The use of wind power to generate electricity, both for grid-connected and individual power, has increased by 25 per cent in the last four years.

Renewable energy technologies 9

A shift away from fossil fuels to renewable energy sources is the best long-term solution to the environmental problems caused by the production and use of energy based on fossil fuel resources. How fast this happens depends on the commercial viability of the different renewable energy technologies and their competitiveness compared with fossil fuels.

Renewable resources include some of the oldest known to humankind, such as wind and water. The technology exists to make use of such resources, and performance, reliability and cost-effectiveness are all improving steadily. As a result, solar energy, wind power, landfill gas and biofuels are all being used on a commercial scale around the world. Although their share of the commercial market is small at present, most forecasts project they will capture a bigger share. However, the cost of renewables in many applications is still higher than the cost of using fossil fuels, which reflects an energy pricing system that does not take environmental costs into account. Moreover, in many countries fossil fuels are subsidized at various stages of the energy chain (extraction, transportation, generation). Solar energy systems, for example, are more expensive because they are rarely subsidized.

Yet the trend towards renewables is growing impressively, not least because they are becoming increasingly price competitive. The cost of wind power has fallen by about 70 per cent since the 1980s and is close to the cost of power from a new coal-fired plant. The cost of electricity from solar power stations built in California's Mojave Desert in the mid-1980s and early 1990s has fallen with each new installation: one 80-megawatt solar thermal plant, built in 1989, produces power at a third less cost than that from a new nuclear plant.

Many experts now believe that renewables are poised to achieve a major breakthrough in the world's energy market for four main reasons.

- *Population*. About 2 billion people worldwide are without power at all, while another billion have access for only a few hours each day. According to some estimates the developing countries, taken as a whole, will spend over US$700 billion on electricity supply and transmission infrastructures during the next ten years. This shows the energy market's potential: the issue is how much of this market renewables can manage to capture.
- *Technology*. Technology advances are bringing the costs of renewables closer and closer to conventional fuels. In some situations, they are directly competitive. Also, energy technologies are going through a process of miniaturization and modularization, which means they are becoming smaller and more suited for local usage.
- C*ompetition*. Policy makers, especially in developing countries, are increasingly looking for more flexibility in bringing electricity to large populations, searching for alternatives to big, centralized monopoly utilities. This may not necessarily mean more renewables (the environmental impacts of power-market restructuring are not yet clear) but it does present an opportunity.
- *Environment*. The environmental case for renewables becomes even stronger with the growing concern over global climate change and growing acceptance that we cannot continue to rely on burning carbon fuels as the primary energy source.

Two recent electricity-supply scenarios show the difference a shift towards renewables could make to the developing world. A 'business-as-usual' approach would mean that competition among well-established technologies will lead to a net decrease in the market share of renewables. But, in an alternative scenario, supportive public policies, strategic private investment and commercial deployment would cause a dramatic growth in renewables' share of the power generation market, to more than 40 per cent by 2025. Scenario one will entrench the market share of fossil fuels because, once installed, the physical infrastructure of power generation will be hard to shift. The alternative scenario would offer both economic and environmental benefits.

An additional advantage of renewable resources is that they are distributed over a wide geographical area, ensuring that developing regions have access to electricity generation at a stable cost for the long-term future. This is not the case with fossil fuels. For example, more than half of all Latin American, Asian and African countries import over half of the commercial energy they use. For many off-grid applications, for which there is a considerable demand in developing countries, several renewable technologies are already cost-competitive. Renewable generating equipment comes in various sizes, from household to utility scale, and can be located close to customers, reducing investment in transmission and distribution, while capacity can be increased as demand rises by adding on units. Moving from fossil fuels to renewables in developing countries will also cut air emissions and air pollution and help them meet their international obligations to curb carbon dioxide levels.

Cost is the key

With the anticipated growth in capacity, the requirement for investment capital will be significant and cost effectiveness will be a decisive factor in encouraging developing countries to use clean generation technologies. It will also be the key to the worldwide growth of renewables. By some estimates, certain renewables will start to gain a competitive advantage from 2005 in many markets and, as the cost comes down, the opportunities for introducing them more widely in developed countries will increase. This will give consumers more choice about the source of the electricity they use and some will undoubtedly make their decisions on environmental grounds.

The World Energy Council says the costs of renewables will continue to come down as the technology improves and higher volumes of renewable energy are produced. By contrast, it expects the cost of fossil fuels to rise in the years ahead because of emission controls and increasing scarcity of the fuels themselves, although other forecasts project that fossil fuel costs are not likely to rise before 2010.

Some experts believe that during the next few decades, new technologies will allow today's giant power plants and refineries to be replaced by a new generation of small, decentralized energy systems. Oil, for instance, will be replaced by hydrogen produced from solar and wind energy, using electrolysis. Meanwhile, the short-term prospects for renewable energy technologies are difficult to predict for both developed and developing countries.

The European Commission (EC) has outlined a new strategy for renewable energy that aims to double its contribution to the European Union (EU)'s energy consumption to 12 per cent by 2010. The original target was an 8 per cent share by 2005, but the EC now believes that 12 per cent is realistic "given political will". In a discussion paper in November 1996, it said: "Despite the fact that in Europe, we have developed the technologies necessary to harness renewables efficiently, they are not being widely used." To address the cost handicap of renew-ables, the EC's outline strategy put particular emphasis on the need to internalize the external costs of conventional fuels through proposed energy taxes. But there is no guarantee that the EU member states will accept the tax plans. Indeed, the discussion paper itself has met with a mixed response, with some countries arguing that it is too ambitious. Several EU energy ministers have stressed that the renewables industry must bring down its costs to compete with conventional energy sources without subsidy. The EC's document did not favour any particular renewable, but said that wind power, solar heating, photovoltaics, biomass and geothermal approaches all required a "stronger political signal" to boost their contribution.

Despite the political difficulties and cost problems, renewables will certainly take an increasing share of the total worldwide energy mix, though how big a slice of the cake remains uncertain. Two studies commissioned by the EC in 1992 found that renewable energies could in future meet almost half of Europe's energy requirements. Indeed, Norway (and, outside Europe, Brazil) already obtains over half its energy from renewables. The United Nations Development Programme (UNDP) suggests that the contribution from commercial renewable energy sources to total global commercial energy will grow from 9 per cent in 1990 to 10-30 per cent in 2020-2025.

Solar power

There are three basic types of solar energy systems:

- passive solar power technology, incorporating features into the design and construction of buildings so that they trap the heat available for use in space heating or cooling;
- solar thermal systems, to produce heat for electric power generation, and domestic and commercial uses;
- photovoltaic systems, which produce electric power directly from the sunlight.

The energy crises of the 1970s boosted enthusiasm for solar power, but this abated as oil prices fell and the costs of converting sunlight into electricity remained stubbornly high. However, a combination of new technology developments and rising demand in developing countries is reviving the prospects for solar power.

BOX 9.1

Solar-powered telecommunications in Australia

Telecom Australia has been relying on solar energy since 1975. It was one of the world's first companies to use photovoltaic systems to meet off-grid requirements and rise to the tough challenge of providing a reliable, affordable telephone service to the Australian outback, with its extremes of climate, distance and geography.

The utility runs a network of remote microwave and optical repeater stations, small satellite stations and customer radio links, many of which rely on photovoltaic power. It is Australia's biggest photovoltaic user and has developed more than 8,000 solar power sites with a peak capacity of over 2 megawatts.

The Kimberley system spans a distance of 2,500 kilometres and has 41 solar-powered repeaters. The Kimberley base itself operates on loads ranging from 70 to 300 watts. For loads of 700-2,000 watts, some facilities use a hybrid of diesel and solar power: the diesel component supplies only a fraction of the energy, but it allows the use of a far smaller solar array and a battery reserve of just a day or two.

Passive solar

Heating and cooling applications impose different requirements on passive solar design. Space heating is mostly needed during cold periods, when the availability of solar power is lowest. This means that passive solar designs for space heating need large collection areas, usually involving substantial glazing, which can cause a problem of overheating in the summer. Solar cooling of buildings relies on creating temperature differences, which drive air movement through convection. However, the use of passive solar cooling is in decline in a number of countries as new buildings incorporate air conditioning. The rate at which passive solar technology is adopted depends largely on the

Energie Noord West (ENW), the energy utility company in the north-western part of The Netherlands, including the capital, Amsterdam, provides electricity to 1.1 million people, natural gas to another 0.7 million, and is connecting a growing number of customers to local district heating networks.

Despite the challenge of rapid liberalization of the energy market, ENW keeps the long-term target of a sustainable energy supply firmly in mind.

The key to this is developing a decentralized energy supply tailored to the specific demand requirements of individual customers and local areas – and includes promoting energy saving, combined heat and power (CHP), the use of heat pumps and storage, and implementing an ambitious renewable energy programme.

