



## Issue Brief

# NON-HYDRO RENEWABLES

(IN ELECTRICITY GENERATION)

### SHARE OF ELECTRICITY GENERATION

Renewables could play a significant role in electricity generation. Non-hydro renewables generated almost 2% of the world's electricity in 2002.

The International Energy Agency (IEA) projects that the share of non-hydro renewables in electricity generation will grow to 6% by 2030.<sup>1</sup> Shares are projected to be highest in OECD countries, with over 15% in OECD Europe, and lower in developing regions, ranging between 1% and 5% (see Figure 1). China recently announced higher aspirations in connection with its new renewable energy law.

To reach a share of 6% in 2030, non-hydro renewables are projected to grow at a rate of 7% per year, with significant growth rates projected for all world regions. This growth rate:

- Is equal to the recorded growth rate in generation from non-hydro renewables in OECD countries over the period 1995-2003<sup>2</sup>;
- Is approximately three times the projected growth rates in electricity consumption (2.5% per year to 2030);
- Exceeds the growth in generation from natural gas, which grew at an average rate of 4.9% per year from 1971 to 2002 and is projected to continue growing at this rate to 2030.

Other studies and scenarios, and other commentators, indicate that the potential for non-hydro renewables could be significantly higher. The "World Alternative Policy Scenario" in the IEA's *World Energy Outlook 2004* is based on the assumption that a series of challenging energy efficiency and emissions reductions policies are successfully implemented worldwide. As an example, it is assumed that the European Union's (EU) target of 12% primary energy in 2010<sup>3</sup> is met, and can be extrapolated to 2030. The share

of EU electricity generation from renewables would then be 34%. The "World Alternative Policy Scenario" sees a 30% increase in the use of non-hydro renewables, excluding biomass, when compared to the reference scenario (the basis for the figures presented in preceding sections). Biomass projections are for similar increases – these would translate into roughly 9% of electricity being generated from non-hydro renewables worldwide in 2030.

Other commentators, particularly from advocacy groups and green non-governmental organizations (NGOs) advocate market shares for non-hydro renewables much higher than the projected world average of 6% in 2030. If sufficient financial and policy support could be brought to bear, the share of electricity generation from non-hydro renewables could exceed 10% in 2030, albeit with significant extra costs to the economy. It is unlikely that any policy scenario could raise the share as high as 20% by 2030.

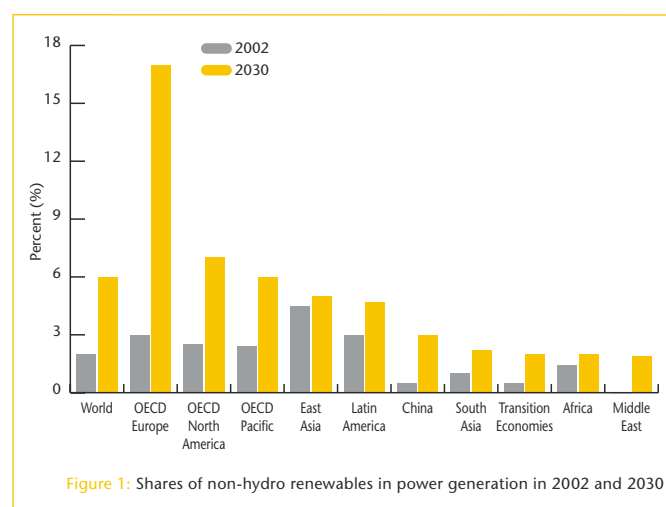


Figure 1: Shares of non-hydro renewables in power generation in 2002 and 2030

Source: International Energy Agency, *World Energy Outlook 2004*.



