Drivers for Renewable Energy: A Cross-country Comparison

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Motivation

Statistics and observations indicate disparities in renewable energy development across countries.

We want to know

- **Why?**
- **How can countries learn from one another in developing renewable energy?**

Objectives

- **To identify major drivers for renewable and bioenergy development in IEA/OECD countries; and**
- **To identify commonalities and differences in these drivers across IEA/OECD countries.**

Selected previous work

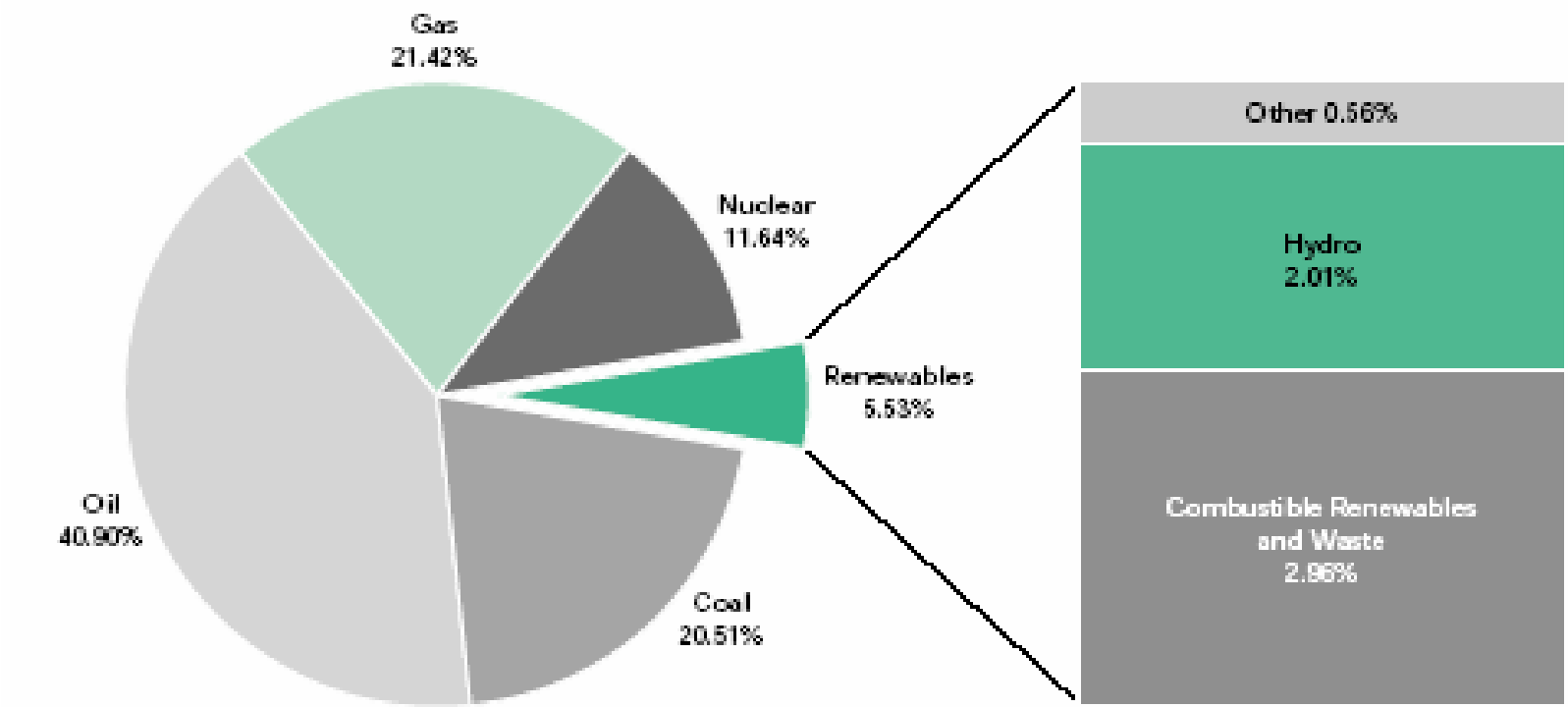
Björheden, R. 2006	Drivers for forest energy in Sweden
Hakkila, P. 2006	Driver for forest energy in Finland
McKay, H. 2006	Environmental, economic, social and political drivers for woodfuel in Britain
Birda, L. 2005	Policies and market drivers for wind power in the US
Domac, J. 2005	Socio-economic drivers
Silveira, S. 2005	An overview (Bioenergy--Realizing the potential)
IEA. 2004	An overview (Renewable energy—Market and policy trends in IEA countries)
Klass, D. 2003	Drivers for renewable energy in the US

There are many drivers, global and local.

Some background information and potential drivers

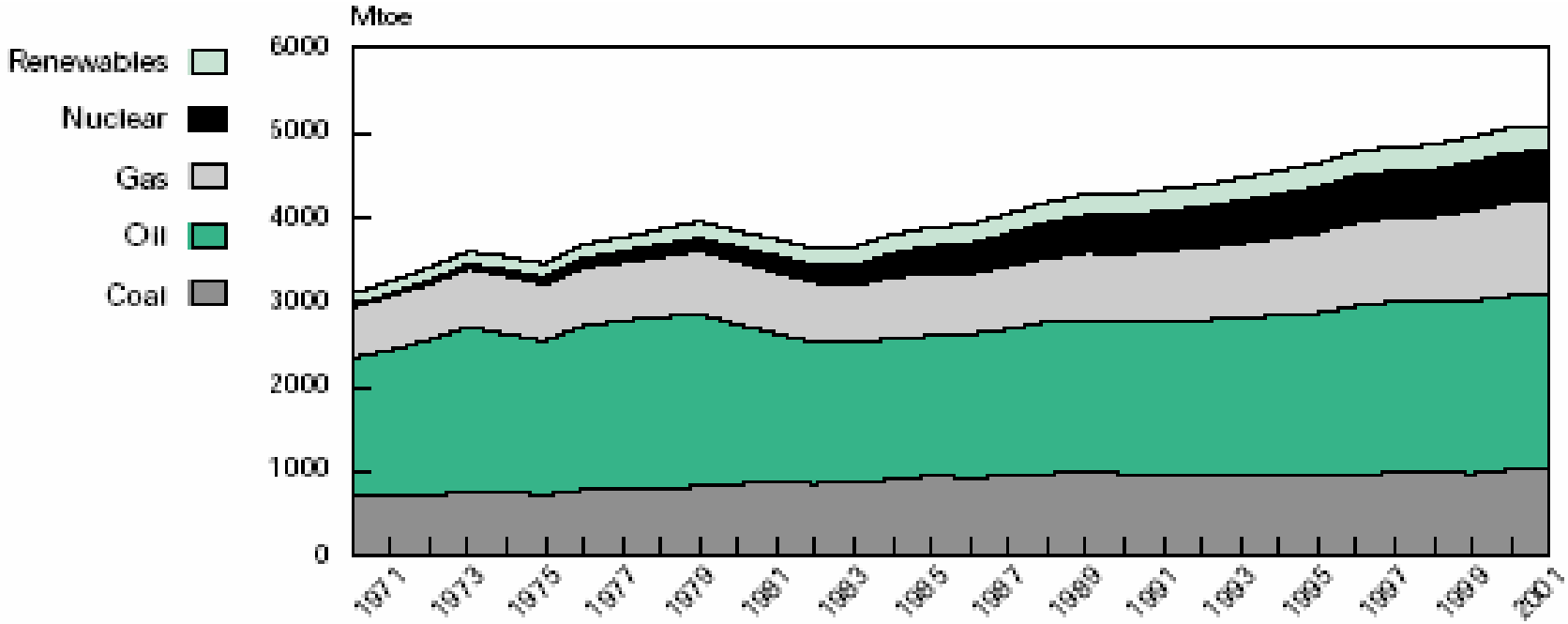
- Role of renewables in total energy supply
- Potential drivers:
  - Oil/energy price
  - Renewable energy resources
  - R&D expenditures
  - Energy policy
  - Environmental concern
  - etc.

