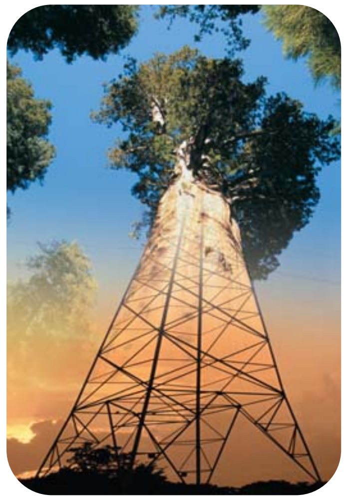

Energy and Sustainable Development

Energy plays a strong role in sustainable development. It contributes to economic activity and higher living standards, but is also costly and the source of considerable environmental degradation.

This series examines six facets – energy security; improving energy efficiency; renewable energy; making markets work; transportation; and environment, health and safety – of sustainable development in the energy sector. It envisages a sustainable energy system as providing ***universal access to adequate supplies (now and for future generations) of affordable, safe and reliable energy produced, distributed and used in a manner that is efficient and environmentally-friendly.***

All countries – developed and developing – will need to design their own policy mix. National circumstances will affect the scope for action and the appropriate policy choices in and between countries.

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INTERNATIONAL ENERGY AGENCY

Renewable Energy

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World Summit on Sustainable Development

Renewable Energy

RENEWABLE ENERGY

Renewable energy sources – solar, wind, biomass, geothermal and hydro – could make important contributions to sustainable development. Currently, their exploitation in commercial markets is low, being constrained by costs and uncompensated benefits (externalities), as well as intermittent supplies and other technical and institutional considerations. But they hold promise for:

- enhanced energy security by providing supplies that are abundant, diverse and indigenous (non-import dependent), with no resource exhaustion constraints;
- reduced global and local atmospheric emissions when used in place of fossil fuels;
- improved options to meet specific user and infrastructure needs, particularly in rural areas and in newly industrialising and developing countries; and
- increased local and regional employment opportunities in energy infrastructure manufacturing, installation and maintenance for developed and developing countries alike.

What are renewable energies

Although the terms **hydro-electricity, solar** and **wind** power can be easily understood, other terms are less common.

Bioenergy covers a wide spectrum of energy activities from direct production of heat through combustion of fuel wood and other biomass residues, to the generation of electricity, and the production of gaseous and liquid fuels and chemicals. It is widely used globally. In developed countries, it usually involves the combustion of biomass residues for heat and electricity. In developing countries, biomass in the form of wood and agricultural residues is often the most common fuel for cooking and heating. In North and South America, the production and use of ethanol in transport is an established and growing option.

The **geothermal** resource is the internal heat of the earth. Its use covers a range of options from power generation to space heating and/or air conditioning. One of the advantages of geothermal energy is that it is viewed as a base-load power, i.e. not faced with the concerns of intermittent supply.

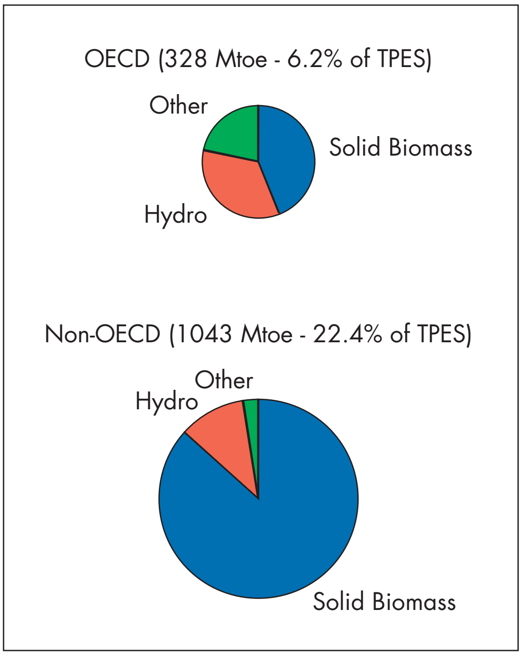
Over the next twenty years economically recoverable renewable resources will increase as a result of cost reductions from technological improvement and expanding markets, and new market valuations (e.g., of carbon emissions). Environmental concerns have increased the attraction of these sources to policy-makers and growth in demand in industrialised countries is leading to economies of scale. Such growth enables increased access by the developing world.

