

Geothermal Energy  
for  
Electricity Generation  
Catching Up- The R&D Priorities

*Ladislaus Rybach*

Vice-Chair, Geothermal Implementing Agreement

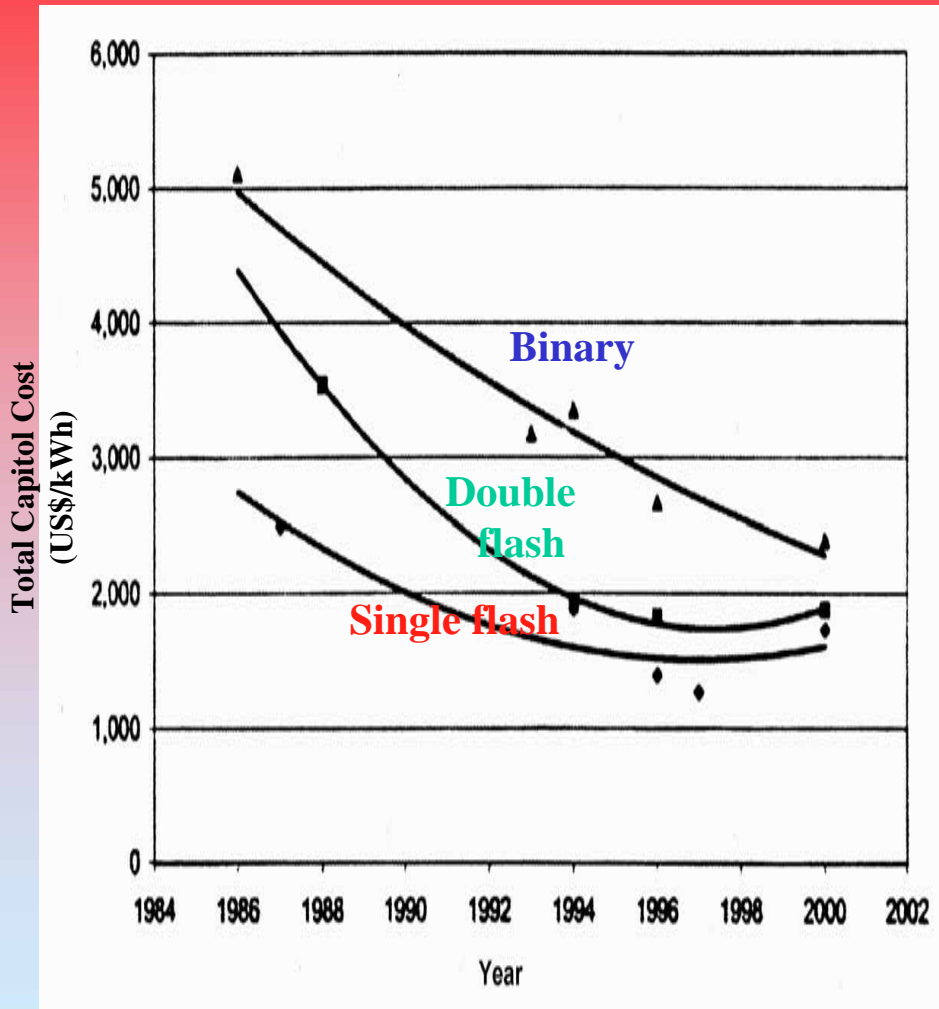


# Geothermal Potential and Utilization



- Geothermal Globally Distributed
- Technical Potential 5,000 EJ/y (66% of total RE potential)
- 2004 Resources Reported in 80 Countries
  - Used in 71 countries
  - Electricity generation in 24 countries
    - Installed capacity: 8,900 MW<sub>e</sub>
    - Generated: 56.8 TWh/y
    - Capacity factors: 75-90%
    - Saving 14 Mtoe and 47 Mt CO<sub>2</sub> emissions/y
- Unique Capability Use Separated Hot H<sub>2</sub>O from Power Generation for Direct-Use
  - Installed capacity 27,825 MW<sub>t</sub>
  - Energy use: 72.6 TWh/yr
  - Saving 14 Mtoe and 45 Mt CO<sub>2</sub> emissions/y

