	0.3	5.31	0.0618
Renewables	17.9	317	3.69

Within the renewables share (17.9%), a majority, or 16.1%, is produced from hydro, 1.0% from biomass and 0.8% from geothermal, wind, solar and tide combined (one third of which is from geothermal).

Unfortunately, capacity factors (number of equivalent full-load hours of operation per year for electricity generation) and energy generated for each of the renewables, are only available from IEA and OECD (Organization for Economic Co-operation and Development) countries which include most of western Europe, Czech Republic, Hungary, Slovak Republic, Canada, United States, Australia, New Zealand, Turkey, Japan, Korea, and Mexico. A summary of renewables for OECD countries is shown in Table 4. The majority, 80.5% of the generated energy (around 1,650,000 GWh/yr) came from hydro, followed by 12% from biomass, 5.4% from wind, 2.0% from geothermal, 0.12% from solar and 0.04% from tides. OECD countries supply only 21.8% of world renewables while consuming 49.8% of world TPES. However, when considering new renewables, OECD countries account for most of the production of wind, solar and tide energy in 2004 (86.3%).

Table 4. OECD countries electricity production in 2004 from renewables.

Fuel	Net Capacity (MWe)	Electric Energy (GWh/yr)	Load Factor (%)
Hydro	428,000	1,343,000	35.8
Biomass	30,000	196,000	74.6
Wind	43,000	77,000	20.4
Geothermal	5,900	35,000	67.7*
Solar	3,000	1,400	5.3
Tides/wave/Ocean	300	600	22.8
<b>TOTAL</b>	<b>510,000</b>	<b>1,650,000</b>	<b>37.0</b>

\* Based on country updates summarized in Bertani, 2005, the capacity factor = 73%.

## EXAMPLES OF RENEWABLES DEVELOPMENT IN SELECT COUNTRIES

As examples of the use of renewables, data from the United States, Germany and China are provided (IEA 2006):

**United States:** Total renewables produced are 97.76 Mtoe or 4.2% of TPES (2,319 Mtoe); electricity: 393,918 GWh/yr or 9.3% of total electricity produced, which comes mainly from hydro and biomass.

Table 5. Renewables in the United States, 2004.

Renewable	MWe	GWh/yr	TJt/yr
Hydro	96,699	291,187	0
Geothermal	3,094*	16,729*	31,239*
Solar	753	602	62,186**
Tide/wave/ocean	n/a	n/a	0
Wind	6,522	15,347	0
Biomass	10,256	70,053	13,167
<b>TOTAL</b>	<b>117,324</b>	<b>393,918</b>	<b>106,592</b>

\*\*From: EIA, 2004, since no data were listed by IEA

\* from: Lund, et al., 2005, since no data were listed by IEA

**Germany:** Total renewables produced are 6.66 Mtoe or 11.3% of TPES (59 Mtoe); electricity 73,350 GWh/yr or 14.3% of total electricity produced, which comes mainly from wind and hydro.

Table 6. Renewables in Germany, 2004.

Renewable	MWe	GWh/yr	TJt/yr
Hydro	8,271	27,874	0
Geothermal	<1	2	11
Solar	708	1,000	0
Tide/wave/ocean	0	0	0
Wind	16,629	26,500	0
Biomass	2,061	17,974	12,877
<b>TOTAL</b>	<b>25,608</b>	<b>73,350</b>	<b>13,288</b>

**China:** Total renewables produced are 250.90 Mtoe or 15.6% of TPES (1,609 Mtoe); electricity: 356,129 GWh/yr or 20.7% of total electricity produced, which comes mainly from hydro and biomass.

Table 7. Renewables in China, 2004.

Renewable	MWe	GWh/yr	TJt/yr
Hydro	128,570	353,544	0
Geothermal	28	96	45,373*
Solar	0	0	0
Tide/wave/ocean	0	0	0
Wind	0	0	0
Biomass	n/a**	2,489	12,571
<b>TOTAL</b>	<b>128,598</b>	<b>356,129</b>	<b>57,944</b>

\*from: Lund, et al., 2005 and Bertani, 2005, since no data were listed by IEA.

\*\* based on a load factor of 75%, the installed capacity for biomass = 380 MWe.