Some renewable technologies are now commercially available and cost-competitive in particular market circumstances, but most are still at an early stage of development and technologically not mature. Their costs remain high, but are continuing to fall. Further reductions are needed for them to compete broadly with the cheapest fossil-fuel alternatives.

SITUATION AND OUTLOOK

In 2000, renewable energy sources provided 1 371 Mtoe, about 13.8 per cent, of the world's primary energy supplies. Biomass (1 048 Mtoe) and hydropower (226 Mtoe) dominated the supply. Rural household bioenergy use was estimated at 510 Mtoe. Non-OECD countries use much more renewable energy than OECD countries; 22.4 per cent of their primary energy demand, compared with 6.2 per cent in the OECD. Renewable energies contribute significantly to the energy mix of many countries.

Figure 1. Total Primary Energy Supply from Renewable Sources, 2000



	World	OECD	Non-OECD
Primary Solid Biomass	76.4%	44.0%	86.6%
Hydro	16.5%	34.4%	10.8%
Geothermal	3.2%	9.0%	1.4%
Municipal Wastes	1.3%	5.5%	< 0.05%
Industrial Wastes	0.8%	2.4%	0.3%
Liquid Biomass	0.8%	1.1%	0.7%
Biogas	0.5%	1.8%	0.1%
Solar Thermal	0.3%	1.0%	0.1%
Wind	0.2%	0.8%	< 0.05%
Tide, Wave and Ocean	< 0.05%	< 0.05%	< 0.05%
Solar Photovoltaic	< 0.05%	< 0.05%	< 0.05%

Source: IEA Statistics.

Production of primary energy from renewable sources is expected to grow rapidly over the next two decades. Nonetheless, their share in the global energy mix will probably remain small in the absence of further cost reductions and determined government interventions. The reference case of the IEA's World Energy Outlook projects that all renewable energy use in developing countries (including hydro and "non-commercial" combustible renewables and waste) will increase by 35 per cent (see Table 1). But their share of total developing country energy demand will decline from 26 per cent in 1997 to 18 per cent in 2020. The global share of renewables in energy use is projected to decline from 14 per cent in 1997 to 12 per cent in 2020. These are baseline projections that could change with the adoption of new policies.

Hydropower met 3 per cent of the world's primary energy needs in 1997 and is currently the world's second largest source of electricity (about 20 per cent of total generation) after coal. The world is expected to be using some 50 per cent more hydroelectricity by 2020. The largest increases are in developing countries, where it is expected to be the fastest-growing renewable energy supply. Growth, particularly in the OECD regions, is limited by the availability of suitable sites and environmental considerations.

Commercial biomass, wind, solar and other non-hydropower renewables are expected to be the fastest growing primary energy source in OECD countries, with an annual growth rate averaging 2.8 per cent over the next two decades. Most of the growth is expected to come from wind and bioenergy, supported by policies and measures to curb greenhouse-gas emissions and to diversify the energy mix. Despite this strong growth, the share of non-hydro renewable energy in the global energy mix will reach only 3 per cent by 2020 because of the current low starting point (2 per cent of world's energy mix).

Table 1. Total Primary Energy Supply of Renewable Energy by Region (Mtoe)

	1997	2020
World	410	697
OECD	286	434
• **Europe**	106	190
• **North America**	150	191
• **Pacific**	30	53
Transition Economies	23	32
Developing Countries	101	231
• **China**	17	56
• **East Asia**	15	49
• **South Asia**	9	20
• **Latin America**	53	91
• **Middle East**	2	4
• **Africa**	6	11

Note: Figures do not include bioenergy in developing countries.
Source: IEA (2000), *World Energy Outlook 2000*, OECD/IEA.