# Geothermal- Current and Future Costs



- Current Costs Depend on
  - Reservoir characteristics
  - Project size
  - Location
  - Plant type
- Development Costs Reduced 50% in last 20 years; now
  - Capital: US\$ 1,150/kW
  - Power: US\$0.02-0.10/kWh
- Future Generation Costs Down to US\$0.01-0.08/kWh
- Applicable for
  - Large-scale integrated schemes
  - Distributed and decentral generation



# R&D Challenges and Priorities

**Goal: To Generate at Least 5% Global Electricity by 2020**

## *Major Challenges*

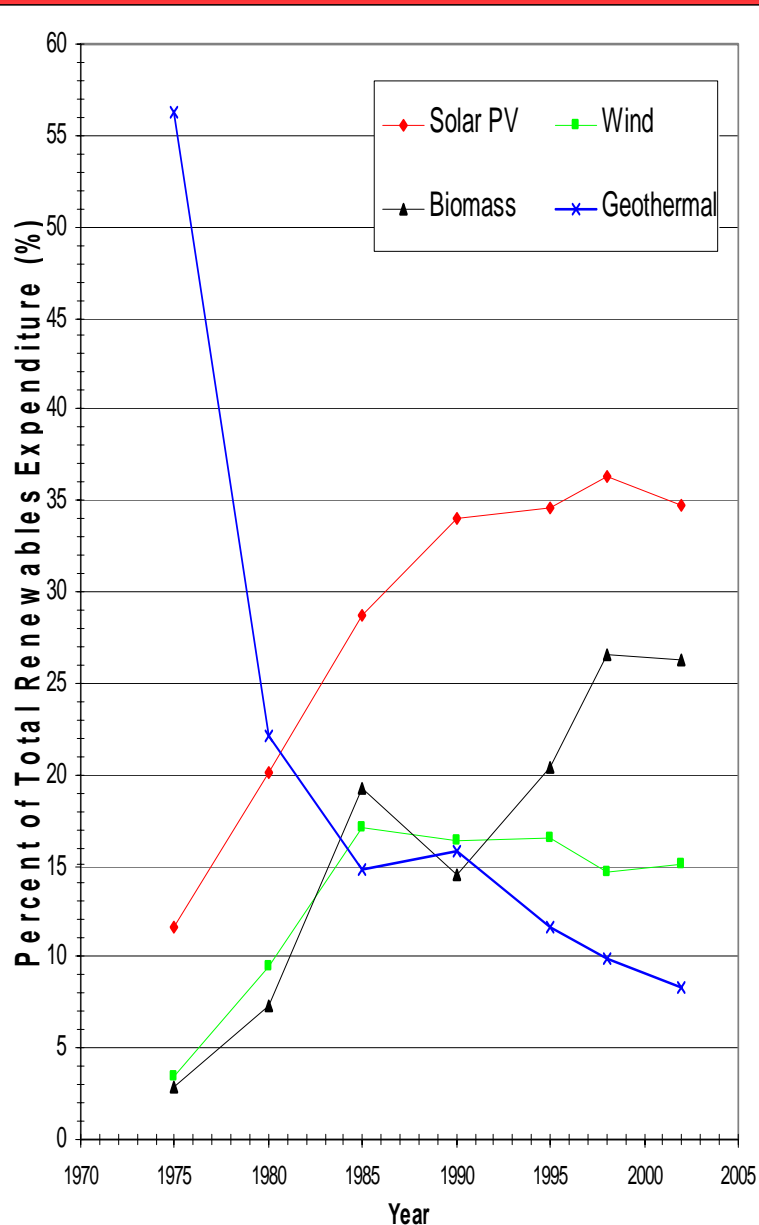
- Reduce Generation Costs
- Increase Geographical Distribution of Use
- Expand Technology for New Uses
- Sustainable Use

## *Priorities*

- Better Exploration, Resource Confirmation and Management Tools
- Commercial Development of
  - Enhanced geothermal systems (EGS)
  - Deep geothermal resources
- Increased Co-Gen and “Cascading”
- Mitigation of Environmental Effects
- Better Information Dissemination
- Enhance Benefits to Community
- Government Support for Mitigation of CO<sub>2</sub> Emission
- Increase Private Sector Investment