Biomass<sup>4</sup> was the most important generator of electricity in 2002 (57% of the total of non-hydro renewables), with geothermal (22%) and wind (20%) making up almost all the remainder. Projections to 2030 are that the majority of growth in generation will be from wind, whose generation is projected to grow by an annual average of 11% (note that average growth rate in OECD countries between 1995 and 2003 was 30% per year). Wind is projected to contribute 55% of global generation from non-hydro renewables in 2030.<sup>5</sup>

## RESOURCE AVAILABILITY

Renewable resources are by definition inexhaustible because they are continually renewed. The amount of energy that can be recovered within a given period is determined by the:

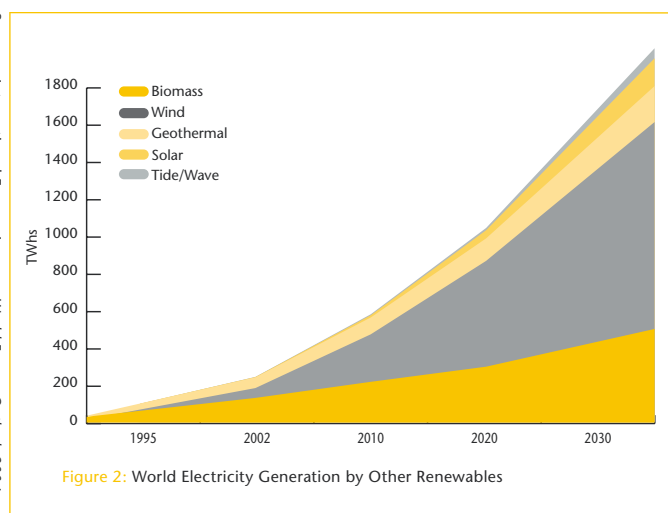
- *Density* of the resource, which is the quantity of energy available per unit area or volume. The energy density of renewables is significantly lower than that of fossil fuels, meaning that the infrastructure required to harness a given amount of energy must be significantly larger.
- *Rate of renewal* of the resource. This rate may be variable and/or intermittent (e.g., sunlight and wind), requiring storage or a combination with other renewable or non-renewable resources to meet continuous loads or supply need on demand.

Renewable resources with higher densities and renewal rates are more readily recoverable than those with lower densities and renewal rates. Densities and renewal rates can vary markedly within a technology type. For example, the annual output of a wind turbine is clearly dependent on the regularity and strength of the wind regime at sites.

Table 1 summarizes resources and their exploitation. The total quantity of renewable energy available globally is enormous – the energy from a solar, wind or ocean/tidal source is sufficient to meet current world energy demand many times over.

Only a fraction of renewable resources are economically accessible with today's technologies, for a range of physical, technical, practical and environmental reasons. Economic recovery for electricity generation requires reasonable cost, sufficient available surface area and an acceptable proximity to transmission and/or load centers. Even where resources may be very good, renewable energy may have to compete with alternate uses of the land or area.

The endowment of low-cost resources varies greatly between different parts of the world, both between countries and within countries. At this local level, resources can vary widely – wind power may be economic in one valley but uneconomic in the next; the costs of biomass increase with distance from where it is grown/produced. Specific local conditions also affect technology choice – wind turbines designed for northern European weather may not be sufficiently strong to resist potential Asian storms.



Distributed renewable generation is an important application but constitutes a relatively small component of total renewable generation and of total distributed generation. The bulk of the growth in non-hydro renewables will be seen in 10 MW or larger wind parks and combustible renewables. Distributed renewables are likely to remain a very small component of power generation in the coming decades.<sup>8</sup>

Today new renewables play a greater role in direct use, where they are more convenient and competitive than for electricity generation. Examples are biodiesel and other transport fuels and solar water heating.

Sources: International Energy Agency, *World Energy Outlook 2004*, (data for 2002 and Projections to 2030),<sup>6</sup> Online Statistics (data from 1995),<sup>7</sup>