Some examples of state-of-the-art energy supply activities by ENW include:

- In Amsterdam, a neighbourhood of 600 houses was built with a strong emphasis on sustainable building. ENW developed a corresponding energy infrastructure – a local heating network, with heat supplied from a local CHP plant, a heat pump and heat storage capabilities. The heating network temperature is lower than the usual 90ºC, thereby increasing overall energy efficiency. Both heating and hot water supplies are metered, which is an incentive for users to save energy. All the houses are well insulated and fitted with double glazing to make optimal use of passive solar energy. Households are encouraged to use hotfill washing machines and dishwashers. These characteristics will now be implemented in a new suburb with 18,000 houses.

- ENW's $20 million environment programme aims to stabilize CO_2 output by the year 2000 at 1990 levels. The main feature is the ranking of energy-saving measures on the basis of costs per reduced ton of CO_2 – an approach which results in lower energy bills for customers.

- Although relatively expensive, renewable energy is a 'must' for the future. To bridge the financial gap with energy from fossil fuels, ENW sells 'green electricity' to customers choosing to contribute to sustainable energy supply – guaranteeing them that each 'green kilowatt-hour' they buy is generated from a renewable source. ENW also invests in renewables.

- Short-term, the most important source is wind energy. ENW aims for 200MW of wind turbine capacity on land, and 300MW on near- and off-shore locations by 2010.

- Medium-term, biomass gasification is the most viable option. ENW is participating in a 30MW biomass gasification plant to be built near Amsterdam. The second option is heat pumps as individual heating devices for households.

- Long-term, photovoltaics (PV) has the largest technical potential in The Netherlands, especially when integrated into buildings and connected to the grid. ENW has a long history of applying PV, ranging from the first autonomous PV-house in Castricum, with a 2.5 kWp PV generator, to the largest home-integrated solar generator in the world, PV-Sloten (250 kWp on the roofs and facades of 71 houses).

ENW has a long-term commitment to an efficient, sustainable energy supply. It will continue this approach as long as market conditions make it a viable option. This leaves an important role for governments in defining the boundary conditions for the energy market.

The near-shore wind turbine park, Lely, owned by Energie Noord West, consists of four NedWind40 turbines with a combined power of 2MW.

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PV-Sloten, the largest house-integrated PV generator in the world, offered valuable opportunities for multi-party cooperation.

rate of new building; hence the need to develop passive solar technologies that can be retrofitted to existing buildings.

Solar thermal systems

Solar thermal electrical technologies work by focusing sunlight onto a receiving station or collector to heat a fluid, which can then be used to raise steam for electrical generation. A flat plate collector, metal or plastic, is the most important type of solar collector, although collectors with built-in storage are also used. Three technologies are utilized:

- longitudinal parabolic mirrors which concentrate the sun's rays on a trough in the centre of the dish;
- mirrors in the form of parabolic dishes where the heating occurs at the focal point;
- banks of flat mirrors set at an angle which concentrate radiation on a central receiver placed at the top of a tower (this system produces the most power).

There is a wide range of applications for solar thermal energy, some of which are described below.

- Probably the most used at present is domestic water heating, which requires a flat plate collector and an insulated storage tank. As solar energy heats water in the collector, it rises to the top of the tank and when withdrawn is automatically replaced by cold water flowing into the bottom.
- Forced circulation systems are used to provide the large amounts of hot water needed in dairies, textile industries, hotels and hospitals. They need large arrays of flat plate collectors and a pump to circulate the water.
- Hot air obtained from collectors can be used to dry various agricultural products such as tea, tobacco and grains. Drying is done faster than in open sunlight, and in a controlled way.
- Space heating by solar energy is becoming important for many industrialized countries with cold climates.

BOX 9.2

Solar power in Freiburg

The historic German city of Freiburg is a showcase for various solar energy technologies, including the country's first all solar powered home.

- Two large open-air swimming pools are supplied with solar heated water.
- A demonstration block, built in 1978, and consisting of 12 apartments, is supplied with a 43 square metre tube collector which provides 63 per cent of the domestic hot water and 12 per cent of the space heating demand.
- Photovoltaic cladding is used on a recently built commercial solar centre in Freiburg.
- Passive solar technology is used in a group of terraced houses built in 1985. These are compact buildings, optimized for solar gain with conservatories and heavy insulation of non-transparent parts. This project uses a new approach to transparent insulation. The insulation material is transparent and mounted in front of a massive wall, painted black to absorb the solar radiation. The solar energy is transmitted through the material and absorbed by the wall. The wall's temperature increases but, because of the material's insulating properties, the heat is transferred through the wall into the building. In hot summer temperatures, automatically controlled blinds reflect the solar rays and prevent overheating.
- The latest demonstration project is the home that is self-sufficient in energy: the first building in Germany to use the sun as its sole energy source. It combines the most advanced solar and energy storage technologies: transparent insulation and highly insulated windows for passive gain; a high efficiency collector for hot water demand; and a photovoltaic generator for electricity supply. The building uses hydrogen for cooking via a catalytic burner – the first time this has been done in a domestic situation.

- Refrigeration and air conditioning can be achieved using solar energy.
- Cooking is an important solar thermal application. Cooking time varies from 45 minutes to two and a half hours, depending on the food and the solar radiation available.
- Water pumping is an emerging solar technology, but still has to overcome problems of cost and technical reliability.

Almost all sorts of collectors have been tried for power generation by solar energy. However, the

BOX 9.3

Affording solar electricity

Can households in sparsely populated areas in developing countries afford solar electricity? The evidence suggests they can. Moreover, solar schemes may help governments cut the cost of bringing electricity to rural towns and villages.

At the moment, grid-based electricity is seldom financially viable. It can cost US$10,000 per kilometre to connect areas to the grid, and because demand in rural areas is usually low, utilities are providing the electricity at a loss. In a community with a daily load of 100 kilowatt-hours, locally diesel-generated electricity can cost between 20 and 40 US cents a kilowatt, whereas photovoltaic-generated electricity costs between 50 and 150 US cents a kilowatt, irrespective of load. At lower loads however, diesel-generated electricity becomes more expensive, and when the electricity use is down to 12 kilowatt-hours, diesel and photovoltaic prices are the same.

Governments may be prepared to accept utilities making a loss on rural electrification because they want to give the whole population equal access to electricity. Photovoltaics may be a cost-effective way of achieving this, at a lower cost. But can poor people afford solar electricity?

A solar home system consists of a solar cell module, a charge controller, a battery, cabling and fluorescent lights. Studies show that this costs households less than they spend on buying candles, kerosene and batteries for lighting, radios and television. It is estimated that between 5 and 15 per cent of rural households in most developing countries would be willing and able to pay for a solar system. The percentage tends to be higher in Latin America, and lower in Africa. Changing from candles to electric light may also bring other direct economic benefits: for instance, the possibility of doing extra work at home in the evening.

In a pilot project, initiated in 1991, 40 photovoltaic systems were installed in the rural village of Manyana, Botswana. An evaluation after two years found that 100 per cent of the households that had not been given photovoltaic lighting wanted it; 83 per cent of the users did more reading; 50 per cent of the teachers said their pupils were performing better; and 30 per cent of the households were earning extra income.

The project also found that the villagers were willing and able to pay for the photovoltaic installations. They were given two-year loans to buy their systems, with monthly instalments varying from US$8.75 for a two-light system to US$31.25 for a six-light system. But, because incomes in Botswana tend to fluctuate with the seasons, it was found that fixed, monthly repayments were too rigid, and the system needed to be more flexible.

Similar results were experienced in Kenitra, Morocco, where 120 households were photovoltaic-electrified. Examples of extra incomes came from weaving, carpet making and repairing farming equipment during evening hours.

huge initial cost of solar power stations is a major disincentive.

Solar thermal energy for industrial uses is a particularly important area for developing economies, where energy use in the industrial sector is quite high compared with other sectors and where there is considerable potential for using solar energy for industrial process heat, especially in countries where solar radiation is abundant. Possible applications include the dairy industry, textiles, and the processing of food and agricultural crops.

However, there are still difficulties to be overcome. Storage needs depend on the application for which the solar system is designed, but in some situations large areas are needed to collect the solar energy, which can be a constraint for industries located in heavily built-up areas. Providing back-up conventional energy supplies can also contribute to the high initial costs of solar systems. The cost per kilowatt-hour generally remains twice that of a fossil fuel plant.

Photovoltaic cells

The other, and potentially most attractive, means of capturing and converting the sun's energy into electricity is through photovoltaic cells.

They are already cost-effective and used in a wide range of applications including electricity supply to small, isolated communities; water pumping and desalination; and powering service equipment. They consist essentially of two or more layers of treated semiconductors. When radiation falls on them, there is an interaction between photons and electrons, which generates electrical charges and then direct current power. There are many potential applications, including community television and even telecommunications. A key advantage of photovoltaics is their versatility: they can be used not only in large electricity plants, but also to power small water pumps, rural communications systems and individual residences.