RENEWABLES AND THE ENVIRONMENT

The environmental impacts of renewable energy are site specific, but generalisations are still possible. Renewable energy is usually more environmentally friendly than alternative energy sources, especially with regard to air emissions. The likely life-cycle emissions (taking into account fuel cultivation, harvesting, collection, transportation and processing, as well as power plant construction, operation and decommissioning) from main renewable energy technologies and conventional electricity generation are shown in Tables 2 and 3. The results are purely indicative but show the variations and relative differences between the various fuel inputs. Life-cycle emissions from renewable energy use are small compared with those from fossil fuel plants. The studies upon which the figures are based did not examine nuclear energy. Though nuclear power generation does have a major environmental impact, it releases no sulphur dioxide (SO_2) or nitrogen oxides (NO_x) and little carbon dioxide (CO_2). Its life cycle emissions of these gases falls within the ranges shown for non-hydroelectric renewable energy.

Table 2. Life cycle air emissions from renewable energy (g/kWh)

	Energy Crops		Hydro	Hydro	Solar	Solar	Wind	Geothermal
	Current Practice	Future Practice	Small Scale	Large Scale	Photo-voltaic	Thermal Electric		
CO_2	17-27	15-18	9	3.6-11.6	98-167	26-38	7-9	79
SO_2	0.07-0.16	0.06-0.08	0.03	0.009-0.024	0.20-0.34	0.13-0.27	0.02-0.09	0.02
NO_x	1.1-2.5	0.35-0.51	0.07	0.003-0.006	0.18-0.30	0.06-0.13	0.02-0.06	0.28

Source: IEA (1998), *Benign Energy? The Environmental Implications of Renewables*, OECD/IEA.

Table 3. Life cycle air emissions from conventional electricity generation in the United Kingdom

	Coal		Oil	Gas	Diesel
	Best Practice*	Flue Gas Desulphurisation & Low NO_x	Best Practice	Combined Cycle Gas Turbines	Embedded
CO_2	955.0	987.0	818.0	430.0	772.0
SO_2	11.8	1.5	14.2	–	1.6
NO_x	4.3	2.9	4.0	0.5	12.3

* Not representative of state-of-the-art technology.
ETSU Report No. R-88,"*Full Fuel Cycle Atmospheric Emissions and Global Warming Impacts from UK Electricity Generation*", HMSO, London.

Renewable energy entails a number of other potential environmental impacts. On the negative side, renewable energy can make large tracts of land unusable for competing uses, disrupt marine life, bird life and flora/fauna, and produce visual and noise pollution. Generally though, these potential environmental impacts are site-specific and there are a number of ways to minimise the effects, which are usually small and reversible. There are environmental benefits from renewables other than reduction of greenhouse gas and other air emissions. For example, hydroelectric schemes can improve water supplies and facilitate reclamation of degraded land and habitat.

The use of **bioenergy** can have many environmental benefits if the resource is produced and used in a sustainable way. If the land from which bioenergy is produced is replanted, bioenergy is used sustainably and the carbon released will be recycled into the next generation of growing plants. The extent to which bioenergy can displace net emissions of CO_2, will depend on the efficiency with which it can be produced and used. Bioenergy plants have lower emissions of SO_2 than do coal and oil plants, but they may produce more particulate matter. These emissions are controllable but they increase generating costs.

The environmental and social effects of large-scale **hydropower** are site specific and are the subject of much controversy. Large-scale projects may disturb local ecosystems, reduce biological diversity or modify water quality. They may also cause socio-economic damage by displacing local populations. A number of projects in developing countries have been stalled or scaled down for these reasons; obtaining loans from international lending institutions and banks for major projects has become more difficult. Although these ill effects can be managed and mitigated to some degree, they may affect the future of hydropower in general. Mini- and micro-hydro systems have relatively modest and localised effects on the environment, but their kWh cost is generally higher. Hydro-power emits some greenhouse gases on a life-cycle basis (especially methane generated by decaying bioenergy in reservoirs), but in most cases far less than the burning of fossil fuels.