Resource	Available Resource	Where is resource located	Notes	Potential
Biomass	3,000 million PJ/year	Worldwide	<ul style="list-style-type: none"> <li>• Less than 10% could be used as an energy resource – much for heating rather than power generation</li> <li>• Production limited more by lack of systems to manage collection and use</li> </ul>	Total power generation could grow by 10 times over coming decades
Wind	Vast	In most countries – needs average speed in excess of 5 meters/second	<ul style="list-style-type: none"> <li>• Utilization is limited by the availability of areas with good resources near suitable transmission infrastructures</li> </ul>	IEA <i>World Energy Outlook 2004</i> projects capacity increase of 10 times 2002-2030. Upside could be significantly higher
Geothermal	60,000 MW capacity	Economically recoverable resources are in Pacific Rim, and some areas from Asia to the Mediterranean Sea		Considerable but limited to certain countries
Solar	Vast	Africa, Australia, China, India, Mediterranean, Middle East, southwestern USA, Central and South America	<ul style="list-style-type: none"> <li>• Although resource is available in all countries, resource only considered “good” if &gt; 1,700 kWh/m<sup>2</sup>/year insolation</li> <li>• Limitations are due to cost, land area requirements (near to point of use) and intermittency</li> </ul>	Potentially huge over the longer term
Ocean	Unknown but vast	Worldwide	<ul style="list-style-type: none"> <li>• The energy density of most of the resource is low</li> <li>• Distance to load centers can be very high</li> <li>• Estimated that 20-40 sites could be exploited commercially</li> </ul>	Likely to be low unless a way can be found of exploiting low-density resources
Tidal	Unknown but vast	Worldwide	<ul style="list-style-type: none"> <li>• High construction costs currently preclude significant development</li> <li>• One large commercial site exists (in France, 240 MW); a second is under construction in South Korea</li> </ul>	Likely to be low – expensive, requires high tidal amplitudes and can impact estuary ecosystems/migratory fish

Table 1: Renewable Energy & Resource Availability<sup>9</sup>

## CURRENT TECHNOLOGIES

### Technology type by renewable resource

*Biomass* is similar to fossil fuels and is used in comparable technologies, often with the simultaneous production of heat (combined heat and power). Sources of biomass include crop waste, by-products of processing food and wood (such as fruit pits and sawdust) and wooden waste from construction and demolition. The supply of agricultural biomass can be highly seasonal and influenced by changing market conditions. One important and growing use is the “co-firing” of solid biomass in coal generation plants, with appropriately processed biomass making up 5-20%, and sometimes more, of the fuel input.

Liquid biofuels are another renewable resource. While biodiesel is typically used for transportation, others such as black liquor from paper production or mill effluents from food processing have been used for power production. These fuels have the advantage of virtually no sulfur emissions.

Landfill gas is an abundant and important resource. Rich in methane, if it escapes to the atmosphere, it has a powerful global warming potential. If harnessed to produce useful energy, its global warming potential is avoided, and a net benefit is produced. Landfill gas projects were among the first to be approved as clean development mechanism (CDM) projects under the Kyoto Protocol. Power production from landfill gas is relatively straightforward. Landfill gas can also be co-fired with other fuels in other units, though clean-up would be required to remove contaminants. Gas from sewage treatment facilities is also in this category.

*Geothermal* energy is accessed using wells, typically 200-3,000 meters in depth. Depending on local geological conditions, these wells deliver water or steam. Each well typically delivers enough heat to drive a 4-10 MW turbine, with sites generally having sufficient wells for 20-60 MW of electricity generation. Load factors are high, and the plant can be used as base load. Operating costs are low: the majority of costs arise from developing the wells and constructing the turbine.

Commercial *wind turbines* range from 600 kW to 4 MW, with larger units offering the lowest capital costs per unit of capacity. Offshore sites are becoming more common.

*Solar* energy can be harnessed to provide electricity either through:

- Photovoltaic (PV) panels which use crystals or thin films to convert light directly to electricity; or

- Concentrators that reflect light onto collecting surfaces which then heat either air or liquids (solar thermal).

Although research efforts have reduced costs, photovoltaic panels remain expensive and their manufacture tends to be resource intensive; nevertheless they offer ideal low-power off-grid potential (e.g., for powering remote telecommunications equipment). Concentrators appear to offer higher potential, since they use more of the energy of the received light. They can be an addition to a conventional fossil fuel plant, increasing the capacity factor of the balance of plant. Solar thermal electric demonstrations over the past 30 years have not led to any commercial systems or significant take up.