Fuel shares of IEA total primary energy supply, 2001



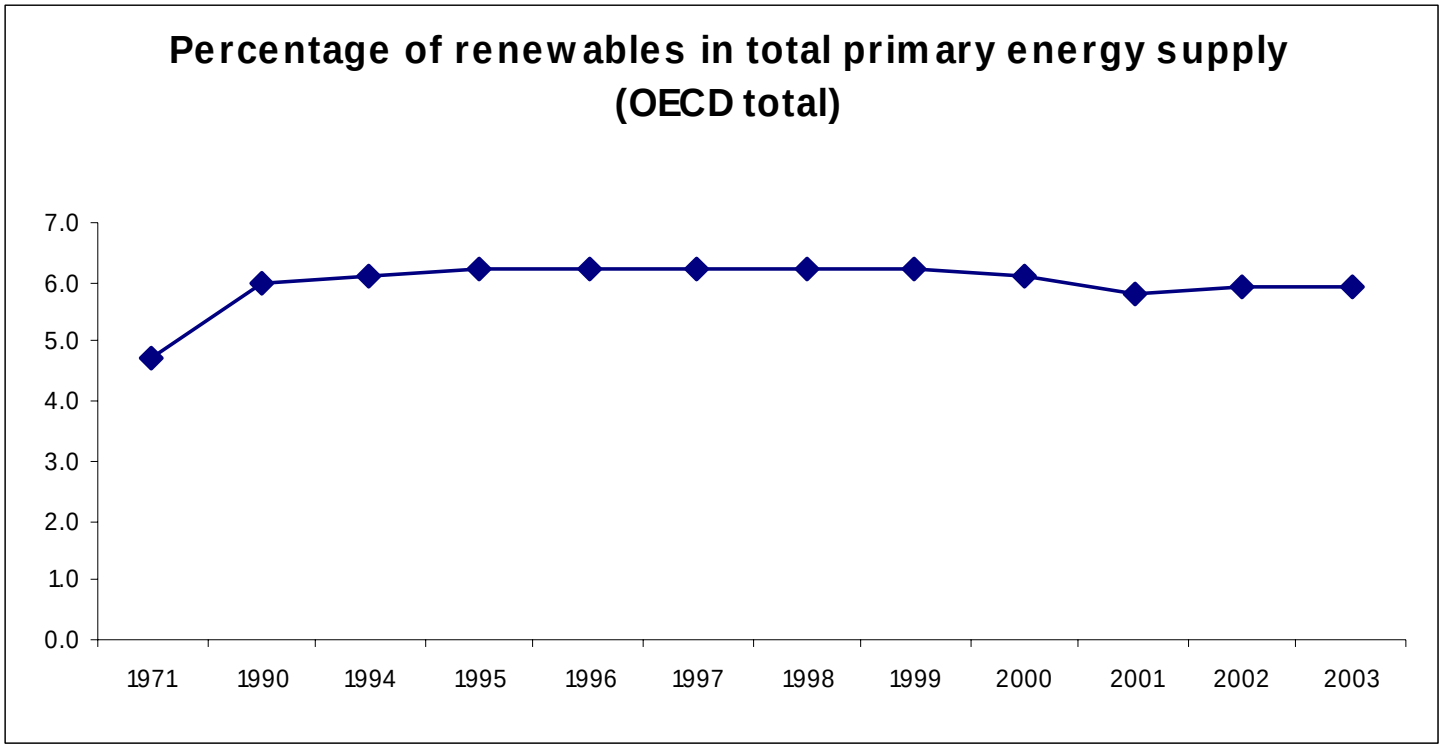
Source: IEA

Historical trends in IEA total primary energy supply



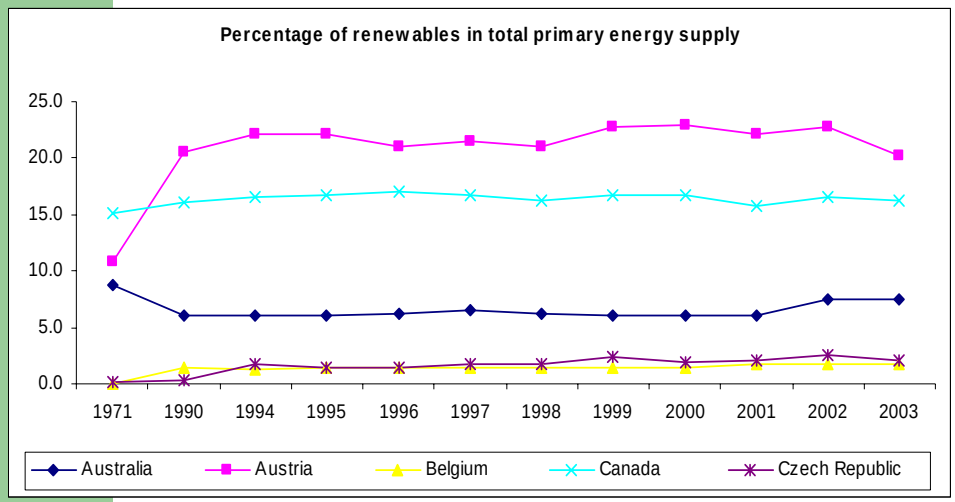
Source: IEA

Share of renewables in OECD total energy supply

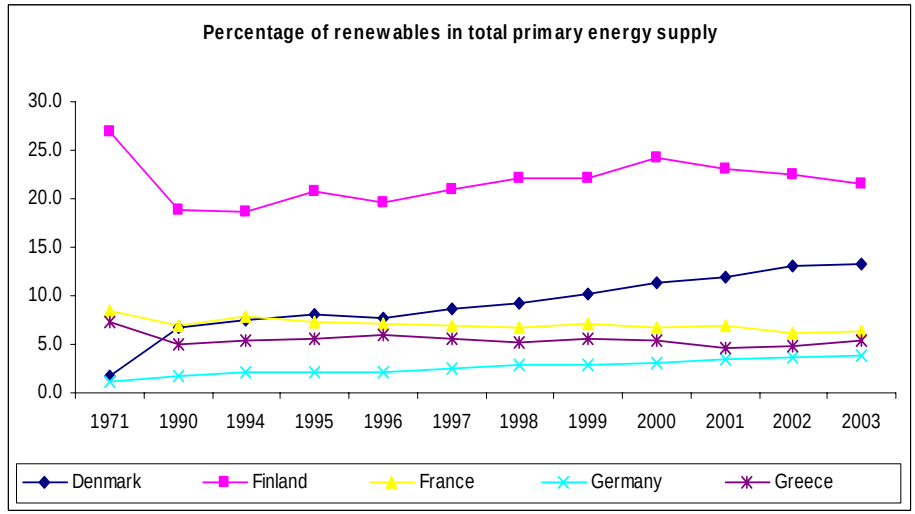


(Source: OECD Factbook 2005)

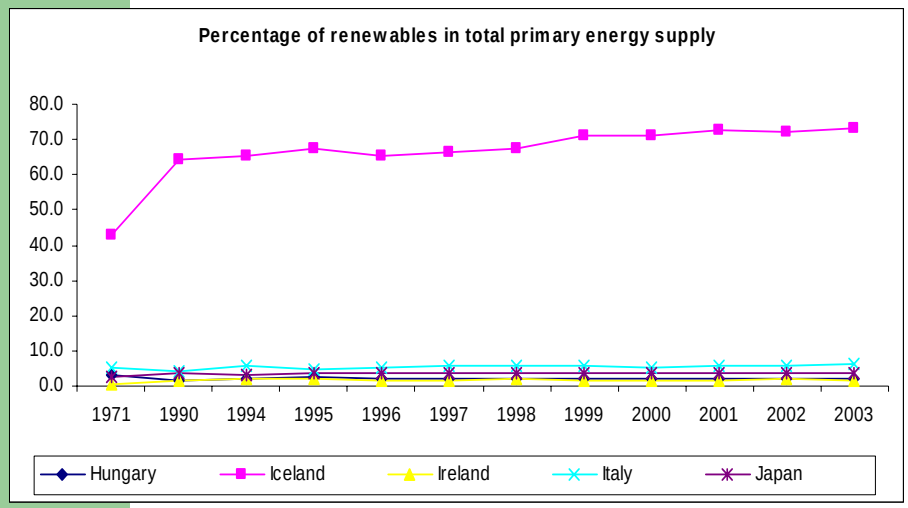
Share of renewables in total energy supply by country (1)



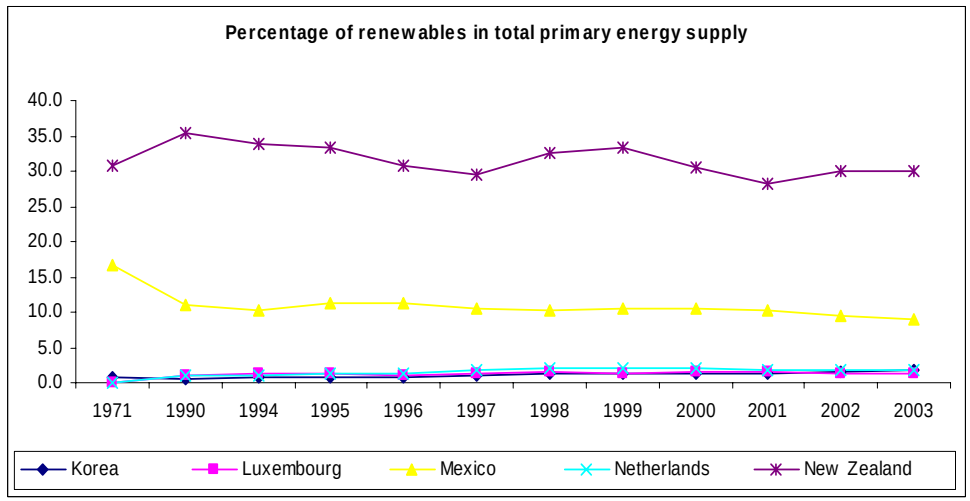
(Source: OECD Factbook 2005)



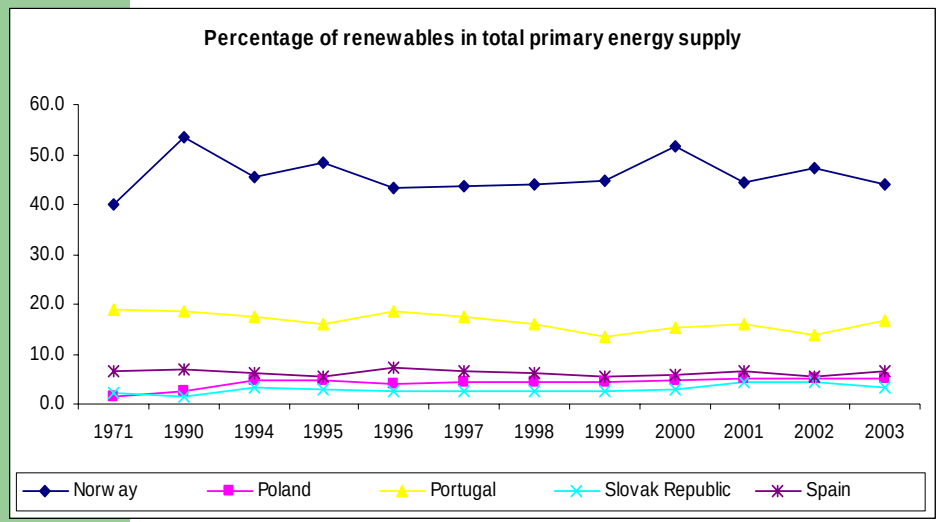
Share of renewables in total energy supply by country (2)