Geothermal plants may release gaseous emissions into the atmosphere during their operation. These gases are mainly carbon dioxide and hydrogen sulphide with traces of ammonia, hydrogen, nitrogen, methane, radon, and the volatile species of boron, arsenic and mercury. This could slow the future development of geothermal resources. Emissions can be managed through strict regulations and by control methods used by the geothermal industry to meet these regulatory requirements. Hydrogen sulphide abatement systems reduce environmental damage but are costly to install.

Wind-power generation has very low emissions on a life cycle basis, but has a number of environmental effects that may limit its potential. The most important effects on the environment are:

- *Visual effects*: Wind turbines must be in exposed areas and are therefore highly visible. They are considered unsightly by some people, and concerns have increased with the larger size of new generation turbines.
- *Noise*: Wind turbines produce aerodynamic noise, from air passing over the blades and mechanical noise from the moving parts of the turbine, especially the gearbox. Better designs have reduced noise, and research continues. Wind farms developed far from highly populated areas are, by definition, less offensive.
- *Electromagnetic interference*: Wind turbines may scatter electromagnetic signals causing interference to communication systems. Appropriate siting (avoiding military zones or airports) can minimise this impact.
- *Bird safety*: Birds get killed when they collide with the rotating blades of a turbine. Migratory species are at higher risk than resident species. Siting the turbines away from migratory routes reduces the impact.

OVERCOMING BARRIERS TO RENEWABLE ENERGY DEPLOYMENT

Despite some gains in recent years, renewable energy sources make only a modest contribution to the provision of modern energy services world-wide. The principal constraints to their growth are their costs and their unrewarded environmental characteristics (the continuing and exclusive use of production costs to compare energy options without adjustment for environmental externalities). Some renewables have also been hampered by siting concerns and intermittent supply. Moreover, there is a variety of challenges stemming from the inertia in turnover of existing energy infrastructure, the relatively recent development of marketable products based on renewable energy, as well as the costs and difficulties of creating new technical, business and human support structures on a global scale.

Renewable energy is, in most cases, an expensive form of energy compared with fossil-fuel alternatives (Table 4). Wind power is in close competition in locations with good wind conditions and bioenergy can be cost effective in Combined Heat and Power (CHP) applications if the cost of fuel is low.

Table 4. Renewable Energy Cost Assessment

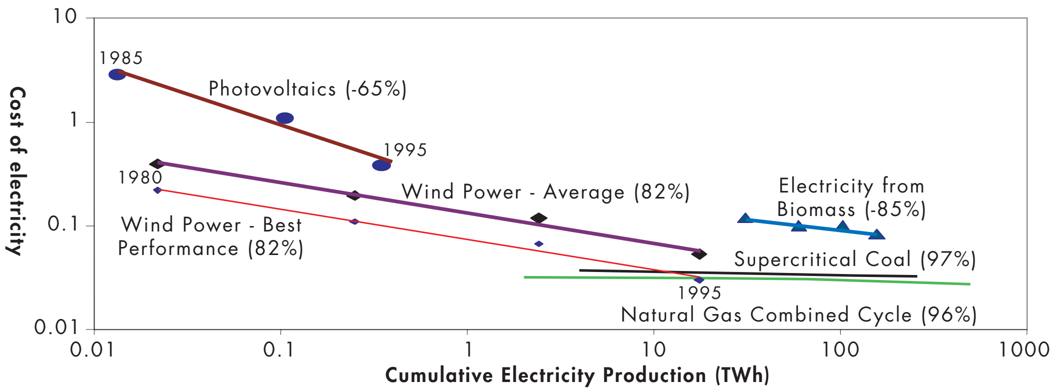
	Current Cost	Cost Reductions by 2020
Bioenergy	High. Cost-effective in CHP applications with low fuel cost. Co-firing is a relatively low-cost retrofit option.	10-15%
Wind onshore	Relatively low; lowest compared to other renewables.	Up to 15-25%
Wind offshore	High.	20-30%
Solar Photovoltaic	Very high. Cost-effective only in niche markets.	30-50%
Solar Thermal	Very high.	30% +
Geothermal	High.	10%
Hydro	Relatively low for large hydro.	10%

Source: IEA (2001), *IEA World Energy Outlook 2001 Insights*, OECD/IEA.
Note: This table presents a quantitative assessment of current costs and the likely average reductions by 2020. Estimates can vary significantly depending on site conditions.