On a smaller scale, high-tech controlled ventilation, passive solar (e.g., water heating systems), and heat pumps (both geothermal and atmospheric) are additional means of making use of solar thermal and geothermal energy. While these do not produce electricity, and some require a small amount of electricity to operate, they may save a larger quantity of electricity or other forms of energy.

*Ocean* power uses the energy of waves or underwater currents to drive turbines (directly or indirectly) and generate electricity. The principle is similar to a wind power turbine with the current of the sea running an undersea turbine. There are early demonstrations of wave systems and prototypes of underwater current systems. The power of a unit is currently limited to hundreds of kW and may approach a few MW in the coming years. Nevertheless, large farms with hundreds of units could be developed. In France a potential of 3,000 MW near to the shore has been identified.

*Tidal* power is actually a lunar energy that uses the power of the tide (created by the moon/earth interaction) to run low-head turbines. The tidal plant concept is similar to the low-head run of a river hydro plant with two main differences: (i) the dam crosses an estuary instead a river; (ii) water can flow in both directions as the tide goes up and down. Tidal schemes are independent from hydrological conditions and thus have more consistent water availability over the year than conventional hydro schemes. Few schemes have been developed to date due to their high construction costs and the specific required conditions (tidal amplitude higher than about 7 meters). The only large tidal scheme in the world is La Rance in France (240 MW - commissioned in 1967), although a second one is under construction (Siwha – 260 MW – South Korea). A number of small schemes (up to 20 MW in capacity) exist in countries including Canada and China.

## Characteristics and performance

The characteristics and performance of non-hydro renewables can be summarized as follows:

- They tend to be capital intensive, but generally have low operating costs. Upfront financing is thus a major issue.
- Fuel costs are generally low and, except for some biomass resources, have low volatility.
- Capital costs per unit of capacity are high in comparison to fossil fuels. The cost of solar photovoltaics is particularly high, and the cost of wind power also exceeds the costs of coal or gas power.
- Units tend to be small in size. Wind, geothermal and ocean wave units all tend to be under 10 MW; solar photovoltaics are particularly small, about 100 W per panel.
- Non-hydro renewables technologies and fuel sources are highly diverse, and they can thus provide a very flexible response to highly diverse needs. They are suitable for both off-grid and on-grid generation.
- The location of renewable resources (e.g., biomass and wind) is often far from existing grids. This gives them an advantage in serving the needs of remoter communities - renewables are one of the key technologies for increasing access to electricity in the developing world, with a high level of attendant sustainability. For the larger demand accessible through the grid, reasonable proximity to the grid is necessary.<sup>10</sup> Feeding electricity generated at remote locations into the existing grid presents a number of challenges. Remote locations are often at the end of networks, where electricity is expected to be delivered, not received. Receiving electricity can require expensive modifications and can be difficult to control.
- Grid connection generally needs power electronics, which have a large fixed cost component. Thus the costs of connecting to the grid decrease per unit of electricity generated as the size of the unit connected increases. Solar photovoltaic panels require the conversion of its direct current (DC) output to alternating current (AC), adding a further cost element.
- The operation of many renewables is intermittent in nature, and can be unpredictable (e.g., wind and solar). Thus sufficient back up capacity and/or storage may be needed for conventional applications, and they are not suitable to provide ancillary services to the grid (reserve or load following).
- The skills to develop and maintain renewables are still emerging in many countries. Development of these skills will be necessary for large scale implementation.

In general, non-hydro renewables are more expensive per unit of electricity generated than conventional technologies, except in applications where resources are particularly favorable and/or the cost of conventional alternatives is high.

Cost improvements over time will depend on technological innovations (see also the section below on R&D), which benefit from increasing scale of deployment, particularly with newer technologies such as solar photovoltaics. On the other hand, increasing scale also means that some resources may become more costly to access. This applies especially to wind power, where many of the most economic onshore sites have already been developed. Figure 3 gives an overview of current and projected cost figures.<sup>11</sup>