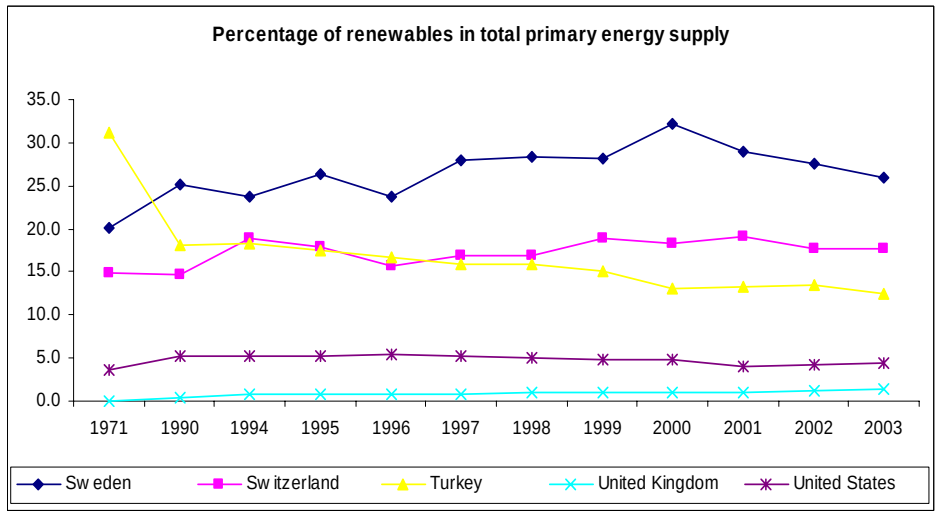
(Source: OECD Factbook 2005)



Share of renewables in total energy supply by country (3)



(Source: OECD Factbook 2005)

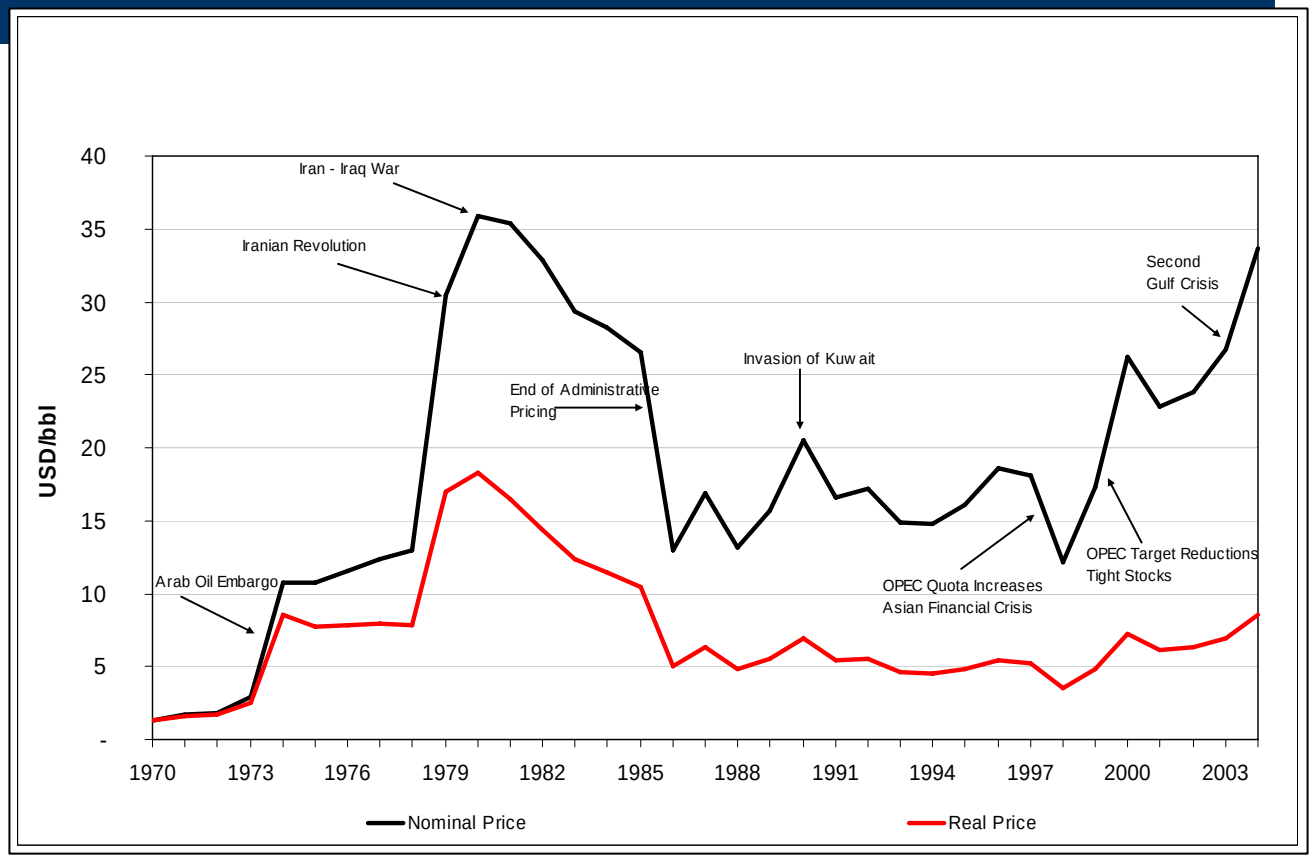


Average annual growth rates of renewable energy—IEA total

	1970-1980	1980-1990	1990-2001
Renewables	3.2%	2.4%	1.2%
*Biomass**	*3.5%*	*3.0%*	*1.6%*
Hydro	*2.6%*	*0.7%*	*0.4%*
Geothermal	*8.3%*	*9.4%*	*0.4%*
Wind/Solar	*6.4%*	*23.5%*	*23.1%*