Recent analyses indicate that the costs of electricity generated through renewable sources are a function of the cumulative installed capacity. Thus, if a larger market could be identified, economies of scale could lower prices and accelerate demand. Figure 2 provides an overview of average costs over time for a number of technologies at different stages of development and deployment.

The competitive position of renewable energy vis-à-vis fossil fuels would improve substantially if a market price were attached to carbon dioxide and other air emissions. Figure 3

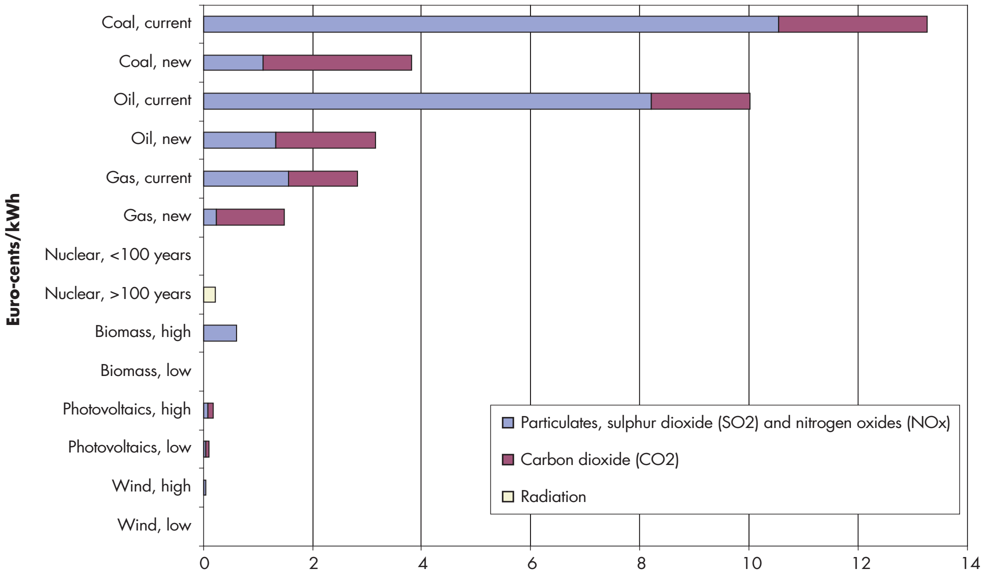
Figure 2. Learning curves for selected electric technologies in the EU (1980-1995)



* ECU 1990/kWh.
Note: Numbers in brackets represent "progress ratios". A figure of 85% means that the price of the technology is reduced to 0.85 of its previous level after a doubling of its cumulative sales.
Source: IEA (2000), *Experience Curves for Energy Technology Policy,* OECD/IEA.

shows that full valuation of CO_2 emissions would raise the price of power generation based on coal, gas and oil by 2.7, 1.2 and 1.8 Euro-cents per kWh, respectively. Similar valuation of particulates, SO_2 and NO_x would add 0.3 to 1.1 Euro-cents per kWh to the cost of new fossil fuel-based power generation.

Figure 3. Comparison of damage costs, for fuel chains in the EU



Notes: "High" and "low" for renewables indicate typical range of estimates. For nuclear, only a single technology is shown (French, with reprocessing), but costs are separated into the period up to 100 years and after 100 years. Production cost of base load electricity in the EU and USA is in the range of 25 to 50 Euro-cents/kWh.
Sources: Rabl, A. and J. Spadaro (2001), "The ExternE Project: Methodology, Objectives And Limitations", in NEA *Externalities and Energy Policy: The Life Cycle Analysis Approach*.