In photovoltaic systems, there is usually a trade-off between cost reductions and the efficiency at which the cell converts sunlight to electricity. Large crystals of 'bulk' semiconductors, while efficient, are expensive, whereas thin films of semiconductor deposited on a surface are much less expensive, but far less efficient. Several materials are under trial. One is cadmium telluride. Another is copper indium diselenide, a semiconductor which converts light to electricity with 17 per cent efficiency in the laboratory. In Switzerland, research is focusing on the Grätzel cell, an electrochemical system which involves a titanium dioxide film, a photosynthesizer chemical and an electrolyte trapped between panes of glass. Glasgow University is researching understanding of how photosynthetic bacteria capture light in the hope of mimicking natural systems' remarkable ability to convert light into energy. The EU's Joint Opportunities for Unconventional or Long-Term Energy Supply (JOULE) programme is supporting several networks of laboratories working to improve the technology of photovoltaic cells.

Innovations in fuel cells are expected to lower the cost of producing electricity dramatically. Over a ten-year timespan, it could initially come down to about a third of the present cost of producing solar electricity. At this level, solar energy would be more competitive and more viable as a significant power source for remote areas, or in countries such as Japan where production costs are high because of a lack of raw materials. By 2010, it is predicted that costs will have fallen to a level where solar electricity may be a truly viable and economic alternative to traditional forms of electricity production in most countries.

One factor in favour of solar power is that environmental problems associated with traditional power stations are likely to lead to both higher generating costs and restrictions on output, which will narrow the price differential. Advocates of solar power believe it can become fully cost-competitive using existing technology through mass production: they argue that the key is economy of scale, in other words, a manufacturing, not a technology issue.

Growing activity

Certainly, some major companies are taking solar power more seriously. Two United States firms, for instance, have formed a joint venture to build the world's biggest solar farm: a 100-megawatt facility using more than a million solar panels that will be built in the Nevada Desert over the next 15 years. This kind of mass production, the companies believe, will cut the costs of the electricity to a price per kilowatt-hour that compares favourably with other fuels. Other United States manufacturers have announced plans to build up to ten solar plants, with 70-80 per cent of the total output going to developing countries.

Solar thermal systems are widely used for water and space heating throughout the world. More than a million homes in the United States have solar-powered heaters. Over 1,000 buildings in Germany and Switzerland have been solar-powered under government-funded programmes. In the Middle East, rooftop solar collectors provide up to 65 per cent of the energy needed to

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EUSKADI-PAYS BASQUE MEDIO AMBIENTE

An Environmentally Friendly Technology Agenda for the Basque Country

In a time of rapid and spectacular technological and economic change, the challenge is to find innovative solutions to both current and future problems.

Nowhere are these solutions needed more than in protecting Nature – once considered an inexhaustible resource, but now seen to be vulnerable and at risk.

We must protect the environment for our own sakes, and for our descendants' sakes. We have a moral obligation to hand over to them a world they can live in. The environment is a common heritage for all humankind: we are not its capricious owners – we are merely in charge of managing it. We have no right to waste and deprive our children – and their children – of the resources they will need when they take on that responsibility.

The way forward is through sustainable development. But it requires determination and commitment to introduce and implement the right policies and programmes – and it also demands the active involvement of all sectors of society.

That is what the Basque Country is aiming to achieve. The Basque Country has carried out an accelerated modernizing process during the past 20 years, and as a land of fragile ecosystems, it knows, at first hand, the dilemma of balancing development and environmental needs.

The Basque Country is committed to achieving the goals of Agenda 21, through plans and projects that include the use of specific technologies adapted to scarce natural resources and very diverse ecosystems – and to achieving them at regional level.

The self-governing region of the Basque Country is determined to make environmental awareness and improvements an integral part of the region's overall industrial structure with its priority being to promote environmentally sound technology solutions.

These solutions are the focus of the activities of the Department of Housing, Regional Planning and the Environment. The Department – which has overall management of the region's environment and coordinates activities aimed at preventing pollution and protecting natural resources – has been given the responsibility for preparing an Environmental Policy.

The key to developing a successful Environmental Policy has been the Department's close working relationship with the different social agencies and, in particular, with the business sector.

The Department – with the support of the Sociedad Pública de Gestión Ambiental IHOBE, S.A. (Public Environmental Management Company) – has created programmes and specific projects aimed at the introduction of environmentally clean technologies, the minimization of production processes, the correct management of waste materials and the reclamation of contaminated land. As a result, the Association of Environmental Industries (ACLIMA) has been established with the purpose of improving competitiveness of the eco-industrial sector in the Basque Autonomous Region by implementing a philosophy of respect for the environment.

Within this framework the Department has prepared an *Environmentally Friendly Technological Agenda for the Basque Region*, focusing on ten key areas:

- Green services and products
- Control, monitoring and instrumentation
- Polluted land
- Industrial waters
- Urban waters
- Evaluation and treatment of waste materials
- Urban solid waste
- Dismantling and recycling
- Air and noise pollution
- Cleaner production in industrial sectors (electrolytic coating processes, paint and foundry sectors).

The Department believes that these areas are indispensable to the future economic development of the Basque Region.

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heat domestic hot water. Solar water heating is also widely used in Australia, Israel and Japan.

Off-grid photovoltaic systems for household lighting, water pumping and other small-scale uses are also proliferating in countries like the Dominican Republic, Colombia, Mexico, Sri Lanka, Zimbabwe and Kenya (where more rural homes receive electricity from photovoltaics than from the grid). In the United Kingdom, the government has helped finance the conversion of a building in Newcastle-upon-Tyne into the country's first solar-powered office block. The government believes that office buildings could generate a third of their electricity needs from photovoltaic cladding. One of Europe's biggest photovoltaic power stations, in Germany's Ruhr Valley, uses solar cells covering nearly 2,500 square metres of roof space and can contribute 225 kilowatts at peak power to the building's energy needs.

Overall, the world market for solar power is small at present. Photovoltaic cells capable of generating about 83 megawatts (enough to power a small city such as Oxford in the United Kingdom) were produced in 1995, yet some forecasts say the industry can grow to 1,600 megawatts by the year 2010 and be worth more than US$7 billion a year. In industrialized countries, solar power could expand through grid-connected applications where photovoltaic-generated electricity can be fed back to the national grid. In the short term, however, the more likely applications will capitalize on the main advantage of photovoltaic generation: power generation at the point of use, avoiding distribution and transmission costs.

The United States Department of Energy has established a joint US$500 million, six-year programme with the utilities, aimed at doubling the numbers integrating photovoltaic products and services into their mainstream businesses. This in turn would double the sale of solar products, leading to the level of high-volume production that could reduce costs significantly. The programme includes both large-scale systems which feed power directly into the electric grid, and cost-effective, grid-independent applications ranging in size from a few watts to several hundred watts. The utilities are attracted to solar power because photovoltaic systems generate surpluses during peak daytime hours, creating an energy pool that the power companies can tap into. In a 1996 survey of United States consumers, a significant proportion said they were prepared to pay a premium on their monthly electricity bills to help fund solar energy programmes.

Japan is promoting photovoltaics through its 'sunshine' renewable energy programme to reduce dependence on nuclear power, and imported oil and gas. The government is running a pilot project involving 1,200 homes to assess how much of a household's energy needs can be met with the latest solar systems. Japan says that new energy sources will account for 2 per cent of its energy requirements by the year 2000 and 3 per cent by 2010. The European Commission has called for EU production of electricity from renewables to be trebled by 2010.

Enormous potential

Connecting homes to the grid is much more expensive in rural than in urban areas, due to lower load densities, lower capacity utilization rates and often higher energy losses. Solar home systems (photovoltaic systems designed for home use) can help by providing lighting and other services to large numbers of households which are either poorly serviced by existing energy sources (batteries, diesel engines, kerosene, candles, wood), or have no service at all.

A typical solar home system consists of a 20-100 peak watts photovoltaic array, a rechargeable battery for energy storage, a battery charge controller, one or more lights (generally fluorescent), an outlet for a television, radio/cassette player or other low power-consuming appliance, switches and

The costs of fuel cells to convert solar energy are expected to fall to about a third of current levels in the next decade.

BOX 9.4

Choosing the right projects

The ability to identify those energy projects with a good chance of success is particularly important when demands on funds are heavy. It is especially relevant for judging renewable energy schemes against conventional ones.

The United Kingdom Department of Trade and Industry's Energy Technology Support Unit has analysed successful renewables projects including wind power, small-scale hydro power, solar photovoltaics, solar thermal, biogas, direct combustion of biomass and co-generation, and identified 53 critical success factors.

Universal critical success factors are essential features without which no project will succeed. They include the use of proven designs or performance guarantees; the existence of an acceptable economic analysis and financial package; a clear identification of social need; and legislative, political and regulatory frameworks in place. Suitable staff, materials, infrastructure and flexible tariff systems are also necessary.