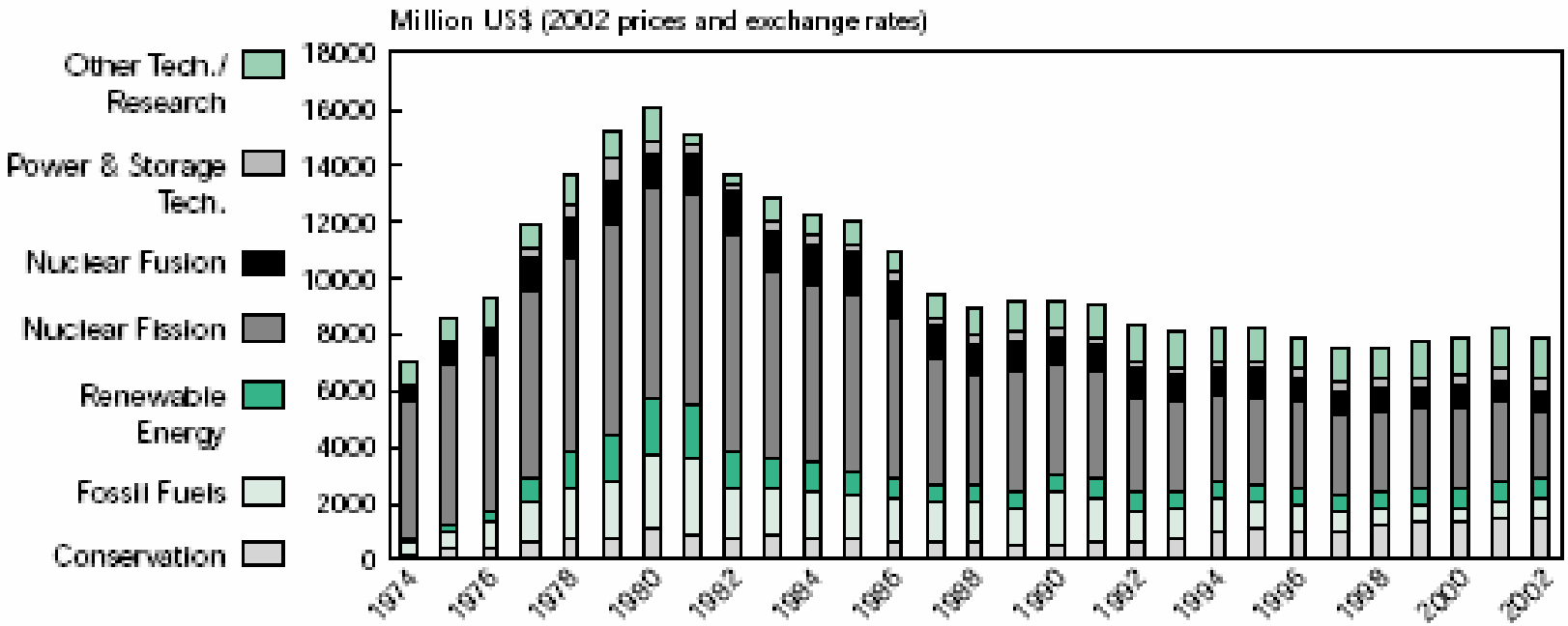
Source: IEA

Crude oil price



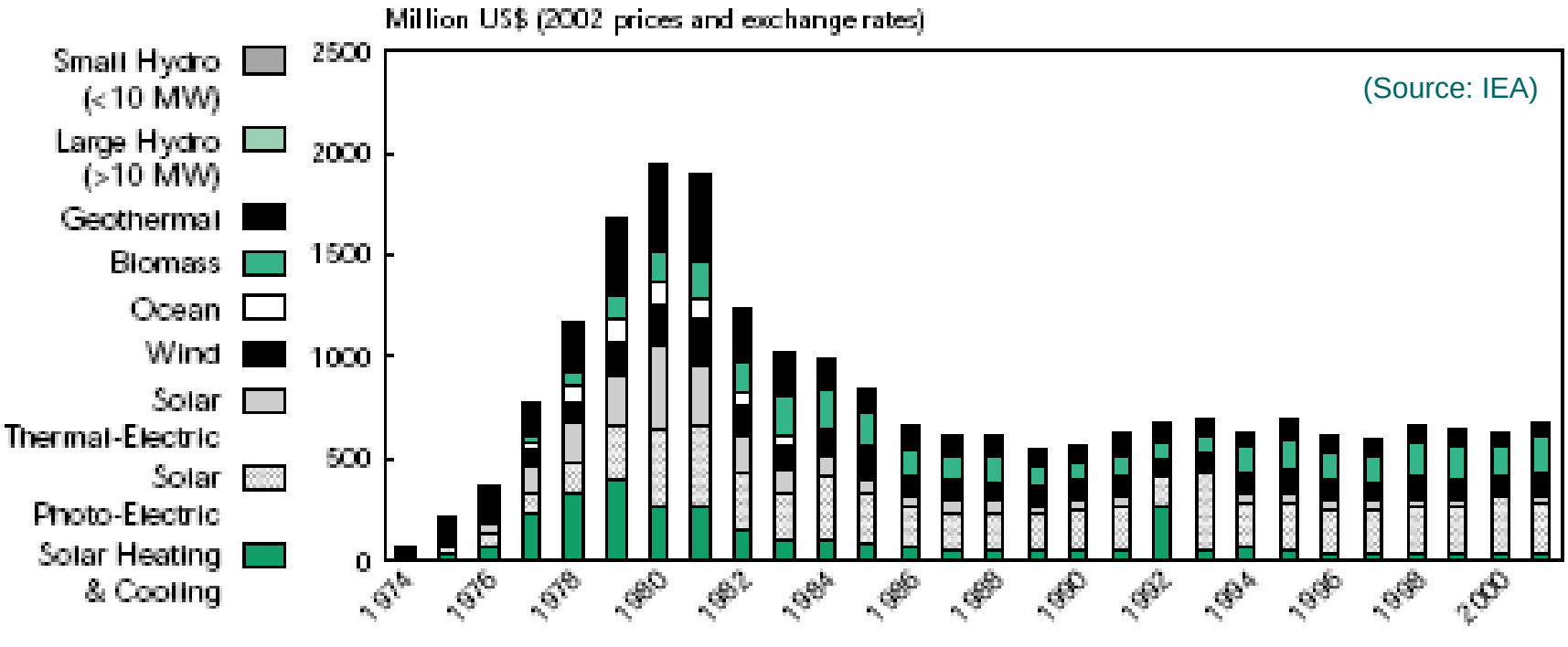
(Source: OECD)

Total energy R&D expenditures—IEA total



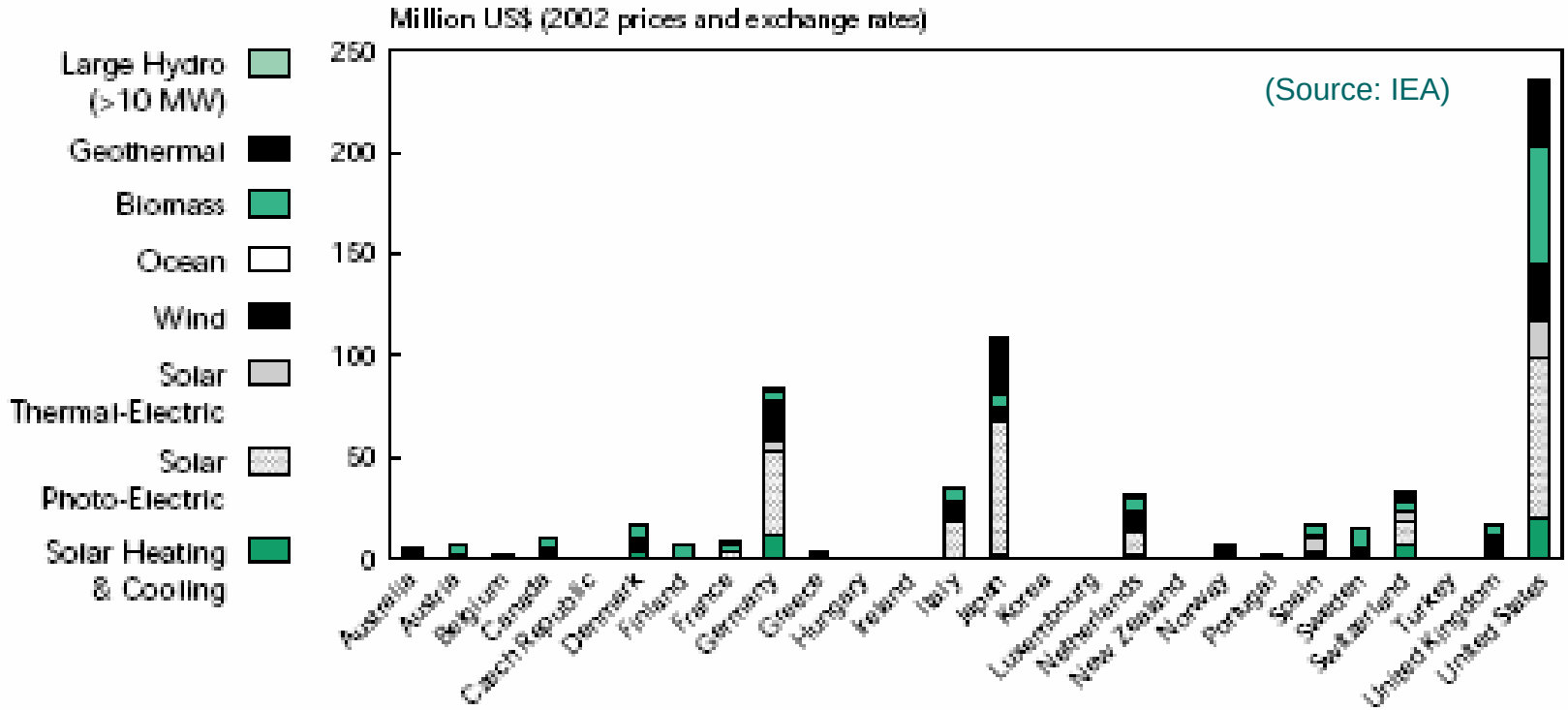
(Source: IEA)

Renewable energy R&D expenditures—IEA total



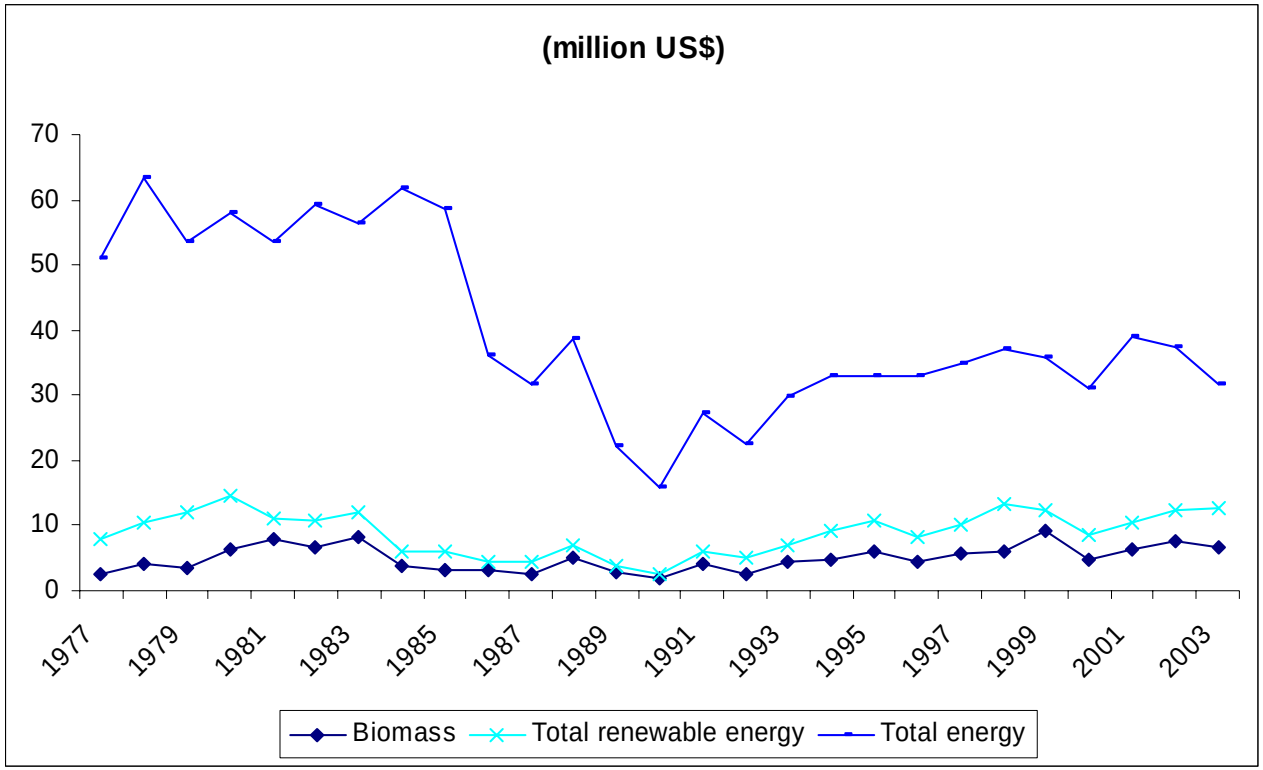
Renewable R&D accounted for 7.7% of total IEA energy R&D expenditures, 1987-2002.