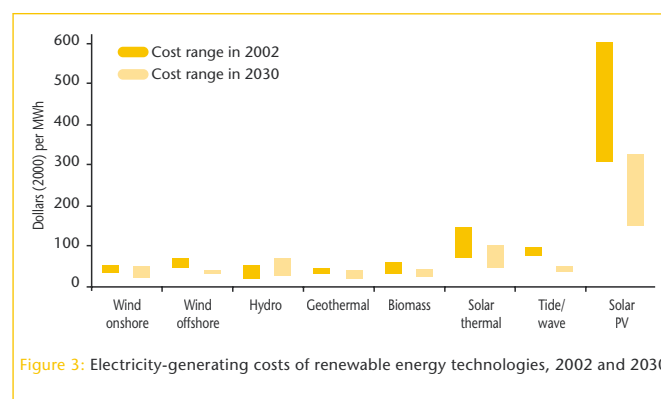


Figure 3: Electricity-generating costs of renewable energy technologies, 2002 and 2030

Source: International Energy Agency, World Energy Outlook 2004.

The current growth of market share is driven by policy and support schemes such as feed-in tariffs, quotas and tax incentives, which vary depending on technology and country. There is little harmonization between country policy and incentive schemes at the moment, even within regions such as the European Union or between States in the US. Policy uncertainty may be a source of considerable risk to investments in renewables.

## DEALING WITH INTERMITTENT GENERATION

Electricity systems with intermittent generators require reserve capacity provided by other plants and/or electricity storage in order to match supply with demand at all times (see Figure 4). The challenge to the system increases as the share of intermittent generation increases. With the growing market share of wind power in some countries, there is a strong effort to increase capabilities for predicting variable power output and for managing intermittent supplies.

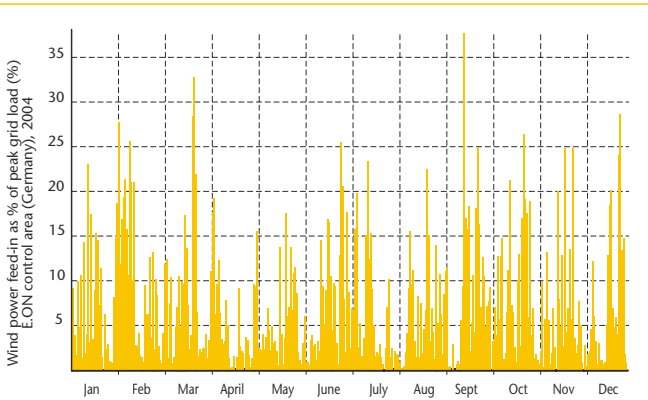


Figure 4: Intermittency of wind power

Storing electricity at the scale required to integrate intermittent generation is currently prohibitively expensive. Bringing down these costs would be an advantage not only for plants which generate intermittently, but also for base load plants which can not easily alter their output to match demand fluctuations.

### Using reserve capacity provided by other plants

Hydro plant reservoirs provide a means to store potential electricity generation and to “load follow”, i.e., to match supply to demand in real time. Pumped storage plants are a key part of many electricity systems, and allow electricity generated when demand is low to be stored (in the form of water pumped up to an upper reservoir) and then released at times of high demand.

Storage using hydro plants depends on the existence of suitable sites for reservoir development. It will only be of use to intermittent generators if they are then attached to the grid – off-grid applications can clearly not be supported. If both these conditions are not met, incorporating intermittent generation will require a “spinning reserve” (a plant that is ready to generate immediately) and/or other forms of storage.

Plants that generate for a significant portion of the year generally provide spinning reserves – if new plants were needed purely for spinning reserve purposes, this would add a major cost to the electricity system.

### Electricity storage

There are no current technologies that would allow for cost-effective, large scale electricity storage. Future storage

options include hydrogen (electricity can be used to generate hydrogen, which can then be used as a fuel for electricity generation), but this option is relatively inefficient and expensive, and widespread hydrogen networks are many years away. Batteries are likely to represent the best storage option in the medium term, and their development is ongoing.

For batteries to go mainstream in the medium term, they must be affordable. Additionally, they must also have the following characteristics:

- High charge/discharge efficiency (and no self-discharge);
- High durability (long lifetime and able to cope with a large number of full charge-discharge cycles);
- Easy maintenance;
- High energy density (i.e., compact).