POLICY CONSIDERATIONS

Renewable energy plays a key role in governments' strategies for curbing CO_2 emissions, as well as for enhancing energy security. As such, it will probably continue to be boosted by a variety of government programmes. At present, many programmes focus on reducing renewable energy technology costs via technological and organisational means. Some countries are introducing targets requiring that a certain share of electricity generation be based on renewables. Renewable energy will probably be made still more competitive through policies seeking to internalise the environmental costs and

The Mediterranean Basin Renewable Energy Initiative

The IEA, United Nations Environment Programme (UNEP) and the Italian Ministry of the Environment and Territory are examining a sustainable renewable energy market system for the greater Mediterranean Region. The initiative seeks to remove project, policy and trade barriers and strengthen the market system within the region. The programme is built on three main themes: 1) tailoring of financial instruments and mechanisms to support projects; 2) strengthening of policy frameworks; and 3) building a stronger private sector infrastructure.

other externalities associated with electricity generation, including the establishment of a market value for CO_2 emissions.

The programmes that governments could devise vary according to market situations. There are three primary potential commercial markets for renewables – utility power, distributed markets and rural off-grid markets. Each poses a different competitive challenge.

Table 5. Overview of Measures to Accelerate Renewable Energy

Generic Measures	Utility Power Markets	Distributed Grids	Rural Off-grid
- Enact facilitative electric utility policies and regulation.	- Independent power producer frameworks and power-purchase tariffs. - Regulatory tools like non-fossil fuel obligation (UK), feed laws (Germany and Spain), standards, system benefits funds and renewables portfolio standards (US). - "Green pricing".	- Consumer net metering.	- Rural electrification policies and planning that integrate renewables in serving areas too costly for grid extension. - Regulated off-grid energy-service concessions. - Model village-power schemes (tariffs, contracts, ownership, financing).
- Develop tools and outreach to increase demand and confidence.	- Renewable resource assessments. - Technology cost and performance information.	- Utility distribution planning and analysis tools. - Technology cost and performance information.	- Market surveys of off-grid households to determine affordability, energy-service needs, and current energy consumption.
- Strengthen national systems of innovation.	- Technical assistance to wind turbine producers in developing countries to reduce production costs, increase quality. - Technical assistance to wind farm developers on siting and operating and maintenance.	- Expanded institutional linkages between distribution utilities in developing countries and solar photovoltaic R&D personnel and utilities in OECD countries.	- Development of technical standards and certification institutions for solar home systems in developing countries.
- Increase financing sources and opportunities.	- Develop financial and institutional intermediaries (like IREDA in India) that can finance renewable energy projects. - Outreach to commercial financiers to familiarise them with technologies and increase confidence in investments.	- Consumer financing mechanisms. - Support development of appropriate business models.	- Development of microfinance and/or fee-for-service financing models in rural areas. - Facilitate private sector funds development. .

Source: IEA (2001), *Toward a Sustainable Energy Future*, OECD/IEA.

Utility Power Markets

In many countries, power production from wind, biomass, bagasse, and hydro resources is already, or nearly, commercially competitive with conventional sources for bulk power generation. Central-station solar photovoltaic, solar thermal hybrids with gas turbines, and integrated biomass gasification/gas turbine power plants, are not yet commercial technologies, but show promise.

Substantial experience has already been accumulated, with specific market development mechanisms to promote the expansion of renewable energy in utility power markets. Examples include the Non-Fossil-Fuel Obligation in the United Kingdom, the electricity feed laws in Germany and Spain, and renewable energy portfolio standards that are applied at the state level in the United States.

Besides utility-regulation and power-purchase mechanisms, other categories of policies which encourage renewable projects include:

- carbon taxes (e.g. Sweden);
- emission taxes (in some U.S. states);
- investment tax credits (adopted in India);
- production tax credits;
- wheeling policies for small producers of renewable-energy-based power (adopted in India);
- green labelling/certificates and green power marketing (in the Netherlands and some U.S. states);
- voluntary agreements by utilities to install renewable energy capacity (Japan); and,
- technology testing and certification procedures and institutions.