Average annual renewable R&D expenditures in IEA countries, 1990-2001



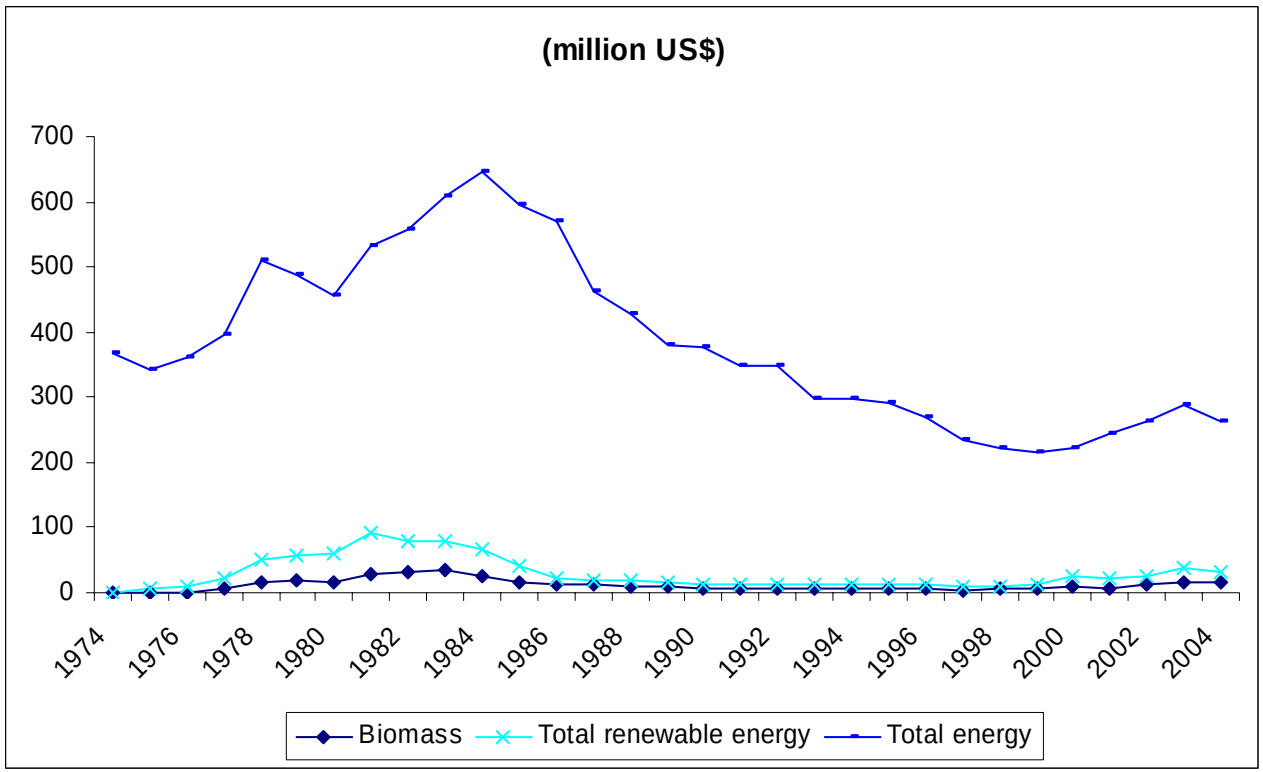
The U.S., Japan, and Germany accounted for about 70% of IEA renewable energy R&D expenditures, 1974-2002.

R&D expenditures—Austria



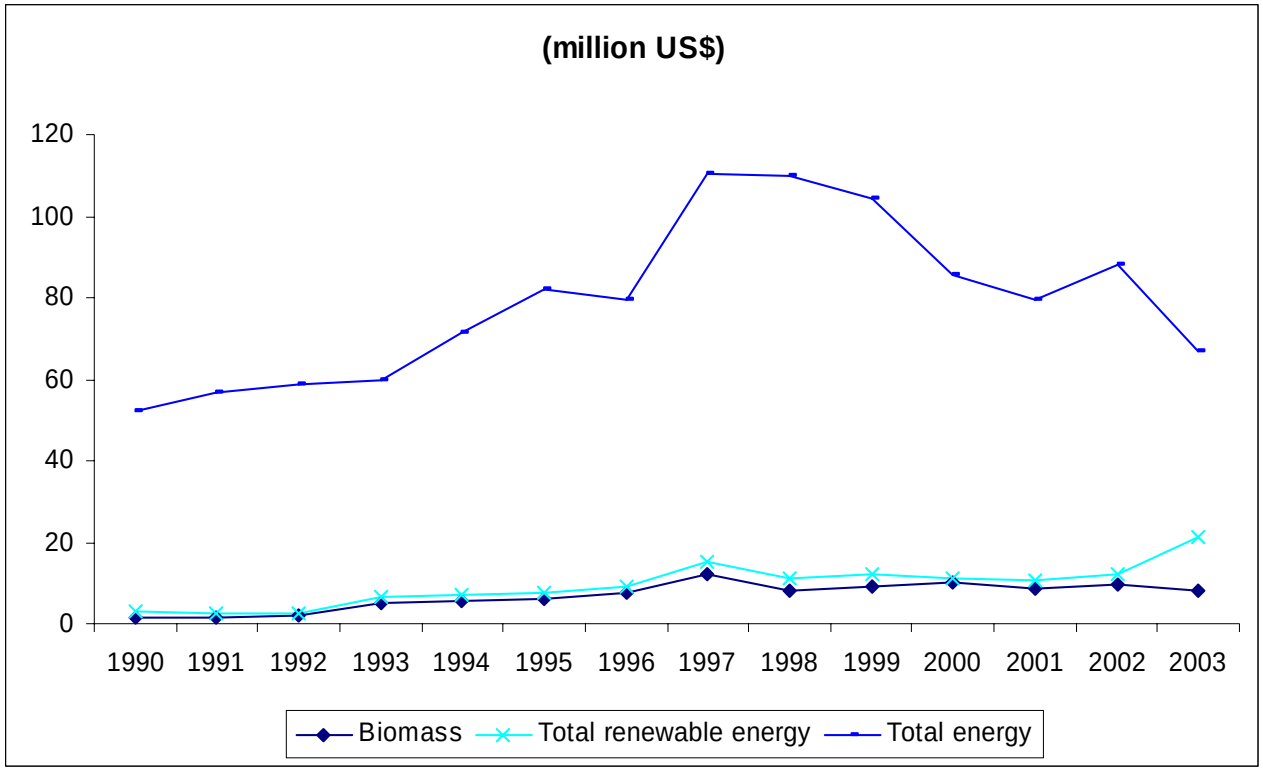
(Source: OECD)

R&D expenditures—Canada

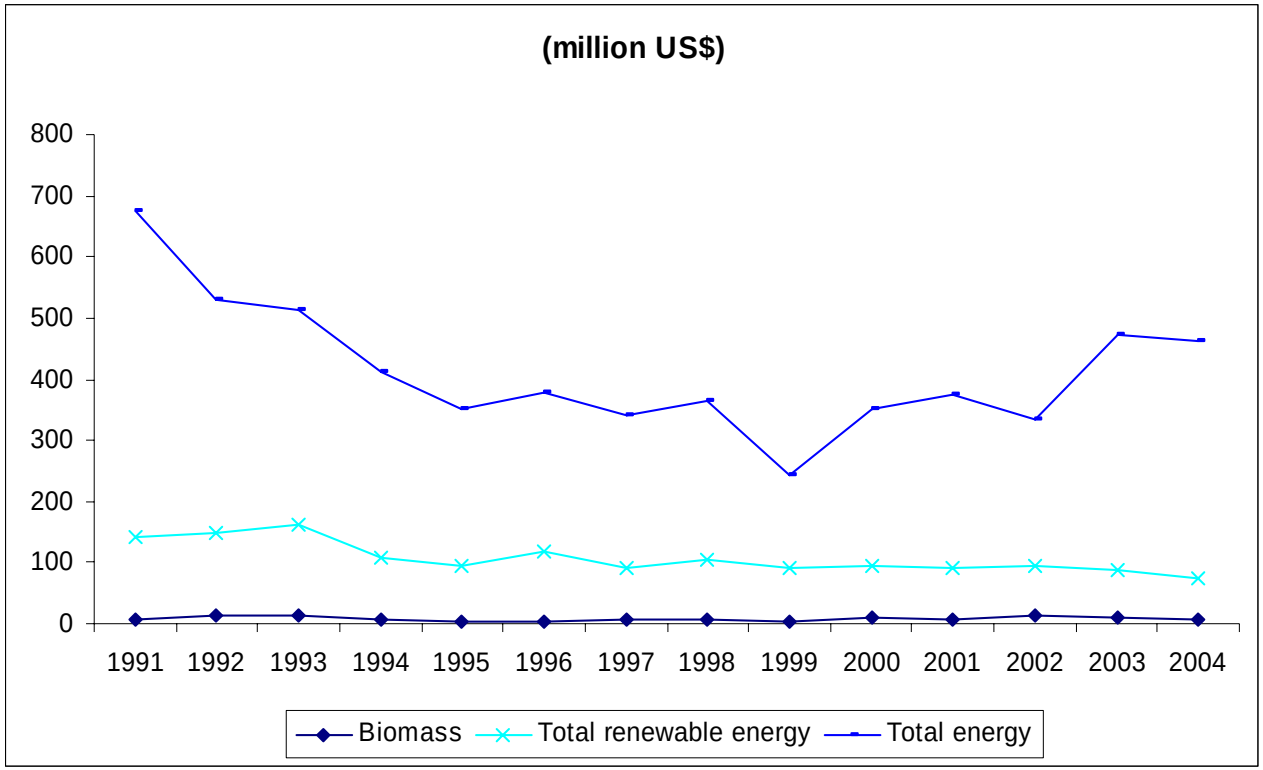


(Source: OECD)