Funding bodies may be bilateral or multilateral aid organizations, government specialist agencies or development banks. Their programmes should be independent of day-to-day political involvement, while remaining compatible with government strategy. Renewables proposals must avoid conflict with wider development plans. Schemes should be targeted where a positive return is possible, and markets should be encouraged to 'pull in' appropriate technologies. Agencies should ensure that schemes rely on market forces, not subsidies, and managing agencies, responsible for seeing projects through, should motivate their staff, give them clear goals and encourage competitive energy markets.

Providing basic energy services to communities is a specific niche energy market. Involving the community is important: its members should be able to repair and develop the chosen technologies. The range of customers should be as broad as possible. Assessments of any scheme should take social as well as economic considerations into account and where targeted incentives are needed they should be planned for phase-out. Rural electrification schemes are another niche market: they should be free from day-to-day government interference and competition should be introduced early on. The programme should also encourage local employment, and develop education, training and infrastructure.

The ability of the selected technology to offer benefits in addition to meeting energy needs should be considered. The intermittent nature of wind, solar and hydro power can become a problem, so resource availability and demand patterns need to be balanced. As the energy market grows, developers must be able to make informed choices between conventional and renewables technologies.

wires. They are safer and more convenient than using kerosene or batteries, or burning wood or candles, and more popular with users. They also reduce reliance on expensive imported fuels. The World Bank says they can offer the most economical means to provide lighting and power for small appliances in sparsely settled and remote areas. Even in areas which one day may be connected to the grid, they can serve as an effective interim measure.

The World Bank estimates that there are 500,000 solar home systems installed worldwide in countries such as Brazil, China, Indonesia, Kenya, Mexico and Sri Lanka. And the potential demand is considerable: a million households in Indonesia and 300,000 in Sri Lanka, for example. However, solar home systems "do not yet have broad market acceptance, and face significant barriers to widespread diffusion", according to the World Bank. The main obstacle is their initial purchase price. The World Bank has called for "adequate financing arrangements, geared to low and middle-income households". Otherwise, solar home systems "cannot play a significant role in rural electrification".

Wind power

Wind has long been utilized for pumping water and other mechanical uses. Now, wind turbines are being built in many countries to generate either grid-connected or independent power, and wind power is the world's fastest growing energy source. Worldwide, installed capacity in 1996 reached 6,190 megawatts, 1,200 megawatts more than in 1995, and a 24 per cent increase over 1994. The American Wind Energy Association (AWEA) forecasts that nearly 30,000 megawatts of new capacity, representing a market share worth at least US$30 billion, will be installed worldwide over the next decade.

The biggest wind power market today is Europe, which in 1995 had 2,420 megawatts of installed capacity, compared to 1,700 megawatts in the United States. The market in Asia is also growing fast, particularly in India, where 500 megawatts of capacity was installed in 1995. In Europe, Denmark and Germany are the leaders, but the United Kingdom has the best technical potential, with more than 126 terawatt (thousand billion watt) hours of onshore wind energy available to be harnessed every year. Europe's biggest wind farm came on line in 1996 in mid-Wales. The US$42 million facility will generate enough electricity to power 25,000 homes at a price competitive with that from conventional energy sources.

Wind resources are sufficient to produce thousands of megawatts of power in Asia and Latin America, especially along coasts, in western China, parts of India, north-east and south Brazil, the Andes and northern Africa. In these regions, small stand-alone systems are especially suitable for remote areas with no access to an electricity grid.

The technology has improved considerably in recent years. Turbine capacities for individual mills have risen from 75 kilowatts to those now commercially available in the 1-1.5 megawatt range, and reliability is close to 99 per cent. Bigger, more efficient turbines and greater production volumes have cut the cost of wind-produced electricity by 30-50 per cent since 1990. In some countries, it is approaching the cost of fossil fuels. Among the various renewable energies, wind is probably the most economically viable.

There may be public resistance to the sighting of onshore wind energy schemes. A wind farm of hundreds, even thousands of machines can be unsightly, while the turbines are also noisy and can affect television reception and communication signals up to 4 kilometres away. The British Wind Energy Association reported in 1996 that in the previous year and a half, 17 out of 22 wind schemes had been rejected by local councils in the United Kingdom because local residents found the wind turbines inappropriate for the landscape. The alternative is to mount wind turbines offshore. In 1991, Danish engineers completed the world's first offshore wind farm, in shallow water near Lolland Island. The Vindeby station has 11 460-kilowatt wind turbines, connected to the grid by undersea cable. They can generate about 10 million kilowatt-hours of electricity every year.

The AWEA expects Europe to continue to dominate worldwide installations over the next ten years, accounting for nearly half the predicted new capacity. Indeed, the EU plans that wind power will supply 2 per cent of electricity demand in 2005, which would allow seven 1,000-megawatt coal-fired plants to be decommissioned and reduce carbon dioxide emissions by 30 million tonnes a year. The AWEA points out that "a price shock of any significant size (to fossil fuel prices) would shift the projections of wind capacity up considerably".

BOX 9.5

Denmark – a world leader

Denmark is a world leader in wind power technology: Danish companies have produced more than a third of the world's wind turbines. At home, wind energy has been one of the main planks of the country's strategy of reducing reliance on imported oil. In 1993, wind supplied 3 per cent of Denmark's electricity and the aim is to raise this figure to 10 per cent by the year 2000. One important point is that commercial banks in Denmark see wind turbines as a sound investment and are willing to finance them. The growth of wind power is also a result of deliberate government policies creating incentives to invest and guarantees so that banks would participate.

In India, too, there has been considerable interest from private investors in commercial wind farms following the success of a pilot programme, initiated by the government in 1986. India faces an electricity shortfall of 10,000 megawatts and already the power shortage is hitting the national economy. Wind energy is seen as one way to overcome this. The potential for wind-powered electricity generation in India has been put at 20,000 megawatts, though some estimates place it as high as 50,000 megawatts.

PROTECTING BRAZIL'S NATURAL RESOURCES

Brazil's natural resources are special – which imposes a particular duty on those industries within the country to protect them.

CEEE, Companhia Estadual de Energia Elétrica, a public utility responsible for the generation, distribution and transmission of electric power in the State of Rio Grande do Sul, is fulfilling its responsibility to the region's environment.

CEEE was one of the founder members of the Comitês do Meio Ambiente e do Sector Elétrico (COMASE) – the authority which enforces environmental regulation – and has had an environmental policy since 1988.

Evidence of CEEE's commitment to caring for Brazil's natural environment is demonstrated by its reforestation and restoration programmes for mined areas and reservoir borders, and maintaining a greenhouse for 2,000,000 exotic, native plants.

So, too, is the Dona Francisca hydroelectric development scheme – where CEEE has adopted a pioneering approach, working with the local community to transport and relocate local wildlife 200 kilometres away from the project.

Protecting the State of Rio Grande do Sul is more important than ever as demand for electricity increases rapidly.

With its 2,750,000 consumers, electricity consumption is currently 3,380 MW/year and forecast to rise by 5 percent a year, so CEEE is investing heavily in new generation and transmission capabilities to add another 3,375 MW to its system.

Two parts of its power distribution network – the North-Northeast and Centre-West regions – are to be privatized and the State Government will invite bids later this year.

Even so, CEEE will remain a major force in the region – providing the means to fuel future development, whilst continuing to safeguard a very special environment.

Micro-hydro power

About 9 per cent of the world's hydro potential has been developed already, providing about 23 per cent of the world's 375,000-megawatt total installed electricity capacity. Water power already accounts for 60 per cent of electricity capacity in Switzerland and almost 100 per cent in Norway. A big proportion of this electricity is produced by large schemes. But micro-hydro is becoming increasingly important.

There is no agreed size of system for hydro to be classified as micro-hydro. But the term is mostly used for hydro systems rated from a few hundred watts to about 300-kilowatt capacity, which is about the maximum size for most stand-alone hydro systems not connected to a grid. Moreover, 300 kilowatts is also about the maximum size suitable for run-of-the-river installation.

Micro-hydro is one of the most environmentally benign energy conversion options available. It can be implemented much more easily than large-scale hydro power because it does not interfere significantly with river flows and offers a number of advantages:

- as long as there is a reasonable head, it is a concentrated energy resource;
- the energy available is predictable, though variable;
- running costs are low because no fuel and only limited maintenance are needed;
- it is a long-lasting and robust technology: systems can last for 50 years or more, without requiring major new investment.

Yet there are shortcomings. It is a site-specific technology and sites need to be close to the water supply and to where the power can be economically exploited. There is always a maximum useful power output available from a given hydro power site, which limits the activities that make use of the power. River flows often vary considerably, which can limit the reliable power output to a small fraction of the possible peak output. Lack of familiarity with the technology and how to use it inhibits its use. The cheapest micro-hydro systems are locally built and can cost as little as US$200 per kilowatt, though most fall within a capital cost range of US$1,000-4,000 per kilowatt.