Distributed Markets

In developed countries, applications of renewables in utility distribution systems are appearing, with generators that range from a few kilowatts to 30 MW. These can be based on solar photovoltaic, biomass technologies and small installations of hydro, wind, geothermal and solar. These applications may involve peak-shaving generation, installations that strengthen the distribution system, building-integrated systems, consumer self-generation, and uses with other non-baseload or seasonal sources.

Policy experience in distributed markets is slowly emerging, primarily in regard to the promotion of early market-learning investments. Experience with "net metering", where a consumer can sell self-generated power back to a utility at the same cost as purchased electricity, is emerging in Japan and the United States. Another emerging policy innovation is the reshaping of traditional utility least-cost planning (which historically has focused on generation costs only), to require a broader optimisation of combined generation, transmission, and distribution costs. This type of utility planning could highlight commercial opportunities for distributed generation based on renewable energy sources.

Several countries, particularly the United States, Japon and Germany are adopting policies that promote "roof top" photovoltaic systems. If used on a large-scale, these applications could displace significant quantities of local fossil-fuel generation particularly during peak periods, thus reducing local air pollution. Employment benefits in the installation and service industries are also expected to be significant. In areas of developing countries with low service availability, distributed generation can offer households, industry and public facilities a more reliable power supply.

Electric power reform will strongly affect the evolution of markets for renewable-energy based distributed generation. Traditional regulation – where rewards are based on the amount of capital equipment owned by the utility or the amount of power produced – will discourage distributed markets and renewable energy use in them.

The rules concerning "unbundling" of generation, transmission and distribution help create fair competition between small producers using renewable energy sources and the new utility entities. It is important that fair rules be incorporated in the process of utility reform; changing the rules "after the fact" will elicit strong resistance from those already operating in the market.

Rural Off-grid Markets

Fixed costs are relatively high for grid extensions to remote communities, where population density and demand is low and concentrated at peak times. Particularly in developing countries, applications of small wind, small hydro, biomass, bagasse, and solar photovoltaic in village mini-grids or for stand-alone household systems are proving commercially competitive with conventional alternatives. Solar photovoltaic home systems can eliminate or reduce the need for candles, kerosene, liquified petroleum gas (LPG), and/or battery charging. Direct economic benefits to rural households include avoiding the cost of battery charging and liquified petroleum gas or kerosene purchases. Other benefits include increased convenience and safety, improved indoor air quality, better light than kerosene lamps provide, and reduced CO_2 emissions. In off-grid rural markets in developing countries, it is not the electricity per se that is valuable, but what it produces: light, heat, cooling or water pumping. Thus a critical concern for the development of a successful large-scale rural renewables deployment programme is its linkage to national rural sustainable development strategies. In this context, grid extension, energy-service concessions and model village power schemes are of particular interest.

Regulated off-grid energy service concessions are one promising way to provide energy services to rural populations without access to electricity. A review of the World Bank's solar home systems project suggests that concession tariff-setting, bidding and regulation require substantial time and resources, and that regulatory models are still being developed.

Policy Instruments in Use

IEA countries are using a variety of measures to enhance renewable use. An illustration of the extent and breadth of these measures is shown in Figure 4 [1]. The number of policies is not an indication of magnitude or effectiveness of actions, numbers are only representative of new policies or modifications to policies taken in 2001; they are not cumulative from earlier years.

