Renewable Energy Markets: Past and Future Trends

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Today, renewable energy sources account for some 13.5% of total global energy supply. Against the backdrop of rapidly rising energy consumption and prices, several scenarios have suggested that renewable energy sources could meet over 20% of energy demand in 2030 and significantly more in 2050. The projected growth in renewable energy markets is based on a competitive environment for all energy sources. Within those projections, three factors affect renewables' cost and market growth: the intensity and availability of the natural energy resource, the maturity of each renewable technology, and the market rules set by governments.

To encourage a larger renewables share, governments are investing in research, development and demonstration (RD&D) and are establishing a range of policies to support market deployment. These investments are underpinning a shift from the first generation of competitive renewable energy technologies, to a second generation. These newer technologies have strong and growing markets, but in just a few countries, and the challenge is to broaden the base of the market to assure continued rapid growth. The key to achieving a high penetration of renewables over the longer term is to foster the development of a third generation of technologies. These technologies are on the horizon, but are not yet receiving sufficient RD&D funding.

In terms of potential business opportunities, if renewable energy technologies succeed in accelerating their market acceptance through technology and market cycles, it is conceivable that they could capture a significant share of the projected $16 trillion of investments for the global energy supply infrastructure over the next three decades (IEA World Energy Investment Outlook 2003).

Renewable Energy Status

At the time of the first oil crisis in 1973, the commercial portfolio of renewable energy technologies included hydropower, electricity from the combustion of biomass, and geothermal heat and power. These technologies entered the market as early as the Industrial Revolution in the late 1800s. Hydropower sprung from an upgrading of water mills, adapting them to drive electric generators. Biomass combustion was an evolution of mankind's longstanding use of fuel wood by improving combustion chambers, enhancing heat recovery, and generating electricity. Geothermal heat and power was an offshoot of mineral mining from volcanic effluent. All these technologies became competitive in locations where the resource was strong, and where there was local demand for their energy. These technologies moved into developing countries as they became competitive, and as industrial demand in those countries developed.

Growth of these three technologies in the late 1970s and early 1980s was largely the result of their improved competitiveness in the aftermath of the oil price crises. Hydropower production in IEA countries increased from 71 Mtoe in 1970 to 91 Mtoe in 1980. Growth in hydropower production, however, slowed considerably in the late 1980s and 1990s. Production actually declined from 1995 to 2001, primarily due to a decrease of 9.7 Mtoe in hydropower production in the United States. Bioenergy supply nearly doubled from 1970 to 1990, but growth also slowed in the 1990s. Growth in geothermal supply also slowed in the 1990s. These more mature renewable technologies have not been a main focus of the policy support that benefited new renewables in the 1990s. Growth in these first generation technologies reached a plateau in IEA countries at about 5% of TPES. While there is some additional potential there, the greatest potential is in those developing countries with abundant resources and growing energy demand.

Table 1. Average Annual Growth Rates of Renewable Energy Sources

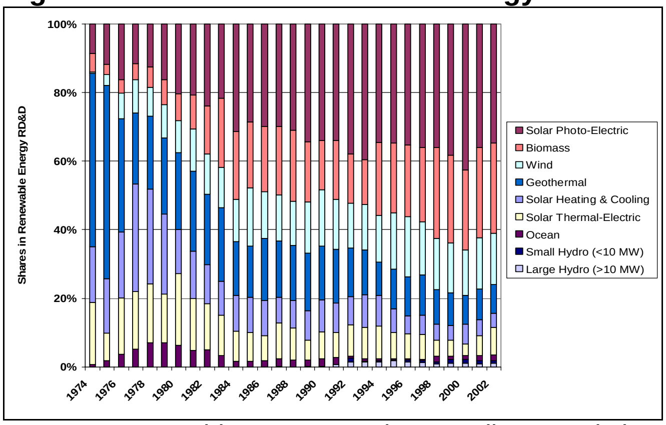
	1970-1980	1980-1990	1990-2001
Renewables	3.2%	2.4%	1.2%
Biomass	3.5%	3.0%	1.6%
Hydro	2.6%	0.7%	0.4%
Geothermal	8.3%	9.4%	0.4%
Wind/Solar	6.4%	23.5%	23.1%

Source: *Renewable Energy Market & Policy Trends in IEA Countries*, IEA 2004

Albeit from a very low base, the second generation of renewables, solar electric, wind power, and some advanced biomass technologies, have grown at impressive rates over the past three decades, by about 23% per year from 1980 to 2001. For some technologies this pace is estimated to have accelerated considerably in the past several years. For example, PV growth in 2004 was over 65%. Despite rapid growth, total production from second generation renewables was only 6.4 Mtoe in 2001, a tiny fraction of the contribution from first generation renewable energy technologies.

Growth in this second generation of technologies is the result of substantial investment by IEA governments in RD&D and support for market deployment policies. As far as we know, there was no RD&D funding for renewable energy technologies prior to 1974. In that first year of funding, geothermal, solar heating & cooling and solar thermal electric accounted for over 80% of renewable energy RD&D, although the total was only about $65 million across all IEA countries. The focus on those technologies remained strong up to about 1978, when a rapid shift in priorities can be seen toward wind, solar PV and advanced forms of bioenergy. By 2002, these second generation technologies accounted for almost 80% of RD&D funding, while the former leaders received the balance.

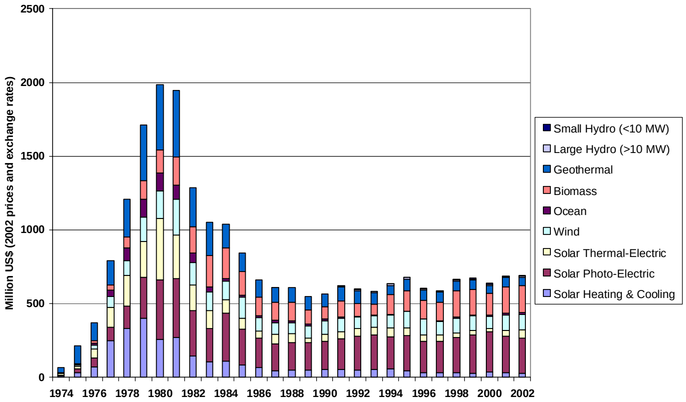
Figure 1. Shares of Renewable Energy Technology RD&D



Source: *Renewable Energy Market & Policy Trends in IEA Countries*, IEA, 2004)

At the same time, the overall level of renewables RD&D funding has been very erratic. From the first year in 1974 at ~$65 million, renewables RD&D peaked at just under $2 billion in 1980, and then collapsed to less than a third of that to ~$600 million in 1987. This follows, but is more extreme than the pattern of total government energy RD&D budgets that increased sharply after the oil price shocks in the 1970s, but then declined to about half of their peak levels by 1987, where they remained relatively stable to 2002.