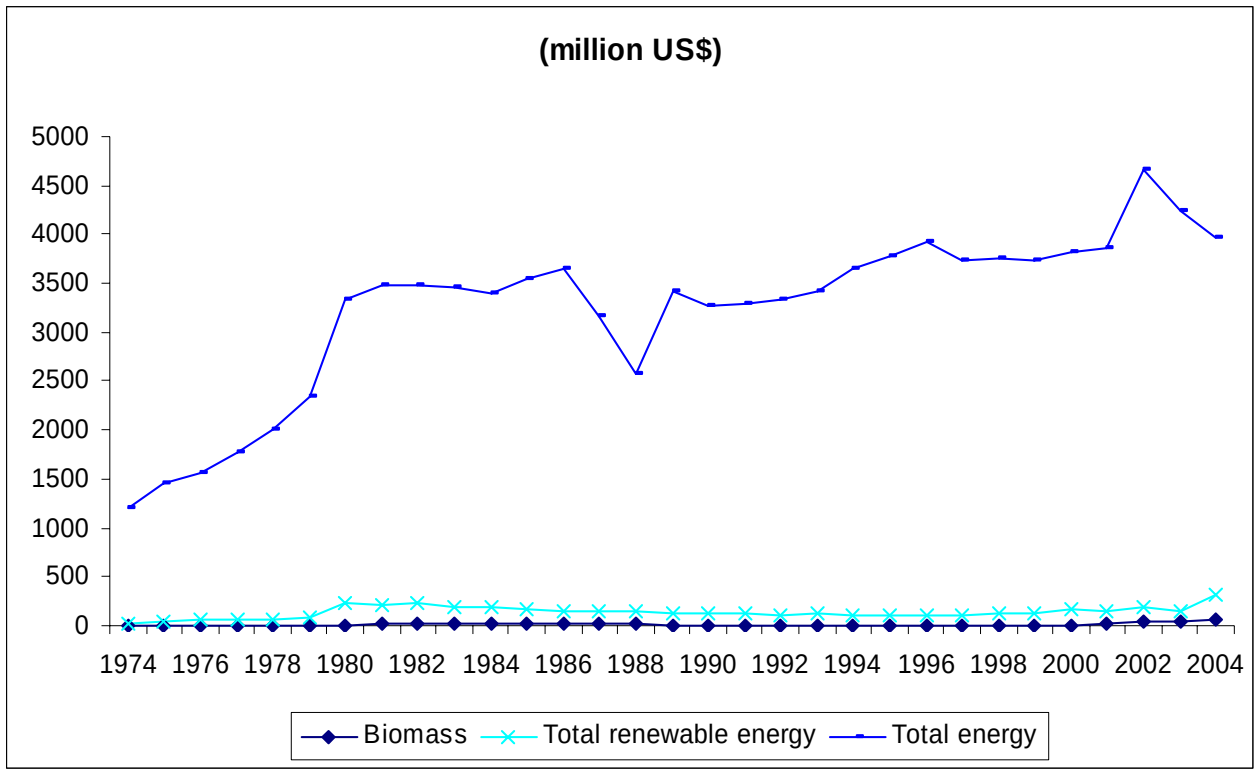
R&D expenditures—Finland



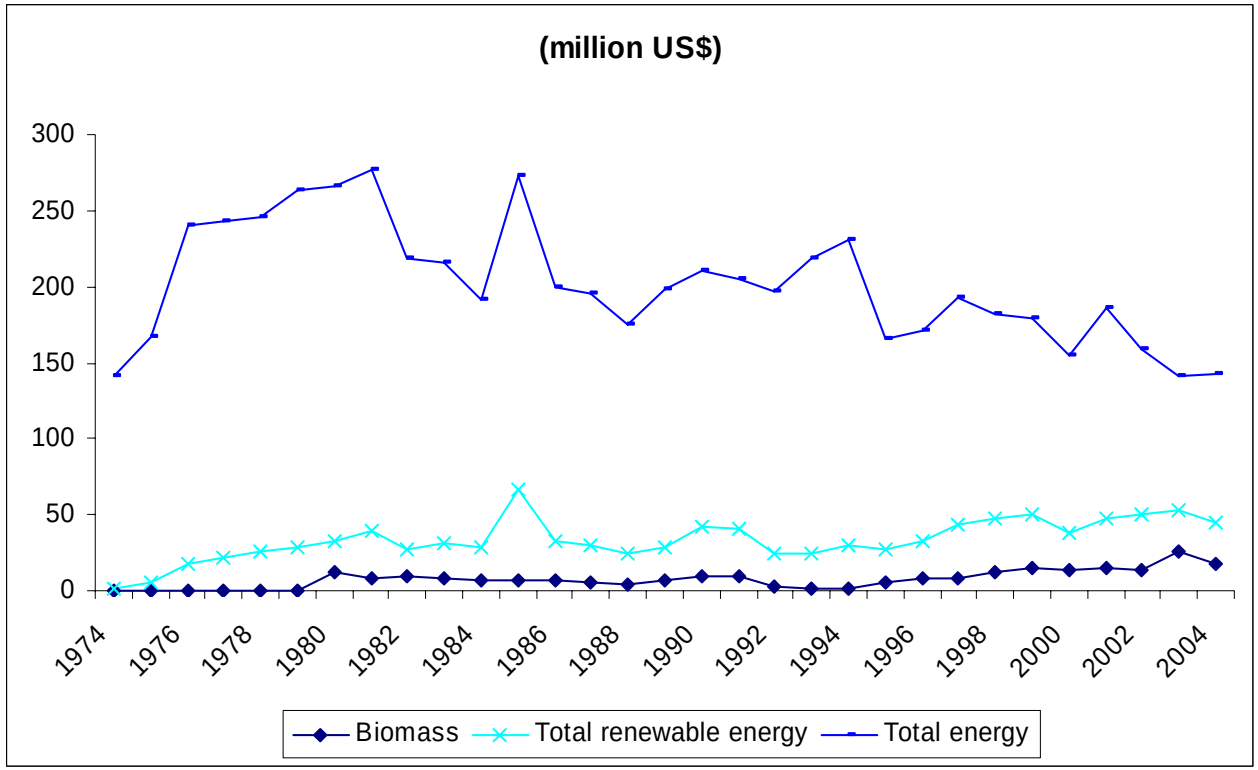
R&D expenditures—Germany



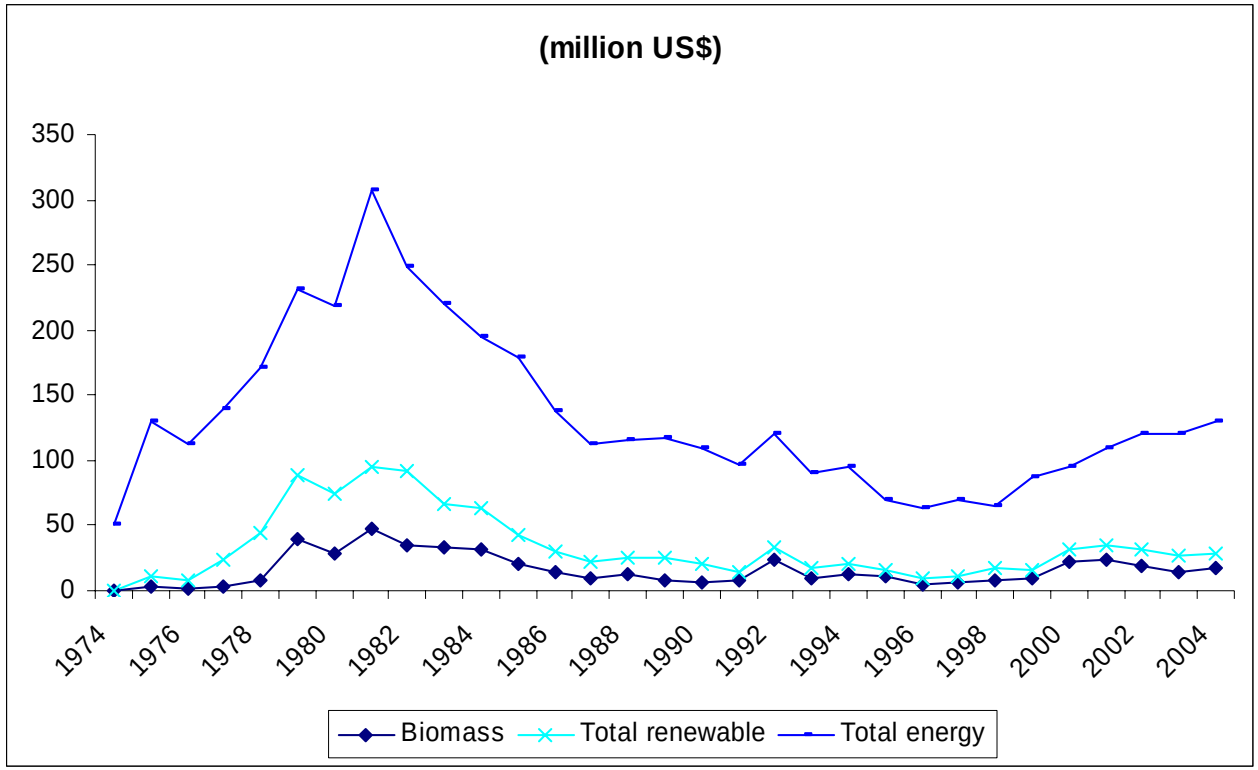
R&D expenditures—Japan



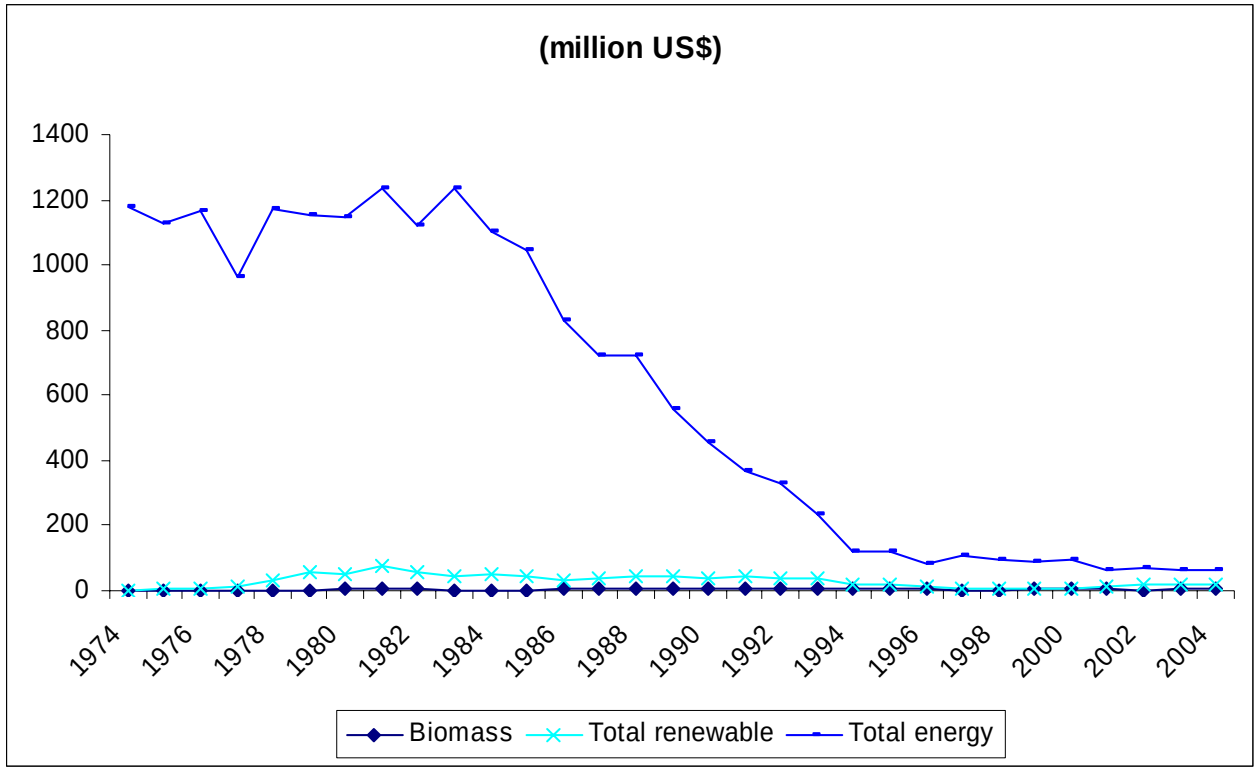
R&D expenditures—Netherlands



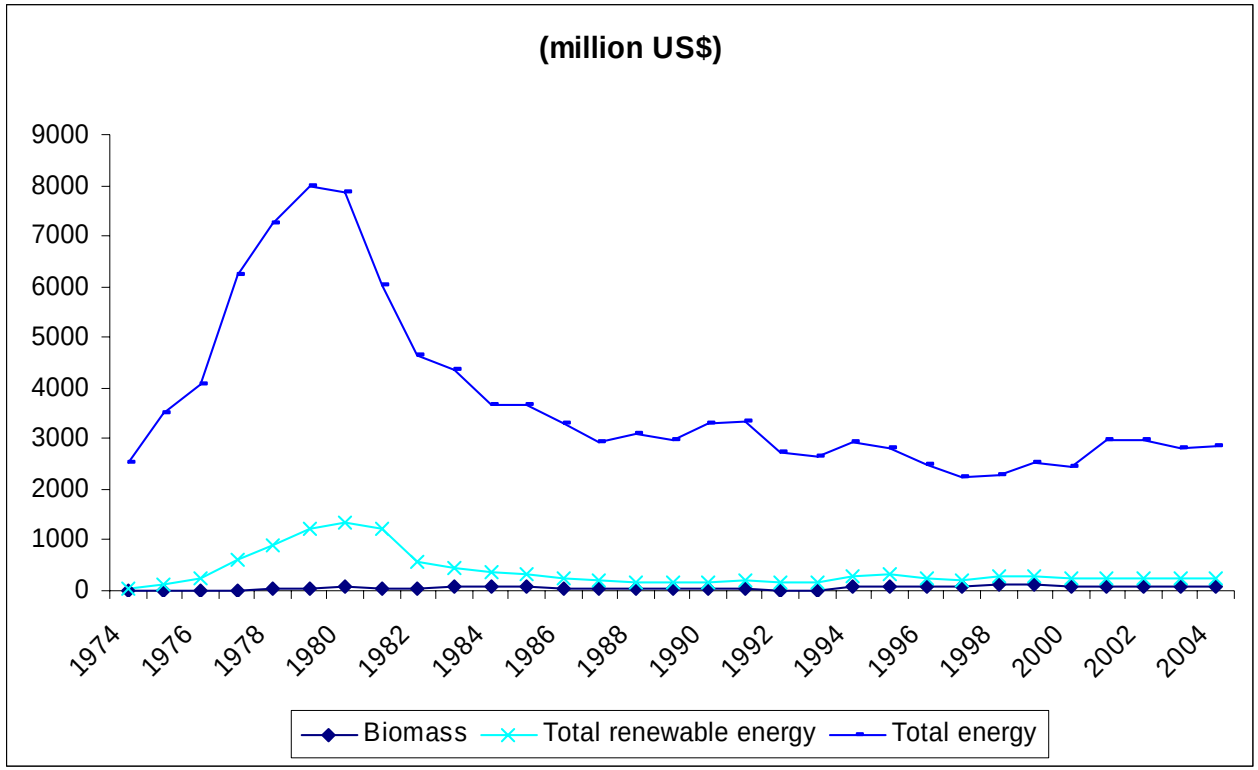
R&D expenditures—Sweden



R&D expenditures—United Kingdom



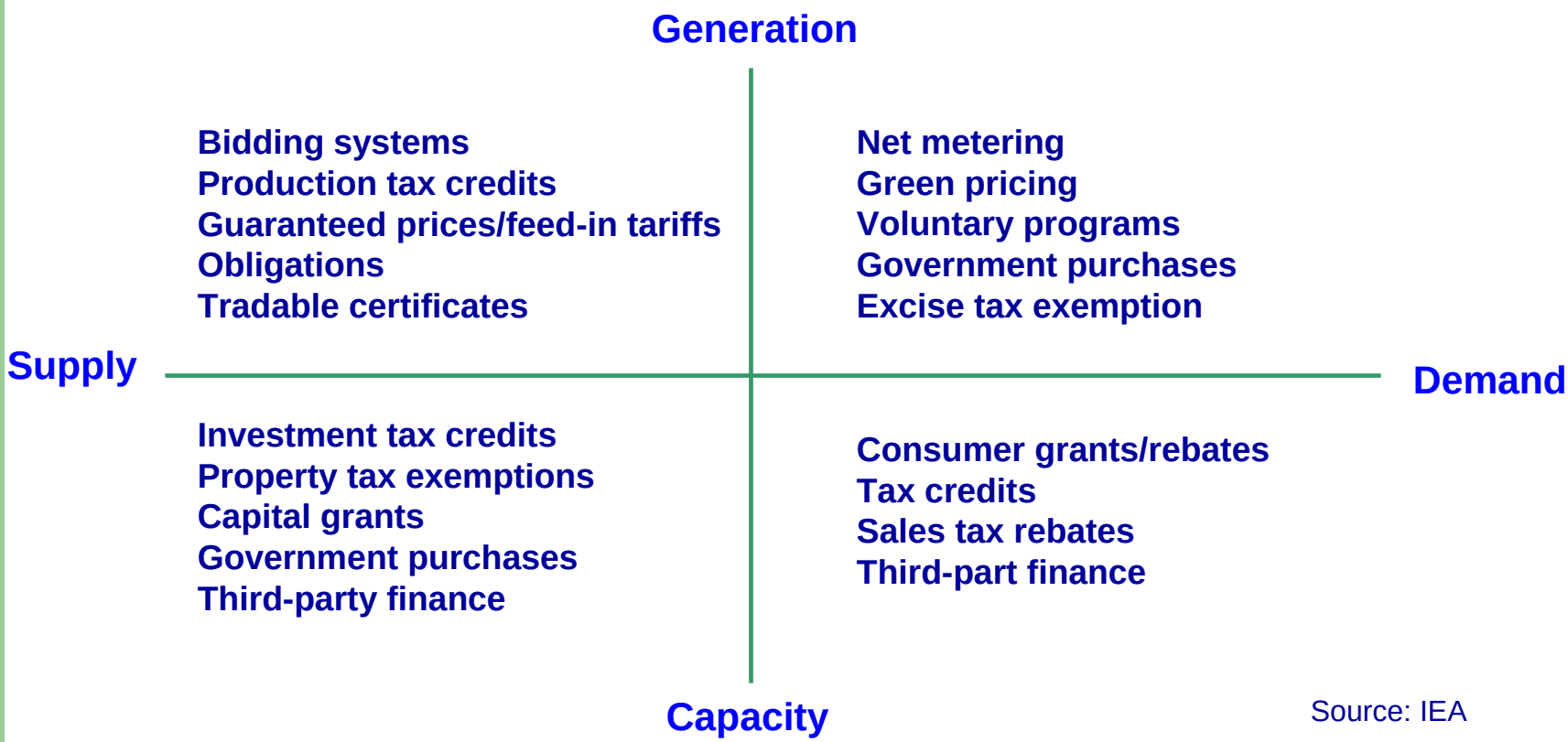
R&D expenditures—United States



IEA classification of renewable energy policies

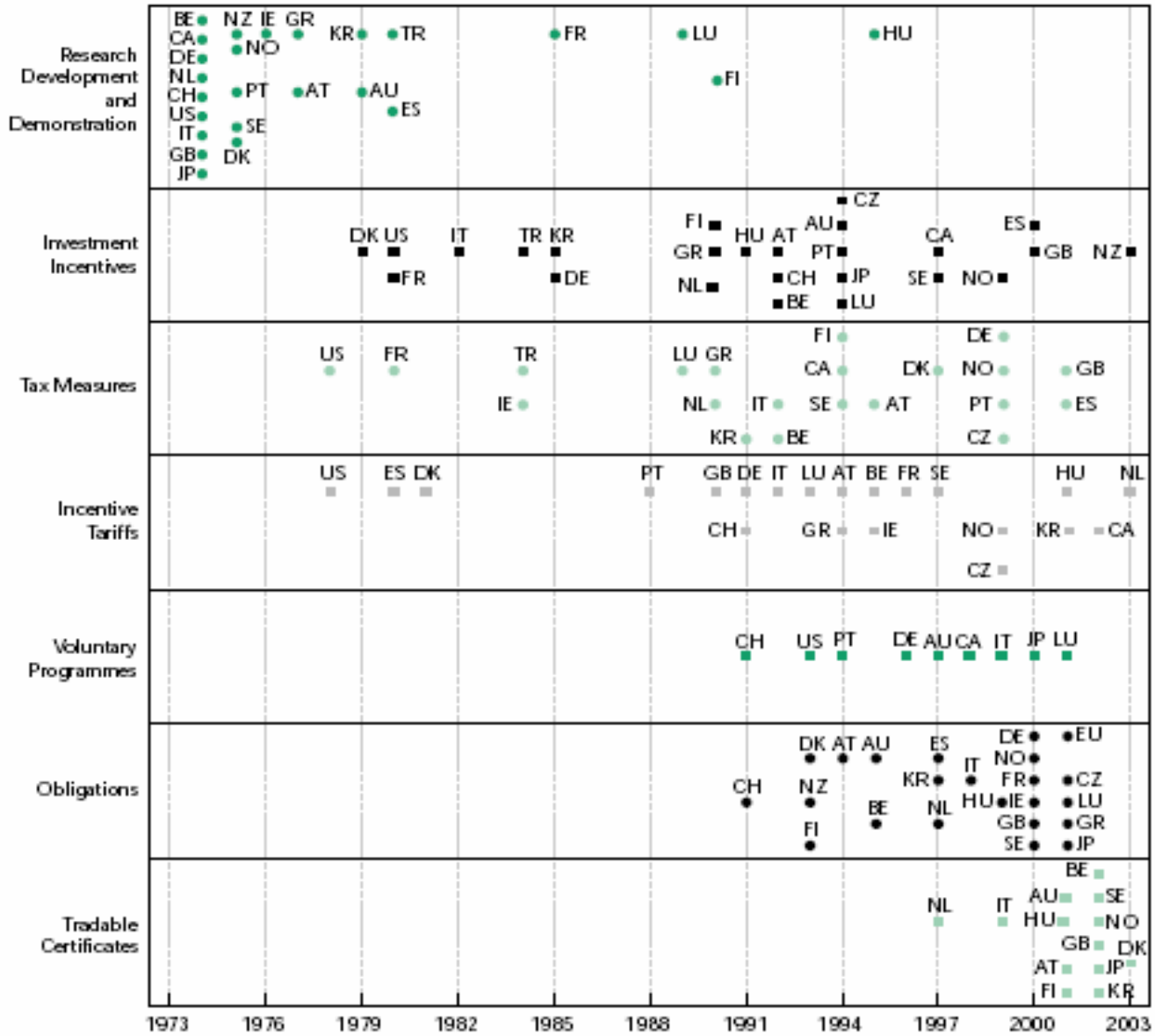
- R&D
- Market deployment
- Energy policy context

Market deployment policies



Source: IEA

Introduction of Renewable Energy Policies by Country



AT=Austria - AU=Australia - BE=Belgium - CA=Canada - CH=Switzerland - CZ=Czech Republic - DE=Germany DK=Denmark - ES=Spain - FI=Finland - FR=France - GB=United Kingdom - GR=Greece - HU=Hungary - IE=Ireland IT=Italy - JP=Japan - KR=Korea, Republic of - LU=Luxembourg - NL=Netherlands - NO=Norway - NZ=New Zealand PT=Portugal - SE=Sweden -TR=Turkey - US=United States.

The method

- **Panel data model**

$$y_{it} = \alpha_i + \gamma_t + \beta' x_{it} + \varepsilon_{it}$$

where
i = 1, 2, …, N;
t = 1, 2, …, T;
y = the dependent variable;
x = a kx1 vector of explanatory variables;
β = a kx1 vector of constants;
α = the individual effect;
γ = the time effect; and
ε = the error term.

Variables and data

- **Variables**
  - **Dependent variable**
    - **Per capita renewable energy or bioenergy supply**
  - **Independent variables**
    - **Policies: R&D, market deployment, and energy policy context**
    - **Energy price (CPI energy, crude oil price)**