# Realizing Geothermal's Potential



➤ Significantly Slowed During Past 20-years

- Major reduced government funding
  - 1980: US\$ 430 million (23% total RE)
  - 2002: US\$ 56 million (8% total RE)
- Small industry contribution

➤ Realizing Potential Requires Considerable Increase in

- Funding
- Manpower
  - Training and Education

➤ Funding Proportional to Geothermal's Potential Significant Energy Payoff

- Global potential; current capabilities; [electricity generation]/[operating capacity] ratio; capacity, availability and load factors

➤ Governments Recognize Major Impact on Reducing CO<sub>2</sub> Emissions

# Conclusions

- Geothermal Globally Distributed with Major Potential (5,000 EJ/y)
- Geothermal Now Provides 57 TWh/y (0.4% global production)
  - ➔ Saving 14 Mtoe/y and reducing CO<sub>2</sub> emissions by 47 Mt/y
- Geothermal Could Contribute 5% Global Electricity by 2020
  - ➔ Saving 180 Mtoe/y and reducing CO<sub>2</sub> emissions by 570 Mt/y
- Use Could be Extended Far from Tectonic Plate Boundaries
- Could Provide Power & Direct-Use to Areas Now Without Power or Where Generation is by Oil
- To Attain Future Goals and Significantly Assist Reaching REWP's Vision (50% World Primary Energy from RE by 2050) Geothermal Requires:
  - ➔ Significant government support of R&D (increased funding and manpower)
  - ➔ Education and skills transfer
  - ➔ Effective private/public cooperation



**RESERVE SLIDES FOLLOW**

# Renewable Energy Technical Potentials

Technical potential of renewable energy resource base (WEA, 2000).

<b>Energy Source*</b>	<b>EJ/year</b>
Geothermal	5,000
Solar	1,575
Wind	640
Biomass	276
Hydropower	50
<b>Total</b>	<b>7,541</b>

\* Note that marine/ocean energy was not estimated.



## Status Worldwide Renewable Energy Technology for Electricity Production at the end of 2001\*.

Technology	Operating Capacity		Electricity Production		Capacity Factor (%)	Increase in Electricity Production 1997-2001 (% per year)	Current Energy Cost (US¢/kWh)	Potential Future Energy Cost (US¢/kWh)	Turnkey Investment Costs (2001 US\$/kW)
	(GW <sub>e</sub> )	(% of Total)	(TWh)	(% of Total)					
<b>Hydro</b>									
-Large	690	87.59	2,600	87.59	35-60	2	2-10	2-10	1,000-3,500
-Small	25	3.00	100	3.37	20-90	3	2-12	2-12	700-8,000
<b>Biomass</b>	40	5.08	170	5.73	25-80	2.5	3-12	4-10	500-6,000
<b>Geothermal</b>	8	1.02	53	1.79	75-90 <sup>¶</sup>	3	2-10	1 or 2 -8	800-3,000
<b>Wind</b>	23	2.92	43	1.45	20-40	30	4-8	3-10	850-1,700
<b>Solar</b>									
-Photovoltaic	1.1	0.14	1	0.03	6-20	30	25-160	5 or 6 -25	5,000-18,000
-Thermal	0.4	0.05	0.9	0.03	20-35	2	12-34	4-20	2,500-6,000
<b>Marine</b>									
-Tidal	0.3	0.04	0.6	0.02	20-30	0	8-15	8-15	1,700-2,500
<b>TOTAL</b>	787.8	-	2,968.5	-	-	-	-	-	-

\* Data from Table 7, World Energy Assessment (WEA, 2004); <sup>¶</sup> Based on current data



# Characteristics and Budgets for Renewable Energy Sources- 2001

Technology	Potential (EJ/year)	Operating Capacity* (GW <sub>e</sub> )	Electricity Production* (TWh)	Electricity Production/ Operating Capacity* (TWh/GW <sub>e</sub> )	Capacity Factor (%)	RD&D Budget <sup>§</sup> (1987-2002) (US\$ millions)	Approximate RD&D Budget for 2002 <sup>#</sup> (US\$ millions) (%)		Funding Priority
<b>Geothermal</b>	5,000	8	53	6.6	75-90 <sup>¶</sup>	1,221	56	8.3	1
<b>Solar</b>									
-photovoltaic	1,575	1.1	1	0.9	6-20	3,636	234	34.7	4
-thermal		0.4	0.9	2.3	20-35	666	55	8.2	
<b>Wind</b>	640	23	43	1.9	20-40	1,465	102	15.1	3
<b>Biomass</b>	276	40	170	4.3	25-80	2,083	178	26.3	2
<b>Hydro</b>									
-large (>10 MW)	50	690	2,600	3.8	35-60	93	29	4.3	5
-small		25	100	4.0	20-90	49	~7	~1	
<b>Tidal (Ocean)</b>	-	0.3	0.6	2.0	20-30	128	~7	~1	6