Micro-hydro power is a well-developed technology, which has been applied worldwide at a large number of sites. Micro-hydro power stations are common in China, and Pakistan also has long experience with small systems, some as small as 5 kilowatts. Tea plantations in the mountains of Sri Lanka often get their electricity supply from their own small power station in a nearby river. The technology is also well established in other countries, including Brazil, India and Nepal. Considerable technological development took place in the 1970s and 1980s, particularly in the area of electronics and control systems. These developments have helped make micro-hydro technology even more reliable and realistic. However, only about 10 per cent of the developing world's potential small hydro capacity has been exploited. Unused capacity is greatest in China and Latin America.

Biomass

Biomass is an energy source which uses certain crops, including wood or crop wastes, either directly as fuels or as a fermentable source of other fuels, such as alcohol or methane. It is a renewable and locally available resource, and falls broadly into three categories: woody biomass, agricultural and agro-industry residues, and animal wastes.

Woody biomass is obtained from natural and cultivated forests, and agro-forestry. Agricultural residues include rice straw, wheat straw, mustard stalks, cotton sticks and jute sticks. In developing countries these residues are harvested at the village level and used essentially as either fodder or cooking fuel. Some biomass residues such as sawdust, groundnut shells, bagasse and coffee husks, are products of agro-industries. The most prominent animal waste is cattle dung, used both

BOX 9.6

The Swedish experience with biomass

Biomass fuels have made a big comeback in Sweden, after falling out of favour after the Second World War, and today meet 18 per cent of the country's total energy demand. The comeback is a result of:

- the large increase in oil prices during the 1970s;
- concern about the environmental impacts of fossil fuels;
- controversy over Sweden's nuclear power programme.

The large-scale use of biomass fuels has increased from about 50 terawatt-hours in 1980 to 84 terawatt-hours in 1995, a 7 per cent shift in the national energy balance and one of the best examples of a successful switch from fossil fuels to renewable energy in the industrialized world.

The Stockholm Environment Institute says this success is due to coordinated government support for research, training and investment in new technologies to enable them to compete with established traditional technologies in an uncertain market. Government incentives have included subsidies for investments in installations using indigenous fuels and special taxes to discourage the use of fossil fuels in some applications.

The institute maintains that Sweden's experience with biomass offers important lessons for Africa where, "with proper management of biomass resources, there is large scope for instance for electric power generation from biomass on a sustainable basis". It says the technologies exist, but institutional barriers need to be overcome, and governments in Africa must establish long-term policies to promote renewable energy technologies.

as fuel and fertilizer. Using biomass can help reduce greenhouse gas emissions in two ways: sustainably harvested biomass produces no net emissions, and biomass can also act as a substitute for commercial fossil fuels.

There are two main ways of converting biomass into useful forms of energy: biochemical and thermochemical. The biochemical route is a low-energy process and relies on bacteria to degrade complex molecules of biomass into simpler ones. The production of biogas (a mixture of methane and carbon dioxide) from animal dung by anaerobic digestion is the most important example of this process (see the section on biogas below). In thermochemical methods, the biomass is raised to high temperatures and, depending on the quantity of oxygen supplied, processes such as pyrolysis, combustion and gasification occur. Burning biomass directly in stoves and open fires supplies a high level of oxygen. Pyrolysis and gasification occur when there are lower rates of oxygen supply, for example, preparing charcoal from wood and burning municipal solid waste.

Under specific conditions of temperature and oxygen supply, a gaseous mixture rich in carbon monoxide and hydrogen is formed. This process is called thermal gasification. This gas has a high calorific value and can be used to drive dual fuel engines or diesel engines. A gasifier used together with a diesel engine is essentially a device for saving on diesel. However, petrol engines can run completely on producer gas, though there is some loss of power, and diesel or petrol still need to be used to start the engines. For example, during the Second World War an estimated 800,000 vehicles were running on producer gas. The gas can also be burned directly in an industrial oil-fired boiler.

An advanced technology that could allow electricity to be produced from plantation biomass is the biomass integrated gasifier/combined cycle. Although this technology is not as advanced as coal integrated gasifier/combined cycle technology, several demonstration projects are under way. Its potential for competing with gasifier/combined cycle technology is promising because much of what has been learned in developing the coal technology can be transferred to the biomass version. The biomass integrated gasifier/combined cycle would also facilitate decentralized rural electrification and industrialization, a potential power-market driver in itself.

Biomass in developing countries

Until the industrial revolution, wood supplied most of the world's energy. Today, it still provides more than 10 per cent, and biomass is the main source of non-commercial energy in developing countries, especially in rural areas, and the fourth biggest energy resource worldwide. In many African states it provides over 50 per cent of industrial energy, particularly for small and medium-sized industries.

In India, there are already a number of small wood gasifier systems in operation. Recent studies indicate that the biomass available there, excluding animal residues, could support electric power plants up to 17,000 megawatts. A research project, funded by the EU, is developing an original method of generating electricity using a burner which gasifies biomass at almost 1,000 degrees C. This process could produce electricity with a yield of almost 30 per cent, which would make it economically competitive.

One issue is the availability of wood from forests. The use of wood as a domestic and industrial energy source is one cause of deforestation, and large amounts of wood are wasted. Moreover, if biomass is used unsustainably (without replanting) there will be a significant release of stored carbon in the form of carbon dioxide. But there is an enormous volume of agricultural and mill residues available. The United Nations Industrial Development Organization (UNIDO) has been running a special programme, initially in Ghana, Tanzania and Uganda, to promote increased efficiency in present biomass use by industry and to encourage users to substitute agricultural residues for wood.

Another issue is the economics of biomass. These seem promising, especially where biomass is available at no or negligible cost: for instance, there is no shortage of forestry residues throughout Africa, Asia and Latin America. Moreover, growing crops especially for energy production by planting trees on marginal lands not currently used for food would greatly expand potential capacity. The wood could be burned directly in a wood-fired power plant, or converted to ethanol. The Worldwatch Institute has calculated that trees planted on marginal, unused cropland in the United States could yield as much as 265 million barrels of ethanol each year, equivalent to 10 per cent of United States gasoline consumption.

BOX 9.7

Heating homes from straw

Biomass projects in Denmark are providing clean and reliable heating for homes and a welcome source of income for farmers.

In Haslem, Denmark, the local electricity utility runs a straw-burning plant that heats schools, factories and about 2,000 homes. The plant burns 28,000 tonnes of straw a year, producing enough hot-water heat to meet all the community's needs in summer and about 70 per cent of demand in winter. It also exports 5 megawatts of electricity to the grid. The straw-fired plant cost US$14 million to build and another US$2 million was invested in the heat transmission system. Measures to reduce pollution accounted for a third of total costs.

Another community heating plant at Feldrin burns woodchip and bark. The fully automatic facility burns 6,500 tonnes every year and provides hot water to about 500 residents through a 24-kilometre pipeline. It cost US$1 million to build in 1986 and was financed by consumers. They either pay a lump sum, or pay according to how much heat they use.

Some problems

Using biomass is not without problems. For instance, there needs to be a continuous flow of gases and biomass for the gasifier to work properly, but the ash content in biomass fuels turns to clinker during the process and can block the production of gas. Ash removal systems add to the cost and complexity of the whole system. The phenomenon of arch formation also causes difficulties. Here some of the fuel is consumed rapidly, leaving a hollow space above the air entry zone in the system.

ESCELSA
ESPÍRITO SANTO CENTRAIS ELÉTRICAS S. A.

OUR COMMITMENT TO EARTH'S LIFE

Espírito Santo Centrais Elétricas S.A. – ESCELSA – is an electricity utility in Brazil. Since 1968 we have distributed electric power in the state of Espírito Santo in the south-east region, and since November 1997 we have been responsible for the power supply to the state of Mato Grosso do Sul in the central-west region.

Supplying power is a long-term issue, so we are used to thinking long-term – and the most important long-term matter is life on Earth. In all our activities – generation, transmission and distribution – we are committed to the environment, and therefore to life.

Our first choice of power supply is renewable resources. That is why we have developed ten small hydroelectric power plants. We are examining integrated micro hydroelectric plants – less than 1,000 kW installed capacity – as a solution for some areas we serve with electricity. And we import 80 percent of our needs from large hydroelectric power plants, like Itaipu and others – also renewable energy sources.

Because we consider renewable sources first, before turning to non-renewable ones, we are continuing to look for renewable sources everywhere. Our search includes participating in the development of hydraulic potentials, especially those located in or near the areas we service, such as in Mato Grosso do Sul.

Natural gas is another option. We have increased our reserves significantly, and introduced natural gas into our plans for future power generation. Using locally produced natural gas means we can generate electricity nearer the load centres, reducing losses and environmental impact. And by using natural gas from petroleum resources, we transform an environmental problem into a solution – electric power.