    - **Natural resources per capita: Land area, forestland area**
    - **GDP per capita**
    - **Government R&D expenditures per capita**
    - **CO_2 emissions per capita**
- **Data**
  - **Cover the period of 1994-2003 for 26 IEA/OECD countries and were obtained from:**
    - **IEA**
    - **OECD**

Model diagnosis

- **Collinearity**
- **Serial correlation**
- **Heteroscedasticity**
- **Fixed effect vs. random effect**

Annual average renewable energy supply per capita, 1994-2003

Country	TOE	Country	TOE	Country	TOE
Australia	0.355	Greece	0.130	Norway	2.569 (1)
Austria	0.794	Hungary	0.051	Portugal	0.366
Belgium	0.085	Ireland	0.065	Spain	0.178
Canada	1.316 (5)	Italy	0.162	Sweden	1.542 (2)
Czech Rep.	0.077	Japan	0.141	Switzerland	0.662
Denmark	0.385	Korea	0.045	Turkey	0.161
Finland	1.392 (4)	Luxembourg	0.118	UK	0.040
France	0.292	Netherlands	0.082	USA	0.387
Germany	0.121	New Zealand	1.406 (3)	Total	0.497

Annual average bioenergy supply per capita, 1994-2003

Country	TOE	Country	TOE	Country	TOE
Australia	0.277	Greece	0.094	Norway	0.265
Austria	0.353 (3)	Hungary	0.050	Portugal	0.244
Belgium	0.083	Ireland	0.053	Spain	0.104
Canada	0.338 (4)	Italy	0.031	Sweden	0.846 (2)
Czech Rep.	0.051	Japan	0.044	Switzerland	0.145
Denmark	0.325 (5)	Korea	0.035	Turkey	0.108
Finland	1.154 (1)	Luxembourg	0.094	UK	0.032
France	0.190	Netherlands	0.079	USA	0.247
Germany	0.083	New Zealand	0.206	Total	0.213

Regression results of the one-way fixed effect model—Renewable energy

Dependent variable	Pr > |t|	Estimate
Policies for renewable energy R&D	0.1077	-0.01119
Policies for renewable energy market deployment	0.0017	0.01200
Policies for renewable energy under the energy policy context	0.3289	0.00945