\* The operating capacity and electricity production figures are for 2001 (see Table 4)

<sup>¶</sup> Based on current data; however capacity factors for geothermal plants can reach 90-95%.

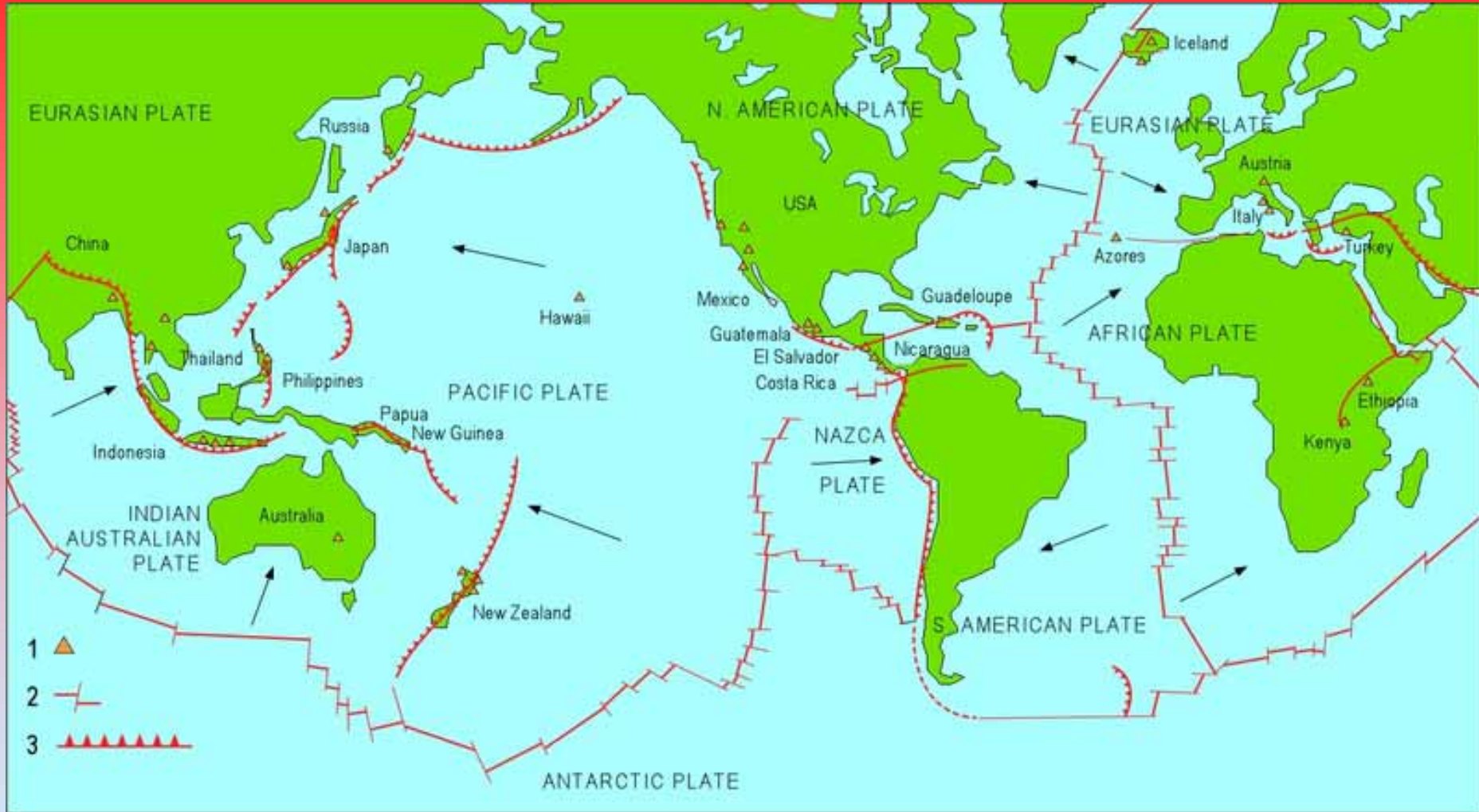
<sup>§</sup> Data from IEA (2004b, 2004c).