Figure 2. Renewable Energy Technology RD&D



Source: *Renewable Energy Market & Policy Trends in IEA Countries*, IEA, 2004

As a percentage of total RD&D funding, RD&D funding for renewables was higher from 1974 through 1986 than in the period since 1987. Taken together, renewable energy technologies accounted for just 7.7% of total government energy RD&D funding from 1987 to 2002. The shares of renewable energy technologies out of total energy RD&D funding over the entire period, can be seen in this table. The United States, Japan, and Germany accounted for 70.4% of government renewable energy RD&D funding in the 1974 – 2002 period among IEA countries.

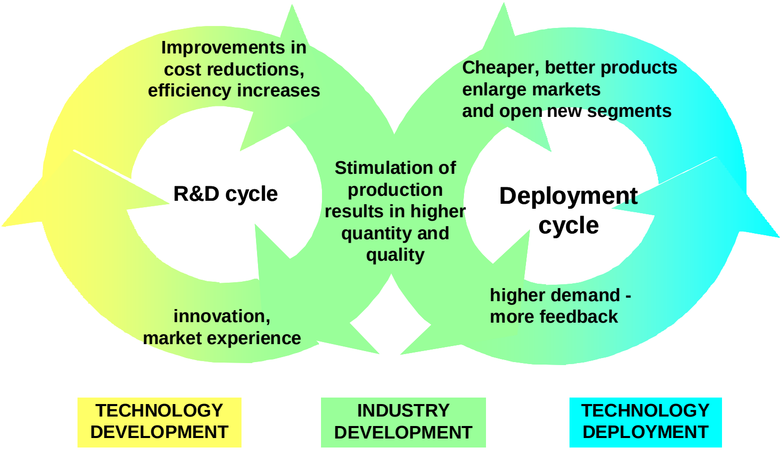
Table 2. Renewable Energy RD&D in IEA countries	
solar photovoltaics	2.7%
geothermal	0.9%
solar heating and cooling	0.7%
biomass	1.6%
wind energy	1.1%
solar thermal electric	0.5%
ocean energy	0.1%
large hydro	0.1%
small hydro	0.04%

Source: *Renewable Energy Market & Policy Trends in IEA Countries*, IEA, 2004

Given public expectations and policy commitments, it is surprising that renewable energy technologies continue to be funded at a low level relative to nuclear and fossil energy. This picture is even more disturbing, if we consider that overall RD&D expenditure in the energy sector is extremely low. In the US, as a typical example, 0.5% of revenue in the electricity sector is devoted to RD&D, compared to 3.3% in the car industry, 8% in electronics and 15% in pharmaceuticals.

To complement the investments in RD&D, governments are also encouraging technology development through support for deployment of technologies into the market. These deployment supports are intended to ensure that technology costs will continue to decline as a result of “market learning.” Because renewable technologies in most cases do not have fuel costs, and virtually all their costs are associated with the manufactured equipment, learning that results from early deployment experience is a necessary step in commercialization and to reduce costs. In principal, market learning provides a complementary feedback loop to manufacturers as they refine products, and each technology exhibits a unique "learning ratio" (i.e. the percent decrease in cost for each doubling of installed capacity). For example, PV exhibits a learning ratio of about 20%, while wind exhibits a learning rate of ~10%. Schematically, the relationship between laboratory R&D and market learning can be seen in the graphic.

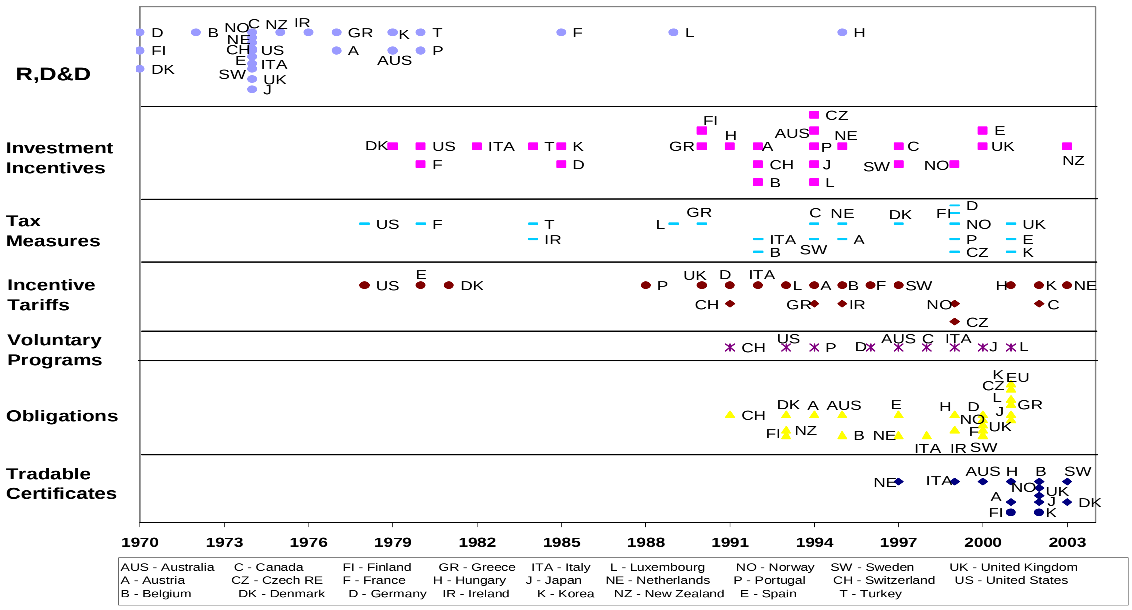
Figure 3. Virtuous Cycle in a Supportive Policy Environment



Source: NET Ltd. Switzerland based IEA/OECD 2000

Policy instruments for deployment support vary considerably from country to country, and can be categorised into four quadrants, based on the direction of their support. Policies can be directed towards consumers (demand-side) to lower purchase prices, or producers (supply-side) to lower costs of sold products. They can also be directed towards capacity (*i.e.,* the facility and/or its capital costs) or generation (*i.e.*, the product and/or the associated price to the customer). In some cases, the same policy can appear in more than one quadrant.

Figure 4. Market Deployment Policies



Source: *Renewable Energy Market & Policy Trends in IEA Countries*, IEA 2004

Deployment policies have been used by many countries, but for wind and solar PV their greatest effect has been in only a handful of countries. Perhaps the following two case studies can best illustrate what has been achieved, and what remains to be done, to bring the second generation of renewable technologies fully into the market.