In the thermal area, we are proposing to use high-efficiency machines which will reduce losses and lead to less exchange of energy within the environment.

As an energy service company, we are also committed to efficient usage and preservation of natural resources. Our programmes in this area include: diagnostic services for industrial and commercial customers, and public lighting; appropriate handling of residuals from some insulating oils; using space cables in urban areas to prevent damage to trees; upgrading old hydroelectric plants to improve their efficiency; and reforesting river borders.

And, in another contribution to sustainable development and to Earth's life, we are supporting elementary schools in teaching young people how to use electrical energy in a rational and efficient way.

Francisco Luiz Sibut Gomide, President

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This stops the biomass falling into the combustion zone. With no fuel supply, and only air supply, the gas quality can deteriorate rapidly, until the production of gas stops completely.

About half the people in the world cook all or some of their meals with biomass, mainly firewood; and biomass in all its forms – wood, agricultural and forestry residues, and dung – meets about 14 per cent of the world's energy demands. In developing countries, it accounts for 35 per cent of energy supplies, more than is met by coal, gas, oil or hydro power. However, using biomass fuels for cooking causes high levels of indoor air pollution, often far above safe levels. The World Health Organization and the World Bank have reported that this pollution is responsible for many acute respiratory infections, and deaths from them, in developing countries. While biomass for industrial energy is an attractive option for businesses in Africa and elsewhere, developing countries are looking for a cleaner, safer alternative to biomass fuels for household use, specifically for cooking. Biogas may be an answer.

BOX 9.8

From distillery wastes to biogas

A large-scale biogas plant in China has achieved impressive results in processing wastes from a nearby distillery and other local factories and is an example of successful technology cooperation. The Beijing Solar Energy Research Institute asked the United Nations Industrial Development Organization (UNIDO) to help with the project, which in turn involved experts from Germany and Denmark to build and test the plant, completed in 1993.

The plant has two 400-cubic metre digesters next to the distillery at Daxing. The distillery waste is highly organic and was previously disposed of in water, using up the dissolved oxygen, killing fish and river life. Now the liquid waste is pumped into pre-storage tanks, then to the digesters, which are concrete tanks with mixers, heating coils and biogas outlets. The biogas is stored in a dome. The plant also treats wastes from a jam factory and oil production.

This biogas plant can treat 10 tonnes of industrial waste a day, producing 2,000-3,000 cubic metres of biogas. The yield is 35 kilojoules of renewable energy per litre of biogas. The project has produced a number of beneficial results:

- a marked reduction in water pollution from the distillery and other local industries;
- a reduction in the use of coal for local domestic energy production;
- major cuts in methane emissions;
- the transfer of technology, skills and understanding which will considerably improve Beijing's capability to design and operate other large-scale biogas plants to treat industrial waste and produce renewable energy.

Biogas

Biogas production is a natural phenomenon: when plant and animal matter decay in the absence of air, the action of certain bacteria produces an inflammable gas. Biogas technology consists of the production of a combustible gas (biogas) and a value-added fertilizer (sludge) by the anaerobic fermentation of organic materials under controlled temperature and other conditions.

The first attempts to recover and use biogas from sewage and animal wastes were made in Europe and the United States in the 1920s. China had its first biogas plant in 1936. There was an increase in biogas-related activities during the 1970s, when two basic biogas plant designs (an Indian model with a floating gasholder and a Chinese alternative with a fixed dome) were developed and field tested. This accelerated the production of biogas in those countries and also led to the spread of the technology to other Asian countries. At that stage, animal dung was considered the main, if not the only input material, and most of the plants were family-sized units attached to rural households. The fertilizer potential of the sludge was not fully recognized either.

The input for biogas production can be any organic material. The most commonly used are human and animal wastes, agricultural crop

BOX 9.9

A "definite sustainable option"

The village of Dhanawas is about 45 kilometres from Delhi. Around 64 per cent of the 151 households had electricity, but it was unreliable and erratic. For example, though the village was electrified, there was not a single streetlight. Eighty per cent of the total energy use in the village was for cooking and heating water, and only 2 per cent of households used electricity for these needs. The main fuels were dung cakes and crop residues.

In 1985, biogas technology was introduced in Dhanawas. The introduction was progressive, partly for cost reasons and partly because plant designs were adapted and modified to reduce costs and improve gas production rates. There was some initial resistance from villagers but by 1994 there were 20 plants installed and others being built.

Those with biogas use it inside the kitchen as a clean fuel substitute for liquid petroleum gas and kerosene. Significantly, the success of the scheme in Dhanawas led to people from neighbouring villages visiting the plants. The Tata Energy Research Institute reported that "biogas technology has emerged as a definite sustainable option to meet the cooking energy requirements in and around Dhanawas".

A survey showed that the biogas generation potential for the village was 237 cubic metres of gas a day. This is the maximum amount of gas that can be generated through community gas plants. The gas requirement for cooking is 340 litres per person a day. However, the villagers have not been keen on biogas community plants: they prefer individual family-size units.

The institute stresses that key to the successful experience in Dhanawas was proper implementation and developing a methodology for post-installation services. Most villagers carry out minor repairs themselves, which has helped to dispel doubts about servicing problems.

residues, aquatic plants, and industrial and municipal solid wastes. The output, biogas, is a mixture of methane, carbon dioxide and hydrogen sulphide, with traces of hydrogen, nitrogen and carbon monoxide. The gas is non-poisonous, does not smell, and burns with a clean blue sootless flame. It is a safe source of fuel that is presently used for cooking, lighting and powering engines.

The potential of biogas technology is in the simultaneous generation of fuel, fertilizer and feed from the same organic material. The benefits for individuals can be clean, efficient cooking and better lighting, as well as improved health by eliminating smoking fuels, and even saving the time spent on collecting firewood. At the community level, biogas is a possible source of power for small-scale, agro-industries and can reduce pollution from human and animal waste. The long-term national attraction is that it can mean savings in foreign currency spent on kerosene and chemical fertilizers, reduce the need for expensive distribution of energy in rural areas, and minimize environmental pollution.

Not without difficulties

There are, however, some difficulties associated with biogas production. The capital cost of a biogas plant, plus the maintenance and repair charges, are usually beyond the means of an average farmer, and even with government loans and subsidies there is still the temptation for farmers to put other needs (livestock, pumps, etc.) first. This raises the question of whether there is sufficient motivation for a small farmer to install a biogas plant. The fact that biogas is a clean, convenient fuel, and the biogas system environmentally sound, is not necessarily sufficient reason. Neither does biogas automatically save energy. Moreover, the amount of food that can be cooked by it is less than can be cooked using dung cakes. Ensuring a steady supply of biogas for any one type of domestic fuel need can also pose problems. For instance, seasonal temperature variations can slow down the pace of biogas production and closing down the system for maintenance or repairs interrupts gas supplies for cooking and lighting. There is reportedly quite a large failure rate of the fixed dome biogas plants, as a result of cracking. Both 'under-feeding' and 'over-feeding' can reduce and even halt the gas production. The biogas plant's main attraction for the farmer is probably as a source of fertilizer.

Small-scale renewable energy production, like this biogas plant, will help provide much-needed energy in the developing world.

> The international community ought to give special attention to promoting the transfer of environmental technologies, a pivotal task in environmental cooperation
>
> Kim Young Sam,
> President of the Republic of Korea

> Transfer of environmentally sound technologies is crucial to the success of Agenda 21
>
> Dato' Law Hieng Ding,
> Minister of Science,
> Technology and the Environment, Malaysia

> I leave here with the fear that unless we all act now with a renewed commitment, my country and many like it would neither have a voice nor a seat at a future Rio
>
> Maumoon Abdul Gayoom,
> President of the Maldives

Increasingly popular

Even with the difficulties outlined previously, biogas technology is becoming increasingly popular in developed and developing nations alike. In many African and Latin American countries, it is being pursued as a rural technology for producing energy and fertilizer, while industrialized countries are turning to it for pollution control and large-scale energy production. Altogether, the technology is being promoted in more than 45 countries. The EU's JOULE programme includes a number of research and development projects aiming, for instance, to increase the sustainable use of biomass for electricity production and fuel manufacture by developing thermochemical conversion.

In many countries, progress is well advanced. In Brazil, where a National Biogas Programme was launched in 1978, there is now a total of 50,000 operational rural biogas plants. Demonstration programmes in Pakistan have generated a demand for 15,000 plants, and nearly 500 family-size facilities have been installed in Pakistan. Countries in Africa are working on adapting the available know-how to suit their agro-climatic and feedstock conditions. Dairy farmers in the United States are investing in biogas plants as an extra farm profit centre. A series of experimental and demonstration plants of various sizes has been installed in Belgium since 1978. Denmark is focusing its efforts on developing biogas generation from farm wastes with the aim of making large farms self-sufficient in energy. Italy has more than 70 agricultural plants built or planned: the largest takes wastes from 24 farms to produce biogas for generating electricity for irrigation.