Standard batteries (e.g., the lead-acid variants used in cars) are unable to meet these requirements. A number of technologies are being pursued, with sodium-sulfur batteries being one of the leading options. Twenty-five years after the proposal of sodium-sulfur batteries by the Ford Motor Company, a 50 kW prototype was developed in Japan as the world’s first practical application, and its grid-connected field test was held in 1992. The test results confirmed high levels of reliability, and safety mechanisms were confirmed sufficient for commercial application. Combined with success in the reduction of production costs, commercial production and sales of the sodium-sulfur battery started in 2002, under the name *NAS battery*. The NAS battery operates at approximately 300 degrees Celsius to keep the sodium polysulfide produced in the positive terminal in a liquid state and to decrease the resistance of the beta alumina tube through which sodium ions pass. Each cell generates approximately 2 volts.

Commercial application to date is at 27 sites with an accumulated capacity exceeding 40 MW. The batteries are used to level load and also to assure uninterrupted power supplies. They serve a niche market where uninterrupted power has a very high value.

Significant cost reductions are still required before batteries could provide general storage services beyond the current niche applications they serve. A further use could be the compensation and/or support for the power system in developing countries where the power network is yet to be developed or augmented.

## IMPACTS

In common with other generation technologies, non-hydro renewables have the potential for both positive and negative social and environmental impacts. Project success requires the careful balance of economic benefits with social development and environmental impact.

### Environmental – Global

One of the primary benefits of renewable energy is that during operation, there are no net emissions of greenhouse gases (GHGs). Biomass releases the same quantity of carbon dioxide it absorbed during its growth and is thus considered carbon neutral if it comes from a sustainably harvested resource. Over the life cycle of the systems, from manufacturing to decommissioning, there are some greenhouse gas emissions, but these are typically low in comparison with the life cycle emissions of fossil fuel power. Solar photovoltaics currently have the highest life cycle emissions: the energy used during their manufacture can be as much as the savings generated from up to 5 years of operation.

### Environmental – Local

Of renewables, only biomass emits combustion products to the air. Particulate emissions from solid biomass can be high and thus plants must be carefully sited to avoid potentially high impacts on human health. Solid biomass also generates solid waste combustion by-products and requires a significant amount of water for cooling and energy conversion. Biodiesel is a relatively clean liquid fuel whose emissions of particulates are significantly lower than those from either solid biomass or petro-diesel.

Renewables have other local environmental issues of varying degrees of importance including:

- Geothermal plants take up significant quantities of land, and can also release the SO<sub>2</sub> (sulfur dioxide) naturally contained within subterranean water;
- Wind turbines cover large quantities of land (although uses for this land, such as farming, are possible), create a hazard for birds, generate noise, create a visual impact, and may interfere with radar and low-level aviation;
- Solar photovoltaic systems require very large quantities of land and the manufacture of solar PV panels may require large quantities of resources such as energy and solvents;

- Ocean power can change water regimes over large tracts of water (e.g., estuaries), potentially altering local ecology.

### Social/Community

The primary benefit of renewable energy is the provision of commercial energy – a necessity for quality of life. This may be particularly important in remote and off-grid areas where people have few other commercial energy options. Renewable systems also provide employment opportunities, since they may be more people-intensive than conventional energy on a per unit basis.

The development of renewable energy in remote areas may also have negative social impacts, particularly if a large amount of land is used, or if large infrastructures are built in areas of cultural, historical or other social value.

Renewables, particularly wind power, have faced opposition by site neighbors who do not want the visual impact of wind farms or other facilities. This is known as the “not in my back yard” (NIMBY) view.

## RESEARCH & DEVELOPMENT

The prospects for non-hydro renewables depend on the levels of carbon constraints agreed, on fossil fuel prices and on how renewables’ capital costs change relative to those from other technologies. In the medium and long term, non-hydro renewables could become significantly more economically attractive than they are now; many studies show the decreasing costs of non-hydro renewables over time, and postulate how these relationships may be continued into the future (see also Figure 3).