Market and Policy Trends: Wind

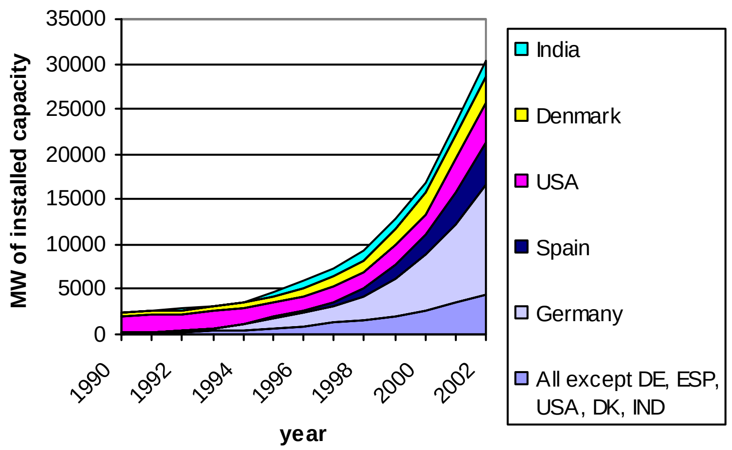
The commercial development of grid-connected wind generators started after the oil price crises in the 1970s, building from mechanical wind machines used for water pumping. In the early 1980s, most commercial wind turbines were assembled using standard components. Only blades and control systems were specially tailored for the wind turbine industry. With increased market volume, more specialised suppliers, including larger companies, are providing tailored components.

As the costs of wind turbines have steadily declined, technical reliability has increased and the last decade has seen an explosive growth in the development of wind power. In 1990, IEA countries had 2 395 MW of installed wind power capacity and by 2001 it had expanded to 21 707 MW, a 22.2% annual average growth rate. While a number of IEA countries have significant potential based on wind resource assessments, wind deployment is highly uneven around the world. Growth in installed capacity has been particularly notable since the mid-1990s, reflecting technical improvements and turbine size up-scaling as a result of research and development, market deployment policies and measures and the growth of the infrastructure necessary to support development, *e.g.*, manufacturers, installers and operators.

On average, wind power supplied less than one-half of one percent of electricity supply in IEA countries in 2001. Only in Denmark does wind power provide a notable share of electricity supply at 11.4%, though the contribution has been increasing in recent years in local regions in Germany and Spain.

There appears to be a strong link between RD&D in wind power technology and the development of markets and a supporting industry. In Denmark, Germany and the United States, for example, significant fund for RD&D were invested in the years preceding rapid market growth. RD&D investments in 1987-2001 by the seven countries with the most significant markets were 85% of the total invested in wind by all IEA countries, and represent 94% of the installed capacity in IEA countries.

Figure 5. Wind Power Comparison of Top 5 – Rest of World



Sources: IEA, WindPowerIndia, Innovation Norway, Windicator, EFChina

The global installed capacity of wind energy technology at the end of 2002 was more than 30 GW. Over 80% of all wind capacity is installed in only five countries: Germany, Spain, the US, Denmark, and India. In fact, over 80% of all wind capacity has been in just these five countries since about 1993, indicating a serious challenge for the wind industry: to achieve sustainable, commercial markets, wind technology must gain a strong foothold in a much wider range of countries. To become a global industry, wind must first achieve an international market, while today it is really the sum of five individual, independent national markets.

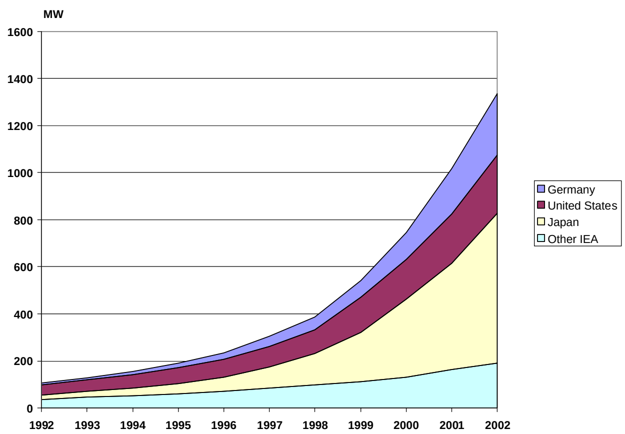
As the best onshore locations are becoming more difficult to develop in several areas, coastal countries are beginning to exploit near-shore and offshore wind power resources, for example in Denmark, the Netherlands, Sweden and the United Kingdom. New installations totalling several GW are planned for Germany, the United Kingdom, Ireland, Denmark, Canada, Belgium and other countries in coming years, suggesting that the transition to an international market is beginning.

Market and Policy Trends: Photovoltaics

Solar PV technology was used primarily for satellites through the 1950s and into the 1960s. The price of PV technology dropped in the 1970s and 1980s allowing the technology to be increasingly used in remote areas where re-fueling a generator, recharging a battery or running a connection to the utility grid was prohibitively expensive. Grid-connected PV generated electricity has seen rapid growth since the late 1990s.

Solar PV experienced an annual average growth rate of 29% between 1992 and 2001 in IEA countries. Installed capacity was 101 MW in 1992, with the United States containing the majority of at 44 MW, Japan had 19 MW, Italy 8 MW, Australia 7 MW and Germany 6 MW. Japan, Germany and the United States accounted for 85% of total installed capacity of about 1 000 MW in 2001.

Figure 6: Solar PV - Installed Capacity in IEA Countries



Source: IEA

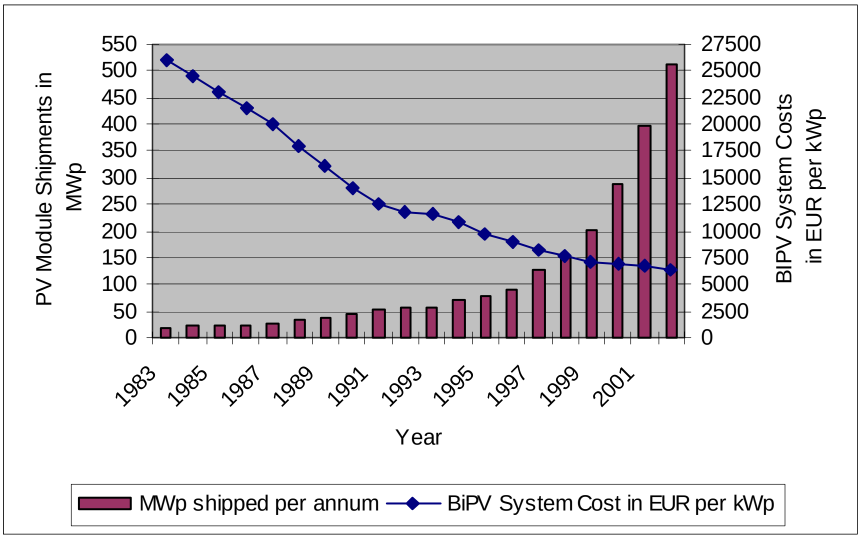
In 2002, Japan, Germany and the United States accounted for 92% of new installations.