The leaders in biogas technology and production, however, are China and India. Between them they have over 8.5 million biogas plants in operation, 90 per cent of them in China. There, for example, biogas from food and agricultural wastes makes up nearly 50 per cent of the gas supply to over 10 million rural households. India has set a target of 12 million units in place by 2001.

The Tata Energy Research Institute has shown that using biogas instead of traditional fuels (liquid petroleum gas and kerosene) cuts cooking time and costs, and is a lot healthier in terms of indoor air pollution. Its experiences in Dhanawas (see Box 9.9) have also convinced the institute that biogas plants are a strong alternative to liquid petroleum gas with "enormous significance" for India's national economy. "In the eventuality of rural areas becoming more and more prosperous", it states, "the demand for liquid petroleum gas would far exceed the supply in future, necessitating costly imports, and development of an elaborate network for gas distribution."

Fuel cell power

Fuel cell technology was first used in the 1960s to provide electricity for United States spacecraft. It generates power through an electrochemical process (a reaction between hydrogen and oxygen) rather than combustion. The technology is reliable, flexible in terms of its fuel sources, and virtually pollution-free, and can produce electricity at efficiencies greater than in fuel combustion. It could be used in vehicles (see Chapter 11), homes and industries with considerable environmental benefits.

But the technology is expensive, mainly due to the cells' high-priced parts, including some that are made of platinum. Because of this, it is in a relatively early stage of commercialization, and the world's first commercial fuel cell factory was only opened in late 1995. One company in the United States has produced a 200-kilowatt phosphoric-acid fuel-cell unit and sold it to hospitals and offices in the United States. Users say it is more reliable than diesel generators. A demonstration project using a 2-megawatt fuel cell to supply energy to 1,000 homes in California was launched in April 1996. Another company now produces fuel cells a tenth of the size they were in 1989, cutting the cost because they use much less platinum. This company is among several working to develop fuel cell engines for mass transit. The EU's Solid Oxide Fuel Cell project is planning to build a unit that will produce 20 kilowatts of electrical power.

Further development so that cell technology can extend beyond the present limited niches depends on advances in electrochemistry, and materials and membrane technology. Phosphoric acid, molten carbonate, solid oxide and proton-exchange membrane cells are some of the other areas being investigated, but their viability depends on bringing costs down, demonstrating reliability and improving performance.

Geothermal power

Naturally occurring hot water and steam formations already provide modest quantities of electricity in some parts of the world. But hot dry rock, magma and geopressurized formations represent huge energy sources virtually untapped at present. World resources of hot dry rock alone are estimated to be 20 times all fossil fuel resources. Current geothermal technology derives mainly from technologies used by the oil and gas industry. One problem is that geothermal exploration involves big investment risks. Moreover, the returns from the upfront costs of developing a geothermal field are more gradual than from mineral extraction.

Nonetheless, geothermal is more than an emerging technology in some parts of the world. In the Philippines, for example, it provided 21 per cent of the national power supply in 1992, and the

ENECO

ENECO is the Netherlands' leading utility company, with products and services in the fields of energy distribution (gas, electricity and heat), cable television and telecommunications, waste processing and, to a lesser extent, electricity generation. ENECO operates in an extremely varied home market including the world's biggest port and industrial complex, and agricultural and horticultural areas, as well as areas of greenhouse growers and numerous urban centres, of which Rotterdam and The Hague are the largest.

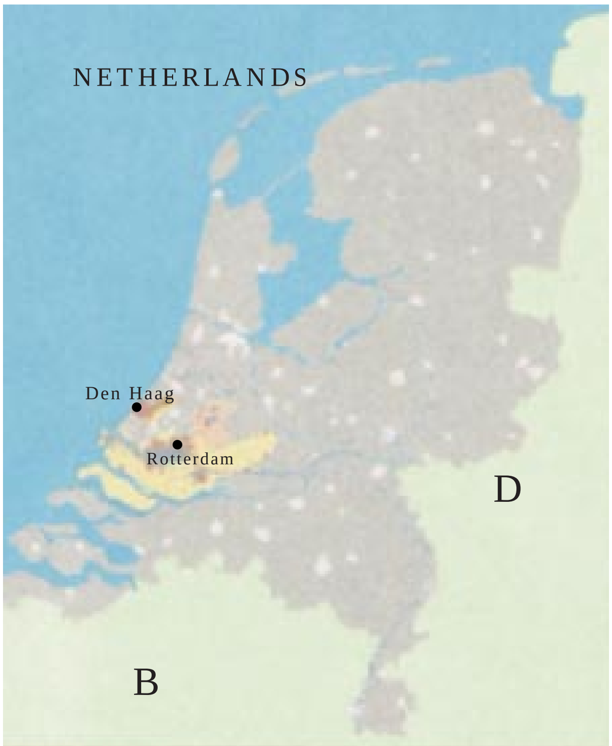
Through its core business ENECO has gained a lot of experience in design, monitoring and managing the necessary networks and equipment for its products. High voltage grids, high pressure natural gas grids and district heating networks are developed by ENECO's engineering departments.

Decentralized production of electricity, combined with the production of heat, is carried out on a small scale. At this moment, ENECO has approximately 170 co-generation units in operation, with a total capacity of 650 MWe. District absorption cooling and gas expansion are examples of innovative technologies which have been applied by ENECO to explore new ways in the field of energy production and distribution.

Consultancy activities are executed on behalf of the beneficiaries of international institutes and banks, such as the European Union, United Nations, EBRD and the World Bank. For an optimal market and customer approach ENECO has established ENERGY & TELECOM Europe B.V., parent company of the organizations for each CEE country which ENECO has entered for developing business. Energy & Telecom Czech Republic Sro and Energy & Telecom Romania Srl are directed by local managers.

International activities
In line with government programmes for the improvement of environmental conditions in Central and Eastern Europe, ENECO supports local energy efficiency measures and develops energy resources for the future. Products and services which are offered on the international market are:

- energy production and supply by means of combined heat-power plants (engineering and investments)
- engineering services in the field of district heating, gas technology and electrical designs
- technical audits, second opinion
- energy measuring, billing and collection, including the required IT knowledge
- energy consultancy services in the field of energy efficiency
- management consultancy in the fields of privatisation, financial accounting, logistics.



International consultancy programmes
During the last decade, ENECO has acquired experience in the field of international consultancy and projects such as:

- environmental audit power plants – Ukraine
- management training programme – Bulgaria
- billing and collection – Russia
- training managers, district heating companies – Poland
- energy efficiency project – Moldova
- gas distribution and district heating – Lithuania and Ukraine
- cable distribution network – St. Maarten (Caribbean)
- evaluation of quotations – Thailand/Jordan.

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government has targeted 1,675 megawatts of geothermal capacity over the next decade. Kenya, one of several East African countries with significant geothermal resources, uses them to meet 6 per cent of its generating capacity. Virtually all the Pacific Rim countries and all those along East Africa's Great Rift and the Mediterranean Sea are well endowed with geothermal energy. Iceland, Indonesia and Japan are among the countries with the greatest potential.

Nor is interest in geothermal confined to the developing countries. Developed countries are active in this area, as just a few examples show.

- Thousands of families in Switzerland are using heat trapped underneath the ground to warm their homes using heat pumps.
- The Netherlands government plans to use heat pumps or low-temperature geothermal energy in 150,000 homes by 2000.
- In France, there are a number of completed projects in Paris, Bordeaux and other regions providing domestic heating and saving the equivalent of 200,000 tonnes of oil each year.
- One of the most ambitious French schemes is in the town of Meaux, 50 kilometres east of Paris, where four wells and a 20-kilometre network of pipes provide heat to 10,500 homes, two hospitals, a swimming pool, several schools, and other commercial and public buildings. This scheme alone has saved more than 150,000 tonnes of oil and is expected to have a profitable life of 30 years.

But geothermal power requires a heavy initial investment, a drawback for most developing and many developed countries. In both the Swiss and French cases, the projects have been possible only with generous financial backing from the government.

Nuclear energy

Nuclear power is an energy source already used in many countries: in 1993 it accounted for 17 per cent of the world's electricity (23 per cent in the Organisation for Economic Co-operation and Development (OECD) region). But it is a technology that attracts so much controversy and opposition that its prospects, at least in the medium term, are extremely uncertain. There is no disputing nuclear energy's performance as an alternative to fossil fuels and in reducing carbon emissions. The Worldwatch Institute estimated in 1990 that increased use of nuclear power during the previous 15 years had displaced 298 million tonnes of carbon emissions annually, 5 per cent of the yearly total. Nuclear reactors also produce negligible emissions of sulphur dioxide and nitrogen oxides. But the technology has several major problems, among them costs, environmental risks and storage of waste.