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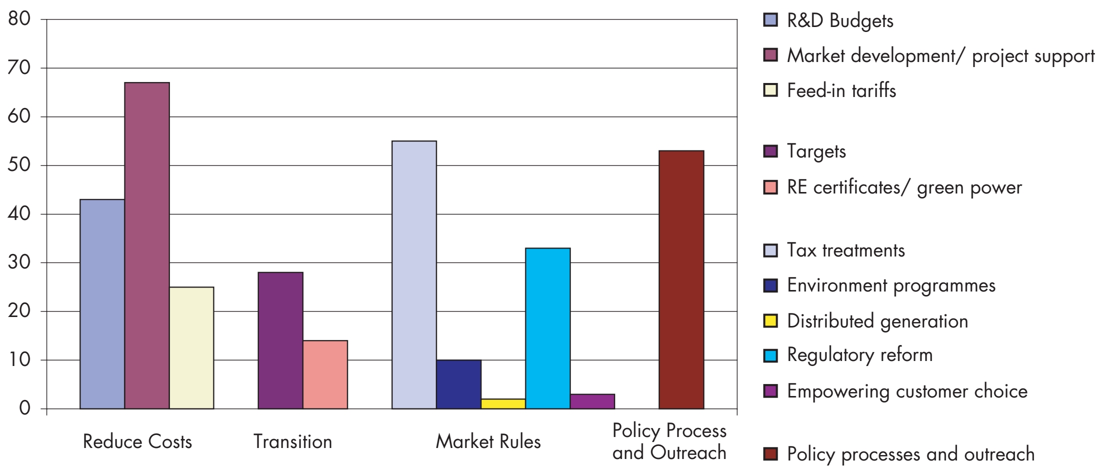
[1] This builds upon data collection efforts under the annual publication *Dealing with Climate Change: Policies and Measures in IEA Countries.*

Figure 4: Number of Renewable Policies Introduced in IEA countries in 2000



The following are some of the main instruments in use:

- *Research and Development*: One of the main goals of research is to find an improved balance between conversion efficiency and material costs, thus reducing total system costs. While publicly funded energy R&D has been decreasing throughout the 1980s and 1990s, renewable energy research has stayed relatively stable.
- *Capital grants* are still a major element of renewable energy policies in IEA countries. There are currently 66 entries in the renewable policies and measure database that relate to public grants for renewable energy development, although information is sparse on actual spending levels [2]. In most cases, this type of instrument is now limited either to very small-scale technologies which cannot directly compete on mainstream markets under current conditions (e.g., PV), or to technologies which are handicapped by high market entry costs.
- *Feed-in Tariffs:* By rewarding energy production instead of investments, feed-in tariffs encourage market deployment while promoting increases in production efficiency. Fourteen IEA countries are applying favourable tariffs for renewable electricity production [3]. Advanced feed-in tariffs, where incentives are reduced over time to reflect technology learning cost reductions, have recently been implemented in France and Germany.

[2] IEA (forthcoming), *Database on Renewable Energy Policy Frameworks in IEA countries*; OECD/IEA.
[3] Ibid.

- *Portfolio Targets*: The European Community has agreed on a directive that sets indicative national targets for renewable energy penetration in EU Member states (EC-wide target of 12 per cent of gross domestic energy consumption by 2010) [4]. The United States is debating a national portfolio target for renewable energy, while 14 US States have already instituted renewable portfolio standards [5].
- *Renewable Energy Certificates*: Tradable Renewable Energy Certificates (TRCs), as a means to achieve Portfolio Targets, are being presented as the future instrument of preference to build renewable markets. They generally include penalties for non-compliance and, sometimes, ceilings on the certificate price. As the use of this mechanism has begun only recently, insights on its effectiveness are limited.
- *CO_2 and other environmental taxes*: Ten IEA countries have implemented taxes to reflect environmental costs based on CO_2 content of energy sources or on electricity consumption [6]. This has resulted in competitive gains for renewable energy projects compared with fossil-fuel projects.

MEMBER GOVERNMENTS OF THE IEA AFFIRM

In light of these considerations, Member governments of the IEA affirm:

- **that renewable energy should play an increasing role in the mix of fuels;**
- **the importance of examining strategies and employing market mechanisms to improve the competitiveness of renewable energies;**
- **that countries should address barriers to renewable energy development, promote technical standards, and reduce regulatory impediments to renewable energy trade and investment.**

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[4] European Commission (27 September 2001), *Electricity Production from Renewable Energy Supply*; Directive 2001/77/EC of the European Parliament and the Council on the promotion of the electricity produced from renewable energy sources in the international electricity market (http://europa.eu.int/comm/energy/en/fa_3_en.html).

[5] *Database of State Incentives for Renewable Energy*; DSIRE, http://www.dsireusa.org/.

[6] However, few of these countries have applied the full CO2 tax on fossil fuel use in electricity generation.