- Japan reached 637 MW, *i.e.*, 48% of total installed capacity in 2002 up from 17% in 1992. Average annual growth over the period 1998-2002 was 48%.
- Germany reached 277 MW, *i.e.*, 21% of total installed capacity in 2002 up from 5% in 1992. Average annual growth over the period 1998-2002 was 52%.

▪ The US reached 212 MW, *i.e.*, 16% of total installed capacity in 2002 compared with 40% in 1992. Average annual growth over the period 1998-2002 was 21%.

In 1990, PV was used mainly in stand-alone systems for rural electrification and small-scale applications. Since then, the number of grid-connected systems has increased significantly. Europe and Japan have the largest number of distributed grid-connected PV systems, mostly building-integrated (BiPV). The market share of distributed grid-connected PV installations has been growing steadily and reached 63% of cumulative capacity installed in countries collaborating in the IEA's Photovoltaic Power Systems Implementing Agreement by the end of 2001.

Figure 7. Annual World PV Module Production and Building-integrated PV System Costs, 1983-2003



Source: NET Ltd. Switzerland; PV News, February 2002

Facilitating International Markets

To continue rapid growth, second generation renewable energy markets need to expand globally, just as the first did many years ago. Strategic deployment in one country not only reduces technology costs for users there, but also in other countries. The greater the number of countries that contribute to lowering costs and improving performance of renewable energy technologies, the greater the overall benefit.

The objective is to achieve market coherence. Harmonization of policy instruments is not required, and perhaps not even desirable, since each country will have different technology preferences based on available natural resources, existing domestic industries and differences in national strategies. However, the underpinning of the market (standards, codes, interconnection rules, environmental regulations, permitting, import duties, etc.) must be consistent and supportive. If there were greater international coordination of deployment strategies, overall costs of deployment programs and technology development could be reduced and greater economies of scale achieved.

The benefits from research and development not only 'spill over' between companies but also between countries. This might induce national governments to free-ride on foreign research and development efforts, but this sharing of experience will just further the objective of large-scale deployment of renewable energy technologies. The benefits are a multiple of the costs of the learning investment. It can still be advantageous for individual countries to finance learning investment, even if they only capture a fraction of the global benefits.

A number of functional agreements would support the globalisation of renewable energy markets. For example, internationally accepted standards for power performance, safety, noise and other environment-related conditions could be developed. Administrative and installation costs could also be harmonised. New locations, especially offshore and non-surveyed terrain, could be mapped and assessed to reduce the visual impact on sensitive populations. Trade barriers, especially protectionist import tariffs, could be eliminated or reduced.

Patterns of Future Markets

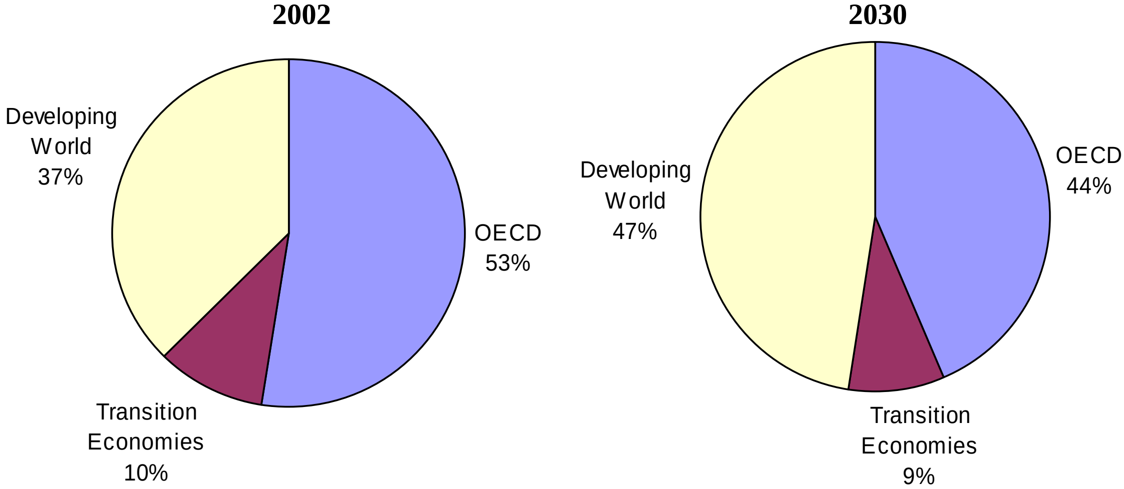
First generation renewable technologies were developed in industrialized countries, and taken up by developing countries on economically competitive terms. This will in many cases be similar for the second generation of technologies that are now emerging into competitive markets. This is leading toward a larger share for renewables as second generation markets build on the base established by the first, as wind, solar and advanced biomass technologies succeed in establishing ever-larger footholds in the market.

The IEA's World Energy Model analyses the possible evolution of energy markets to 2030, generating detailed regional and sector-specific projections for two scenarios, the Reference Scenario and the World Alternative Policy Scenario. The primary objective is to identify and quantify the key factors that are likely to affect energy supply and demand. The Reference Scenario projections offers a baseline vision of how the global energy system will evolve if governments take no further action to affect its evolution beyond that which they have already committed themselves to, taking into account only those government polices and measures that were already enacted – though not necessarily implemented – as of mid-2004.

The World Alternative Policy Scenario depicts a more efficient and more environment-friendly energy future. The Alternative Scenario analyses how the global energy market could evolve were countries around the world to adopt a set of policies and measures that they are either currently considering or that they might reasonably be expected to implement over the projection period. For each major region, the Alternative Scenario considers policies and measures to reduce air pollution and greenhouse-gas emissions, and to enhance energy security. Measures to improve energy efficiency and increase the use of renewables are among the main instruments.

In the Alternative Scenario, global primary energy demand in 2030 reaches 14 654 Mtoe ~10% less than in the Reference Scenario (Figure 10) Energy demand is projected to grow by 1.3% per year, 0.4 percentage points less than in the Reference Scenario. Although energy demand is less in the Alternative Scenario compared to the Reference Scenario, regional similarities prevail. Developing countries will continue to constitute the majority of the increase in energy demand, totaling over 70% of the increase between 2002 and 2030. OECD countries account for 23% and the transition economies for the remaining 6%. The current 52% share of the OECD in world demand will decline to 44% in 2030, while that of the developing countries will increase, from 37% to 47% (Figure 8). The transition economies' share will fall from 10% to 9%. The increase in the share of the developing regions in world energy demand results from their more rapid economic and population growth. Developing countries, China, India and Brazil all exhibit average annual growth rates of at least 2% or more, between 2002 and 2030, where as annual growth rates for the OECD, Transition Economies and Russia all fall under 1% per annum.