<sup>#</sup> Calculated using data and estimate of US\$ 675 million for total renewables RD&D budget from IEA (2004c).

<sup>&</sup> Funding priority based upon criteria presented in Section 3.2.



# Global Tectonic Plate Boundaries and Geothermal Fields



**Figure 1.** World pattern of plates, oceanic ridges, oceanic trenches, subduction zones, and geothermal fields. Arrows show the direction of movement of the plates towards the subduction zones. Legend at the lower left: 1- geothermal fields producing electricity and country name; 2- mid-oceanic ridges crossed by transform faults (long transversal fractures); 3- subduction zones (from Dickson and Fanelli, 2004).

## Worldwide Geothermal Capacity and Electricity Generated for 2004 (Bertani, 2005)

Country	Installed Capacity [MW <sub>e</sub> ]	Annual Electricity Produced [GWh/y]	Percent of National Capacity	Percent of National Electricity Produced
Australia	.2	.5	Negligible	Negligible
Austria	1	3.2	Negligible	Negligible
China, Tibet	28	95.7	30%	30%
Costa Rica	163	1,145	8.4%	15%
El Salvador	151	967	14%	24%
Ethiopia	7	na*	1%	n/a
France (Guadeloupe Island)	15	102	9%	9%
Germany	.2	1.5	Negligible	Negligible
Guatemala	33	212	1.7%	3%
Iceland	202	1,406	13.7%	16.6%
Indonesia	797	6,085	2.2%	6.7%
Italy	790	5,340	1.0%	1.9%
Japan	535	3,467	0.2%	0.3%
Kenya	127	1,088	11.2%	19.2%
Mexico	953	6,282	2.2%	3.1%
New Zealand	435	2,774	5.5%	7.1%
Nicaragua	77	270.7	11.2%	9.8%
Papua New Guinea (Lihir Island)	6	17	10.9%	-
Philippines	1,931	9,419	12.7%	19.1%
Portugal (San Miguel Island)	16	90	25%	-
Russia	79	85	Negligible	Negligible
Thailand	.3	1.8	Negligible	Negligible
Turkey	20	105	Negligible	Negligible
USA	2,534	17,840	0.3%	0.5%
<b>TOTAL</b>	<b>8,902</b>	<b>56,798</b>	-	-



**Table 1. Guaranteed feed-in tariffs (FIT, in Eurocents/kWh) for electricity from renewable sources in Europe. From energie extra 3.03, Swiss Federal Office of Energy, Berne (2003), EU Green-X (2004), Bundesgesetzblatt 2004, Teil I, Nr. 40**

<b>Energy source</b>	<b>Austria</b>	<b>Germany</b>	<b>France</b>	<b>Luxembourg</b>	<b>Portugal</b>	<b>Spain</b>
<b>Solar PV</b>	<b>47 – 60</b>	<b>54.0 – 57.4</b>	<b>15.2 – 30.5</b>	<b>45</b>	<b>22.4 – 41.0</b>	<b>180 - 360</b>
<b>Wind</b>	<b>7.8</b>	<b>5.5 – 6.2</b>	<b>3.05 – 8.38</b>	<b>2.5</b>	<b>4.3 – 8.3</b>	<b>2.7</b>
<b>Biomasse</b>	<b>2.7 – 16.5</b>	<b>8.4 – 11.5</b>	<b>4.5 – 4.9</b>	<b>2.5</b>	<b>0</b>	<b>2.5 – 3.3</b>
<b>Small hydro</b>	<b>3.15 – 6.25</b>	<b>6.65 – 9.67</b>	<b>5.49 – 6.10</b>	<b>2.5</b>	<b>7.2</b>	<b>2.9</b>
<b>Geothermal</b>	<b>7.0</b>	<b>7.16 – 15.0</b>	<b>7.62</b>	<b>0</b>	<b>0</b>	<b>0</b>