For 2007, China reported installed capacity for: solar (80 MWe); wind (2,600 MWe); biomass (2,061 MWe); and tide/wave/ocean (0.8 MWe) (Li, et al., 2007). They have a strong program to develop both solar and wind production.

## GROWTH OF RENEWABLES

Since 1990, renewable energy sources have grown at an average annual rate of 1.9%, as compared to the world TPES of 1.8% per annum. Wind has had the highest growth rate of 24.4%; however, from a small base in 1990. The second highest growth was from non-solid biomass combustible renewables and waste, such as renewable municipal waste, biogas and liquid biomass, averaging 8.1% annually since 1990. Solid biomass grew at a rate of 1.6% per annum. The bulk of the solid biomass (87.4%) is produced and consumed in non-OECD regions, where these developing countries such as in South Asia and Sub-Saharan Africa use non-commercial biomass for residential cooking and heating (IEA, 2006).

Most of the growth in hydro power took place in non-OECD regions, where it had a rate of 3.3% annually, compared to OECD countries at 0.6% annually. The remaining hydro potential appears to be in non-OECD countries, as indicated by China's Three Gorges Dam which represents a 1 to 2% increase in the world production, estimated at 18,200 MW of additional capacity.

Renewable electricity generation grew on average 2.1% per annum worldwide, which is lower than the total electricity generation at 2.8%. The total from renewables was 19.7% of global electricity in 1990, but fell to 17.9% in 2004. This is due to the slow growth of renewables, especially hydro power in OECD countries.

Based on data from the World Geothermal Congress 2005 (WGC2005), the capacity growth (MWe) since 1995 of geothermal energy was almost two-fold for direct-use (6.6% annually – without heat pumps) and 1.3 times for electric power capacity (2.7% annually). In terms of energy production (GWh/yr), the growth for direct-use was almost two-fold (6.6% annually – without heat pumps) and 1.5 fold (4.1% annually) for electricity generation

(Lund et al., 2005; Bertani, 2005). Geothermal (ground-source) heat pumps have been the leader to worldwide growth, with the installed capacity growing at 23.6% annually and the annual energy use at 19.6% annually – mainly in the North America and Europe.

Estimates for the future point to major growth in wind and solar electricity generation, with slower growth in geothermal, hydroelectric and biomass. Tide/ocean/wave are in their infancy with unknown growth. By 2010 the expected electrical generation capacity for wind will be 74 GW, solar 20 GW and geothermal 11 GW. Hydroelectric will grow primarily in non-OECD countries such as China, India and in Latin America. Biomass growth will be strong, especially in OECD countries. By 2004, 48 countries had adopted some sort of policy aimed at encouraging renewable development of which 14 were from developing countries. These policies include: 1) feed-in tariffs, 2) renewable portfolio standards, 3) direct capital investment subsidies or grants, and 4) tax incentives. Europe will most likely lead in developing renewable energy, due to strong commitments by the various European Union members.

## SUMMARY AND CONCLUSIONS

In summary, each of the various renewables have certain limitations, some are better suited for electric energy production and others for direct heating. Some such as solar panels and wind machines can be installed easily and in a short period of time, whereas hydro and geothermal can often take more time, especially with large projects.

Solar obviously depends on daytime sun light and nighttime storage; wind can be intermittent and also depends on storage; hydro is subject to drought as recently experienced in east Africa and New Zealand and limited sites especially in OECD countries; biomass depends on a supply of fuel and can contribute to greenhouses gases and

particulate emission; tide and ocean is limited to areas where sufficient changes are available and where it does not interfere with navigation; and even though geothermal is base load for power and can supply the full load for heating, it is site specific. Thus, all renewables have limitations, but must be supported as they can complement each other. Only geothermal heat pumps have worldwide application for both heating and cooling.

Renewable resources as a total have a significant impact of the Total Primary Energy Supply (TPES), currently providing 13.1% of the TPES installed capacity and 17.9% of the electrical energy production in 2004. Growth over the period 1995-2004 of installed capacity of renewables has been 1.9% annually, and for geothermal it has been 2.7% annually for power generation and 6.6% for direct-use (without geothermal heat pumps). Geothermal heat pumps have increased 23.6% annually over the same period.

## REFERENCES

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