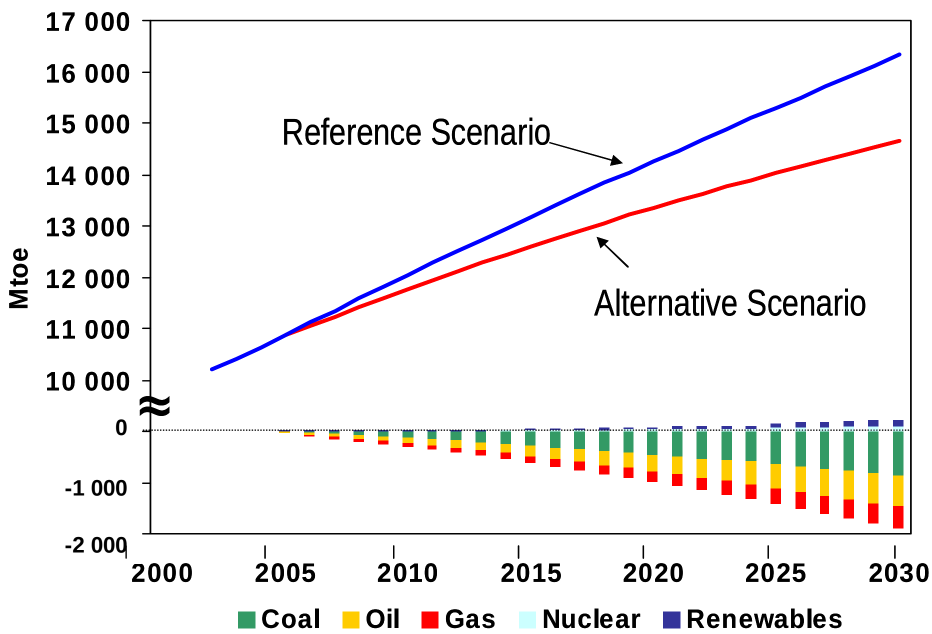
Figure 9. Shares of Global Energy Supply



Source: *World Energy Outlook 2004*, IEA 2004

In global energy demand, fossil fuels contribute 14% less in the Alternative Scenario than the Reference Scenario, although they still account for 78% of energy demand in 2030. On the other hand, the use of non-hydro renewables, excluding biomass, increases strongly. In 2030, their use is 30% higher than in the Reference Scenario.

Figure 10. World Primary Energy Demand in Reference & Alternative Scenarios

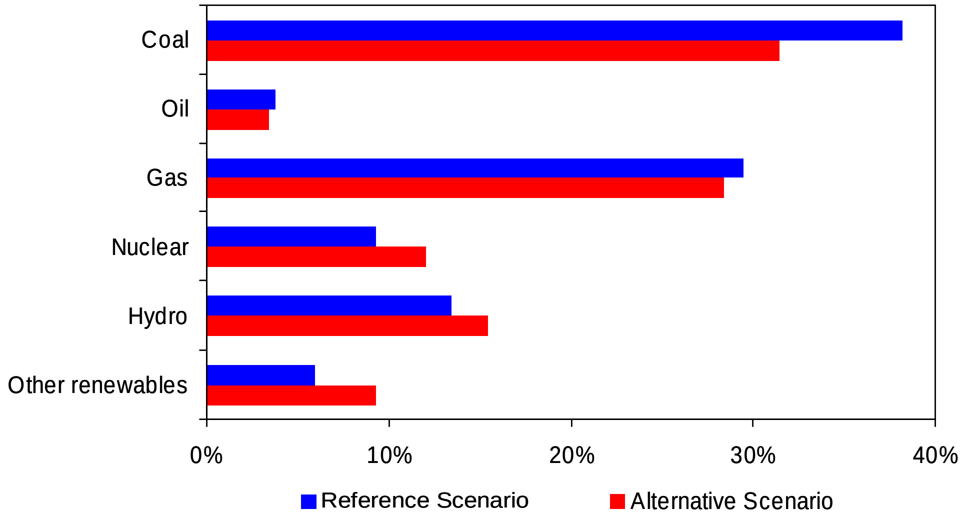


Source: *World Energy Outlook 2004*, IEA 2004

By 2030, global consumption of biomass is 43 Mtoe higher in the Alternative Scenario than in the Reference Scenario. This occurs due to more efficient use of biomass in industrial processes and in household cook-stoves. Government incentives foster increased use of biomass in the power sector and in transportation, mainly in OECD countries. Consumption of other renewables increases even more, adding 75 Mtoe in 2030 – a 30% increase over the Reference Scenario. Power generation drives most of this increase, but solar water heaters and geothermal energy also contribute.

In the Alternative Scenario, world electricity generation in 2030 is 13% lower than in the Reference Scenario. The reduction comes from end-use efficiency improvements, reduced losses in transmission and distribution and greater use of distributed generation. The power-generation fuel mix is considerably different. In the Reference Scenario, fossil fuels account for 70% of electricity generation in 2030. In the Alternative Scenario, the share of fossil fuels falls to 61%, while the shares of carbon-free fuels rise substantially.

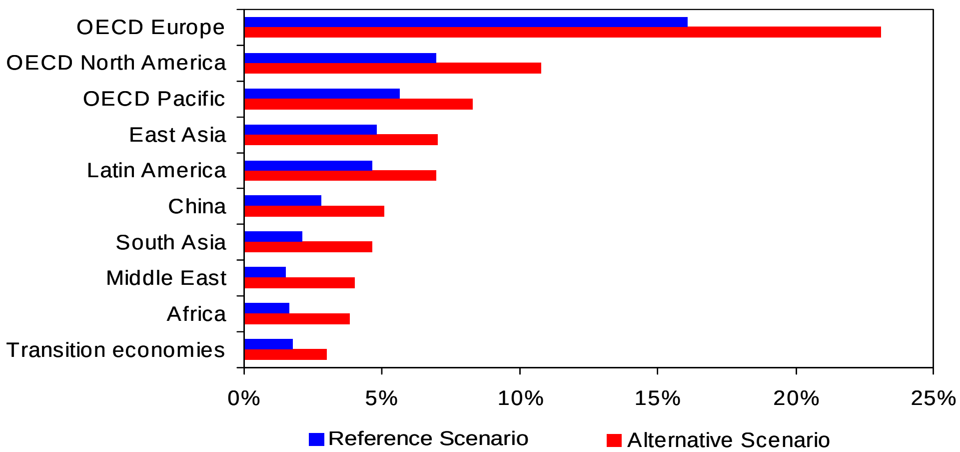
Figure 11. Fuel Shares in Electricity Generation in the WEO Scenarios, 2030



Source: *World Energy Outlook 2004*, IEA 2004

Hydroelectric generation in 2030 is slightly higher in the Alternative Scenario than the Reference Scenario. In the Reference Scenario, hydropower's share in world generation drops from 16% in 2002 to 13% in 2030. In the Alternative Scenario, its share falls only by one percentage point, to 15%. The shares of non-hydro renewables increase much more, from an aggregate 6% in 2030 in the Reference Scenario to 9% in the Alternative Scenario. The strongest increase is in OECD Europe, driven by the European Union's strong support for renewables (Figure 12). Electricity generation using non-hydro renewables is almost ten times higher in 2030 in the Alternative Scenario than in 2002.