CPI--energy	0.3018	-0.00016
GDP, per capita	0.0703	2.81506
CO_2 emissions, per capital	0.9248	0.43134
R&D expenditures on renewables, per capita	0.5972	5.15514

Notes: 1) $R^2 = 0.99$, n=260.

2) Land area was not statistically significant and was removed from the model due to collinearity.

Regression results of the one-way fixed effect model—Bioenergy

Dependent variable	Pr > |t|	Estimate
Polices for bioenergy R&D	0.3651	0.0066
Policies for bioenergy market deployment	0.0926	0.0057
CPI--energy	0.5898	-0.0001
GDP, per capita	<0.0001	3.7093
CO_2 emissions, per capital	0.7959	0.6924
R&D expenditures on bioenergy, per capita	0.3595	9.0319

Notes: 1) $R^2 = 0.98$, n=260.
2) Land and forestland areas were not statistically significant and were removed from the model due to collinearity.

Conclusions

- There are significant differences across IEA/OECD countries in per capita supply of renewable energy and bioenergy.
- Besides the difference across countries, major drivers for renewable energy or bioenergy in OECD countries are market deployment policy and GDP.
- Market deployment policy is the most significant driver for renewable energy; GDP is the most significant driver for bioenergy.

Implications for the development of renewable energy and bioenergy

- **Overall, market deployment policy and GDP matter in the development of renewable energy and bioenergy.**
- **In addition to global (across IEA/OECD countries) drivers, local (country specific) factors also play a role in the development of renewable energy and bioenergy.**

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Thanks

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