Active research is being followed for all plant types:

- The gasification of biomass produces biogases that can deliver higher generation efficiencies in advanced equipment. The production of bio-ethanol is of particular interest for the future, as it could be used as a feedstock for hydrogen production.
- The development of biodiesel processing plants continues, with the principal aim of decreasing production costs.
- The key geothermal development is the exploitation of hot dry rock sites. Demonstration schemes are underway in Australia.
- Wind power research concentrates on improving costs (principally through larger turbines), increasing

availability by reducing wind speeds at which turbines “kick in” (start generating), developing systems which can withstand the more extreme conditions of offshore use and reducing noise and radar interference.

- Solar photovoltaic research is very active. The principal aim is the reduction of manufacturing costs, but lifetime and improving efficiency of converting light (from under 10% towards 40%) are also important. Although major research is underway, finance levels are low compared to the amounts focused on other energy options.
- Solar thermal research is exploring a range of novel system designs, ranging from the demonstration of hybrids (with conventional generating plants) to solar towers as much as 7 kilometers high.
- Ocean power research includes early demonstrations of wave systems and prototypes of underwater current systems.
- Tidal research is focused on developing more economic schemes across a range of sizes.
- Battery research continues to seek lower costs and higher performance (see sub-section on *Dealing with intermittent generation* above).

## REFERENCES AND NOTES

- 1 International Energy Agency. *World Energy Outlook 2004*. 2004.
- 2 See International Energy Agency Statistics Online, “Renewable Energy Information”, <http://www.iea.org/Textbase/stats/index.asp> (last accessed February 2005).
- 3 1997 EU White Paper on Renewable Energy Sources.
- 4 In common with most statistical definitions, the International Energy Agency’s definition of “biomass” includes solid biomass and animal products, gas and liquids derived from biomass, municipal waste and industrial waste. This *Issue Brief* subtracts the contributions of municipal and industrial waste from this total, defining the remainder as the “biomass” category.
- 5 International Energy Agency. *World Energy Outlook 2004*. 2004.
- 6 Note that figures in the International Energy Agency’s *World Energy Outlook* are from a combined “biomass and waste” category. The projections for “biomass” only have been derived by assuming that biomass’ 2002 share of 71% of the combined category remains fixed in the future.
- 7 International Energy Agency Statistics Online, “Renewable Energy Information”, <http://www.iea.org/Textbase/stats/index.asp> (last accessed February 2006).
- 8 Kendall, Gail, “Distributed Renewables: A Competitive Combination?”, IERE Korean Workshop, “Distributed Resources and Renewable Energy”. Cheju, Korea. May 2005.
- 9 World Energy Council (WEC). *Survey of Energy Resources*. 2004. International Energy Agency (IEA). *Renewable Resources for Power Generation, Status and Prospects*. 2003. IEA. *Renewables Information 2004*. World Bank. “Geothermal Energy: The Technology and the Development Process”, see <http://www.worldbank.org/html/fpd/energy/geothermal/technology.htm> (last accessed June 2005).
- 10 See also the *Transmission and Distribution Issue Brief* for a discussion of grid requirements for renewable energy (in particular wind power).
- 11 International Energy Agency. *World Energy Outlook 2004*. 2004.

## About the WBCSD

The World Business Council for Sustainable Development (WBCSD) brings together some 180 international companies in a shared commitment to sustainable development through economic growth, ecological balance and social progress. Our members are drawn from more than 30 countries and 20 major industrial sectors. We also benefit from a global network of 50+ national and regional business councils and partner organizations.

Our **mission** is to provide business leadership as a catalyst for change toward sustainable development, and to support the business license to operate, innovate and grow in a world increasingly shaped by sustainable development issues.

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- **Best Practice** – to demonstrate the business contribution to sustainable development and share best practices among members;
- **Global Outreach** – contribute to a sustainable future for developing nations and nations in transition.

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*Powering a Sustainable Future* is a result of collaborative work among executives from the eight member companies of the WBCSD Electricity Utilities Sector Project. This work was convened and supported by the WBCSD Secretariat. All member companies of the project have thoroughly reviewed drafts of the report. However, this does not mean that every member company necessarily agrees with every statement in the report.