Figure 12. Share of Non-Hydro Renewables in Electricity Generation in the Reference and Alternative Scenarios by Region, 2030



Source: *World Energy Outlook 2004*, IEA 2004

Investment Implications

Based on the WEO model, the investment needed to meet the projected increase in global energy supply is estimated at $16 trillion dollars for the period 2002-2030, an average of $568 billion per year. Although this number does not change between the Reference and Alternative Scenarios, the pattern of energy investment is altered by the change in supply and demand. In summary, larger capital needs on the demand side are entirely offset by lower needs on the supply side. More investment will be needed in end-use equipment; the capital intensity of new power generation will be greater; and research and development on all energy technologies will have to increase.

The Renewable Energy Unit (REU) has estimated the investment cost associated with the addition of renewable energy capacity in 2003 and projected costs for 2030. Investment costs are estimated to increase by almost four times, from approximately $70 billion to over $250 billion.

Table 3: Renewable Energy Investments 2003 / 2030

	2003 investment for added capacity in 2003	**2030 investment for added capacity in 2030**
Wind	$8,910,000,000.00	$64,070,922,918.11
Solar PV	$4,070,000,000.00	$30,830,980,601.50
Solar Thermal	$5,023,714,674.38	$48,409,584,528.32
Solar Thermal Electric		$10,837,569,634.70
Biomass electricity	$2,562,500,000.00	$12,934,432,077.63
Biomass Heat	$2,142,000,000.00	$2,679,881,549.26
Gas from Biomass	$89,861,633.60	$914,226,622.50
Liquid Biofuels	$1,599,586,560.00	$8,678,229,055.04
Liquid Biofuels (biodiesel)	$284,803,200.00	$16,198,832,074.98
Geothermal	$157,700,000.00	$5,182,008,859.72
Hydropower Total		$50,280,151,648.44
Large Hydro	$34,691,666,666.67	
Small Hydro	$10,833,333,333.33	
Total	**$70,365,166,067.98**	**$251,016,819,570.21**

Source: IEA

As outlined above, IEA member countries currently take the lead in these investments. For the second generation of technologies to grow, however, developing countries will have to become part of the global market. Countries like China, India and many other Asian and African countries have excellent resource availability and thus could fulfill this function. For example, projections from the IEA's World Energy Outlook suggest that it is economic for developing countries to install up to 90GW of wind and 25GW of Solar PV in the period until 2030. This would equate to an investment of about $185 billion for the 2005-2030 time period. However, while natural resources are regularly in place for such technologies in developing countries, finance often has to be secured through foreign direct investment (FDI). International lending institutions such as the World Bank play a central role in energy investments in developing countries.

The World Bank has invested over $40 billion in energy projects in the period 1990-2003. However, out of this sum, only $1.3 billion was invested in renewable energy related projects, a 3.25% share of total energy investments. The World Bank vowed at the 2004 Renewable Energy Conference in Bonn, Germany, to achieve a 20% average annual growth in the

Bank's renewable energy and energy efficiency commitments over the 5 years following the conference, which would imply $200 million in additional funds for renewable energies. Whether this is sufficient to truly underpin a globalizing market for renewable energy technologies is unlikely, given the scale of investment projected. The US, being the largest shareholder in the World Bank, can significantly influence World Bank policy.

Trade Implications

An oft-repeated fact in technological development is that developed countries are the technology innovators. With their ability to underwrite sophisticated R&D and adapt innovation from one sector to another, they lead the way in the development of new technologies. However, energy demand is projected to increase substantially more in emerging-market and developing countries. Thus, renewable energy markets could flourish in less developed countries, as well. Furthermore, with the low cost of labor and materials in less developed countries, technology manufacturing is likely to expand in those countries, a trend that has been observed in many technologies before. International trade in renewable energy technologies - both in the actual hardware and the intellectual property which underpins the technology - is thus likely to emerge as a key issue in the development of a global industry. This will be described in the examples below.

<u>Wind Energy</u>

The importance of international trade of technology, services and intellectual property between highly-industrialized countries and emerging market countries can already be witnessed in the case of wind power. The IEA's REU has undertaken some analysis on the share of international trade in the global wind power market. This has been limited to a survey of wind turbine manufacturers, but it is highly likely that along the supply-chain significant amount of technology transfer and trade is occurring in areas such as tower and blade manufacturing and site services such as resource assessment, site surveying and project development. This is despite the fact that developers had to adapt turbines to local market conditions which added costs. There are no universal grid code standards, so wind turbines must fulfill different requirements in each market.

It is estimated that about one-third of global installed wind capacity is the result of international trade, i.e. the import and export of wind turbines and related services. Markets with high installed capacity figures, such as Germany, Spain and Denmark, typically have high shares of domestic supply. These countries were also the first movers in the emerging wind market in the 1990s, designing consistent market deployment policies which allowed a domestic supply chain to emerge and grow. From these niche markets, some of the companies expanded rapidly and are now dominating the world market for wind turbines. In the US, GE Energy has become one of the world leading companies in the wind turbine markets.

The cumulative volume of traded wind turbines is almost 16 GW, which represents about $17.6bn market at today's prices. In the future, trade in wind energy equipment is likely to centre around two issues: trade in intellectual property - the high-tech components that make up wind turbines, such as nacelles and blades - and trade in the actual hardware.

Given the weight and volume of the equipment necessary to build wind turbines there will always be an element of regional and local manufacturing of wind turbines, especially where transport infrastructure is less developed. In this case technology transfer, the use of intellectual property from the world's leading wind turbine manufacturers will be central to access regional markets. Furthermore, the capital intensity of manufacturing will also mean that not every country in every region will host manufacturing bases for wind turbines. A trend, that is already emerging today, is for regional suppliers establishing their plants strategically to cover their key markets, optimizing the balance between distance to markets and access to know-how.

The European market is served to a significant extent from suppliers in the first-mover countries Denmark, Germany and Spain. The Asian market currently sees China, India and Australia emerging as bases for wind equipment manufacturing. In North America, Canada and the USA both seek to attract investment but Mexico seems likely to become a serious contender as the North American market grows.

The WEO Alternative Policy Scenario expects 436 GW of installed wind capacity for on- and offshore turbines in 2030. This suggests a global annual growth rate averaging about 10% for the next 25 years as the rate slows due to increasing market maturity. Capacity additions will be largest in OECD Europe and OECD North America, but the highest growth rates can be found in the emerging markets in China, India and Latin America, as well as the transition economies of Eastern Europe and Russia. Currently, there are few domestic suppliers in these countries, with the exception of Suzlon in India and Goldwind in China, so there exist significant opportunities for technology transfer and trade. These markets are expected to grow to over 100GW or just over $100 billion up to 2030. Today, about 90% of installed wind capacity in China, and about 50% of wind turbines in India are the direct result of imported wind turbines and trade in intellectual property manufacturing under license.

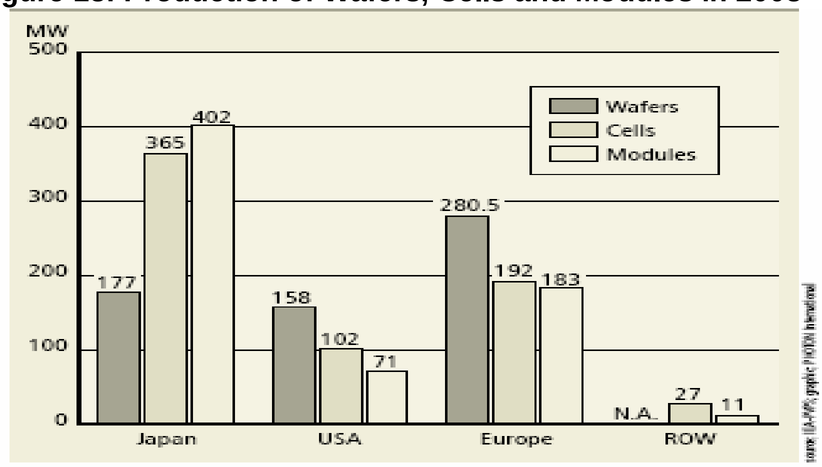
Growth in installed capacity in North and South America is projected to reach 122GW in 2030, where 90% will take place in the USA and Canada. The US market could significantly benefit from cost reductions, which can be achieved through lower cost manufacturing for example in Mexico, while benefiting from the trade in intellectual property of wind technology.

Solar PV

The market for Solar PV is currently heavily concentrated in three regions: Japan, Europe (especially Germany and Spain), and the USA. Together they cover about 90% of global PV cell production. But again, international trade is an important dimension in this market, both for intellectual property and hardware components.

Figure XXX below shows the production figures for wafers, cells and modules. Due to supply shortages and differences in specialization and know-how, wafer production (out of which PV cells are formed) outstrips demand in both Europe and the US, while Japan has to import more than half its requirements.

Figure 13: Production of Wafers, Cells and Modules in 2003



Conversely, installation of PV cells is currently booming in Germany, which took nearly 600 MW or half of the global 2004 PV cell production due to a favorable deployment environment. This meant that Germany had to import nearly two thirds of its need for PV cells in that year.

In the future, the IEA WEO 2004 Alternative Policy Scenario projects significant growth of solar PV installations, at an annual average of at least 15% at a global level until 2030. Growth will continue strongly in Japan, North American and Europe, which are each forecast to reach about 30GW of installed capacity in 2030.

Most of the patents for today's solar PV technologies are concentrated in the US, Japan and Europe. Furthermore, the solar PV industry has not yet converged on one dominant technology or design that everyone agrees on to lead the market in the future. New technologies are constantly emerging, including thin-film and nanotechnology. This is underpinned by significant research and venture capital funding in the above-named regions. These RD&D and investment efforts are likely to underpin technological leadership in this area for the next decades. However, once these technologies mature and are produced at larger scales, standardized manufacturing in countries with a lower cost base and international trade will be an essential element to push the unit costs of these technologies towards further market competitiveness. Unlike wind turbines, PV modules and associated components are lower-weight and lower-volume per value-added, which makes them easily tradable.

Furthermore, international trade appears not only significant for a growing domestic market, but will also underpin strong growth in South- and South-East Asia and Africa, which the IEA projects to have 25GW of solar PV installed in 2030. Trade in the technological know-how will secure market positions in these emerging markets while also expand the low-cost manufacturing base for the industry in general.

Solar Thermal

The solar thermal market is expected to constitute nearly 20% of the total investment cost projected to be spent in 2030 for additional installed capacity or almost $50 billion. Currently, the market is concentrated in areas where the demand exists. Solar hot water systems are a mature and reliable technology. Water collectors are used primarily for hot water in a domestic setting, although a small fraction is starting to be used for space heating and cooling as well.

Typical solar collectors collect the sun's energy and act as miniature greenhouses, trapping heat under their glass plates. Solar collectors can be made in various sizes and constructions and normally provide enough hot water for washing, showers and cooking. They can also be used to supplement or replace existing water heaters. The technology is considered mature and reliable, thus although technological advances in collectors are continually being made, it is not at a level comparable to that of solar PV. The solar heating technology is also considered relatively low cost and less sophisticated technologically, requiring more modest investment per watt of installed capacity compared to both wind and solar PV.

The world market for solar water heaters expanded significantly in the 1990s. Mature and commercial solar hot water markets are continuing to expand in several countries at a level comparable to that of solar PV, particularly China, which alone accounted for half of global installations in 2001 and saw double-digit annual market growth in the early 2000s.

Japan, the United States, Germany, Greece, Israel, and Australia are active solar hot water markets. Driving growth in several countries are mandates that new home construction include solar hot water—notably in Japan, Greece, Israel, and parts of Australia, which tends to drive domestic production and localized industry. The success of the solar hot water industry since, has spurred significant growth in Europe to meet growing demand. It is estimated that the European Union (EU) almost reached their 2004 target of 15 million square meters of collectors, and they have currently set a target of 100 million square meters of solar collectors by 2010.

The growth of the solar hot water market is projected to continue, as more governments mandate the use of solar hot water systems, and as household and community demand continue to drive markets. The United States, Greece, Australia and China constitute the major exporters of this technology. The majority of production, however, is used to meet domestic or regional demand due to the inherent characteristics of the technology, for example, Greece supplies a significant share of only the European market and almost no share in other market. As the market expands and becomes more global, economies of scale and low-cost manufacturing might make this a global commodity market similar to Solar PV and wind.

Biofuels

There is considerable scope for biofuels such as ethanol and biodiesel to replace oil in the transport sector. The Alternative Scenario assumes that government policies boost the share of biofuels in worldwide road transport fuel consumption to around 4% in 2030, more than doubling the level of consumption in the Reference Scenario. The rate of increase varies greatly among countries, reflecting different degrees of interest in biofuels. In OECD countries, biofuel consumption reaches 55 Mtoe in 2030, four times more than in the Reference Scenario. In the developing countries, biofuels remain important in Brazil and start to play a significant role in India.

The recent sustained increase in international oil prices has spotlighted the potential for biofuels to supplement fossil fuels for transport. Another impetus is the rising dependence on oil imports in many countries. Net oil import dependency is expected to rise in all OECD regions and in China and India, and oil exports from the Middle East will represent more than two-thirds of global fossilo trade in 2030. In most countries, however, oil imports have not crowded out domestic production. Just as indigenous industry coexists with imported oil, a global biofuels market could be created alongside protected domestic markets.

Given the wide range of biofuels production costs worldwide and the wide range in production potential among countries, there are substantial potential benefits from international trade in biofuels. These benefits include lower energy costs, energy supply diversification and economic development. Ethanol from sugar cane, produced mainly in developing countries with warm climates, is generally much cheaper to produce than ethanol from grain or sugar beets in IEA countries. For example, production costs of Brazilian ethanol from sugar cane are one-quarter of production costs in the EU and US. In countries where sugar cane is produced in substantial volumes, sugar cane-based ethanol is becoming an increasingly cost-effective alternative to petroleum fuels. A global biofuels markets would enable a wide variety of feedstocks to be planted worldwide, enhancing rural and agricultural markets in developing countries, Actions to diversify energy supply often means more subsidies, but trade would enhance the benefits of diversification by offering alternative, cheaper fuel sources.

Conclusions

- Three factors affect renewables' cost and market growth: the intensity and availability of the natural energy resource, the maturity of each renewable technology, and the market rules set by governments.

- First generation renewable energy technologies are relatively mature. They became competitive in the first part of the 1900's in locations where the resource was strong, and where there was local demand for their energy. These technologies moved into developing countries as their competitiveness grew, and as industrial demand in those countries increased.

- IEA countries are leading the development of second generation technologies that are coming into the market, due to RD&D and market deployment policies.

- The overall level of renewables RD&D funding has been very erratic. From the first year in 1974 at ~$65 million, renewables RD&D peaked at just under $2 billion in 1980, and then collapsed to less than a third of that level at ~$600 million in 1987. As a percentage of total RD&D funding, renewable energy technologies accounted for $23 billion, representing just 8% of total government energy RD&D funding from 1974 through 2002.

- Additionally, overall RD&D expenditure in the energy sector is extremely low. In the US, for example, 0.5% of revenue in the electricity sector is devoted to RD&D, compared to 3.3% in the car industry, 8% in electronics and 15% in pharmaceuticals.

- Policy instruments for deployment support vary considerably from country to country, although most have followed a similar trend in their support of renewable energy technologies. RD&D starts as the primary support and is then followed by market deployment support to underpin entry into the market.

- The last decade has seen an explosive growth in the development of wind power, as the costs of wind turbines have steadily declined and technical reliability has increased. In 1990, IEA countries had 2 395 MW of installed wind power capacity and by 2004 it had expanded to about 46 000 MW, an annual average growth rate of about 22%.

- There appears to be a strong link between RD&D in wind power technology and the development of markets and a supporting industry. In Denmark, Germany and the United States, for example, significant fund for RD&D were invested in the years preceding rapid market growth. RD&D investments in 1987-2001 by the seven countries with the most significant markets were 85% of the total invested in wind by all IEA countries, and represent 94% of the installed capacity in IEA countries.

- Solar PV experienced an annual average growth rate of 29% between 1992 and 2001 in IEA countries. Japan, Germany and the United States accounted for about 85% of total installed capacity of about 1 000 MW in 2001.

- Sustaining market growth rates will improve market learning. To do so, more countries should remove trade barriers and institute similar standards and codes.

- Greater international coordination of deployment strategies could reduce overall costs of deployment programs and technology development and achieve greater economies of scale.

- Non-IEA countries are apt to adopt 2nd generation technologies as costs drop and intellectual property is traded. Non-IEA countries have advantages of low labor and material costs, and scope for domestic and regional markets due to favorable resources. However, the timing of this trade is critical as these countries have subsidized energy and poor investment climates.

- The Doha Round of the WTO reaffirmed a commitment to the protection of the environment and stressed the need for trade and environmental policies to be mutually supportive. In the context of trade and environment, discussions at Doha centered on number of issues including market access. The effects of environmental measures on market access, including access to renewable energy services, in relation to developing countries and the benefits of removing trade restrictions are to be considered.

- Financing energy projects at the World Bank has come down in recent years, although energy projects are an extremely large market. In the 1990 fiscal year, energy projects totaled 3.2 billion in 1990 and totaled $1.2 billion in 2003. Although the proportion of that funding going to renewable energy has increased over the past decade, it remains miniscule. Funding for renewable energy projects have increased from 2% in 1990 to 4% in 2003.

- It is estimated that about one-third of global installed wind capacity is the result of international trade, i.e. the import and export of wind turbines and related services. The cumulative volume of traded wind turbines is almost 16 GW, which represents about $17.6bn market at today's prices. In the future, trade in wind energy equipment is likely to centre around two issues: trade in intellectual property - the high-tech components that make up wind turbines, such as nacelles and blades - and trade in the actual hardware.

- International trade appears not only significant for a growing domestic market, but will also underpin strong growth in South and South-East Asia and Africa, which the IEA projects to have 25GW of solar PV installed in 2030. Trade in the technological know-how will secure market positions in these emerging markets while also expand the low-cost manufacturing base for the industry in general.

- The solar hot water market will grow substantially, as more governments mandate the use of solar hot water systems, and as household and community demand continue to drive markets. The majority of production, however, is used to meet domestic or regional demand due to the inherent characteristics of the technology. As the market expands and becomes more global, economies of scale and low-cost manufacturing might make this a global commodity market similar to Solar PV and wind.

- There is considerable scope for biofuels such as ethanol and biodiesel to replace oil in the transport sector. The recent sustained increase in international oil prices has spotlighted the potential for biofuels to supplement fossil fuels for transport. Another impetus is the rising dependence on oil imports in many countries. Just as indigenous industry coexists with imported oil, a global biofuels market could be created alongside protected domestic markets. A global biofuels markets would enable a wide variety of feedstocks to be planted worldwide, enhancing rural and agricultural markets in developing countries, Actions to diversify energy supply often means more subsidies, but trade would enhance the benefits of diversification by offering alternative, cheaper fuel sources.

- ♦ If renewable energy technologies succeed in accelerating their market acceptance through technology and market cycles, it is conceivable that they could capture a significant share of the projected $16 trillion of investments for the global energy supply infrastructure over the next three decades. The investment associated with the addition of renewable energy capacity in 2003 and projected costs for 2030. Investment costs are estimated to increase by almost four times, from approximately $70 billion to over $250 billion.