Nuclear plants, while relatively cheap to operate, are expensive to build. In addition, companies face long lead times and often delays in gaining approval, meeting environmental safeguards and actually building the plants. They also face the costs of disposing of radioactive wastes and decommissioning plants in the future. Such investments become even harder to justify when fossil fuel prices are low.

The other objection to nuclear power is on safety grounds. Despite the industry's insistence that plants are safe, serious incidents like those at Three Mile Island and Chernobyl have severely undermined public confidence and acceptance. Critics claim that the nuclear industry's problems are not due to engineering mistakes, but stem from basic unresolved technological issues, not least the lack of an 'inherently safe' design. Even if nuclear plants themselves were made 'inherently safe' – and the public accepted they were safe – there remain two other problems: what to do with the nuclear waste they produce and how to decommission plants at the end of their life.

At the beginning of 1993, there were 425 nuclear reactors connected to electricity grids, using one of four main reactor technologies. The most widely used is the pressurized light water reactor and the next is the boiling light water

AIMING FOR THE LOWEST POSSIBLE ENVIRONMENTAL IMPACT

Slovenské elektrárne a.s., created from the former state enterprise in 1994, is responsible for electricity production, operating the 220kV and 400kV transmission grids, and importing, exporting and selling electricity. The company supplies 89 percent of electricity in the Slovak Republic, delivering to three regional distribution companies and directly to several major industrial enterprises.

It operates one nuclear power plant, three thermal plants and 30 hydro power plants. A second nuclear plant is being built, and Slovenské elektrárne is participating in the construction of two hydro power plants and one combined cycle power plant.

Slovenské elektrárne focuses its efforts on producing electricity and heat with minimal environmental impacts. The environment has priority in its development programmes, and the company's environmental policy objectives are to

- comply with Slovak Republic legislation and other regulations
- reduce negative impacts on the environment from its own activities to the lowest level possible
- reinforce awareness of staff of the importance of environmental protection, and involve them actively in environmental activities and programmes
- encourage customers to use electric and thermal power rationally
- develop relations and communication with the public to improve mutual understanding on environmental matters.

Slovenské elektrárne has prepared an environmental management and audit programme to aim for continuous environmental improvement in its operations. Environmental technologies are playing a central role in its ongoing drive to reduce harmful SO_2, NOx and ash emissions, including

- installing desulphurization and new fluid boiler technology at the Novaky thermal power plant
- replacing mechanic ash precipitators with electrostatic precipitators at the Vojany power plant
- using desulphurization, denitrification, fluid boilers and turbine side technologies in the reconstruction of the Vojany plant
- installing monitoring equipment to ensure continuous measurement of emissions, and
- carrying out extensive safety upgrading measures at the Bohunice nuclear power plant.

The company also intends to develop renewable resources – which currently account for almost 20 percent of the total power consumption in the Slovak Republic. It has established a specialist centre to focus on research coordination, participation in preparing relevant legislation, and preparing specific projects concerning hydro and wind power stations, using solar and geothermal energy, and harnessing biomass and biogas.

Since 1991, Slovenské elektrárne has spent more than 6 billion Sk in the environmental area, and it expects to invest a further 15 billion Sk over the next ten years to fulfil its commitment to the goal of generating and supplying electricity and heat in a way that is acceptable to the environment.

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reactor. Both designs are based on the use of a relatively high power density core with water as a cooling and moderating medium. The Canadian Deuterium Uranium (CANDU) design is a pressurized reactor using heavy water to cool and moderate a natural uranium core. Most existing gas cooled reactors are based on carbon dioxide cooling of low power density cores fuelled with enriched or natural uranium fuel. This type of reactor is unlikely to be deployed in the future.

Evolutionary advances

Nuclear technologies typically have a very long lead time, so what is on the drawing board today will not be in service until around 2010. The focus is on evolutionary advances, rather than dramatic breakthroughs, and the industry's goals are to increase safety margins, simplify and reduce building and operating costs, shorten lead times and reduce radiation doses to people working in nuclear plants, as well as to improve output.

Another objective is to reduce the amount of uranium used in a reactor. One way to achieve this could be by using mixed oxide fuel in thermal reactors, replacing fissile uranium by fissile plutonium. There are hopes that uranium consumption could fall by 10-15 per cent by 2000. A number of reactor design concepts have been advocated, with a greater use of inherent and passive safety features. These are small and medium-sized reactors, designed to increase safety margins by virtually eliminating the possibility of a core melt accident. If they win public acceptability, they could have a role to play in district heating. Canada has already developed a 2-10 megawatt passive safety reactor specifically for space heating requirements.

Another type of reactor is the high temperature gas reactor, which uses a thorium/highly enriched uranium fuel and can be cooled with helium at temperatures high enough to produce process heat. Past research and development programmes have demonstrated this technology to be feasible. The fast reactor has been demonstrated at large prototype size and can dramatically increase the efficiency of uranium utilization. However, a fast reactor is currently 1.5 times more expensive to build than an equivalent thermal reactor.

In most countries, there has now been a complete stop or slow down in plans to install more nuclear power generation capacity: France and Japan are the only OECD countries publicly committed to expanded programmes, although the Republic of Korea is looking at nuclear power options. Other countries, for instance China, are also considering nuclear power. The World Bank estimated that in 1992 nuclear power provided less than 1 per cent of the energy used in developing countries and said this share "seems unlikely to rise significantly". The International Energy Agency says that "even those countries with rapidly growing economies may find the required capital investment prohibitive". Nuclear power's main hopes of penetrating into most developing countries probably rest on the development and availability of smaller, less expensive reactors and, in the main, these are unlikely to be ready before 2020-2030.

Thermonuclear fusion

As it is clean and has virtually inexhaustible resources (hydrogen, and its heavy isotope, deuterium), controlled thermonuclear fusion by magnetic confinement looks a very promising energy option and could, according to some experts, become a major energy source in 50 years' time. Scientists have been trying since the Second World War to harness the energy released by the union of light nuclei, reactions which occur at the heart of stars like the sun. However, recapturing those conditions poses some difficult experimental problems, since reactions will only take place within a dense gas at temperatures exceeding 100 million degrees C.

Work is moving ahead, and Joint European Torus (JET), a tokamak or ring-shaped reactor

ITAIPU BINACIONAL

FORGING ENERGY WITH NATURE FOR A SUSTAINABLE FUTURE

Itaipu Binacional was created in 1973 by the governments of Paraguay and Brazil to develop and operate the Itaipu hydro-electric project on the Paraná River in the boundary between the two countries. The Itaipu power plant is the largest in the world, both in terms of plant rated capacity (currently 12,600,000 kW and scheduled to increase to 14,000,000 kW by the year 2001 with the addition of two more units), and annual energy output (over 88,000 GWh this year). The project supplies about 80 percent of Paraguay's total electric energy needs and 25 percent of Brazil's.

But the key point is that the high-quality Itaipu energy is renewable, and generated with no pollution – a true gift of nature and a paradigm of a sustainable business.

Moreover, its environmental impact was very low for such a huge project – thanks to its comparatively small reservoir area, of about 1,350 sq. km. Indeed, the reservoir displaced fewer than 40,000 people – and today, more than 15 years after the reservoir was filled, it is confirmed that it has caused negligible climatic damage to the surrounding area.

Itaipu Binacional has devoted considerable time, effort and resources to fulfilling its environmental and social responsibilities to protect the regional biodiversity and improve the standard of living of the local communities.

Before the reservoir was filled, the area was searched and studied for archaeological sites. A special fauna rescue programme was implemented in 1982, and animals were sent to special breeding centres before being reintroduced into the wild, and also to Itaipu's Zoo for scientific purposes. Suitable areas were also bought for the native Guarani Amerindians living near the Paraná River, and these were developed as reservations before being handed over to the Indians themselves.

One major environmental project designed to protect the reservoir shoreline involved buying a 200-metre minimum wide strip of land, running for 2,900 kilometres and covering an area of more than 640 sq. km. Forested areas, mostly on the Paraguayan shore, have been kept in their natural state – while former pastures and agricultural fields, mostly on the Brazilian shore, are being recovered by reforestation with hundreds of native species. To date, about 15 million seedlings have been planted.

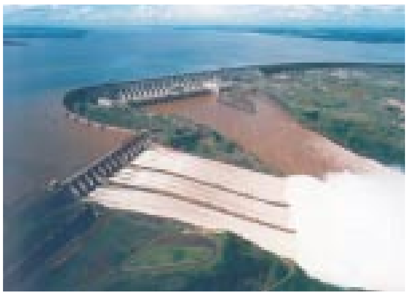
Another major project involves buying pristine forests and other valuable ecosystems near the lake, with two vast biological reserves mostly covered by lush subtropical rainforest, on the Paraguayan shore, five medium-sized biological refuges and a binational park – a total area of about 410 sq. km.

Itaipu is unique among large hydro-electric projects in that the sum of the areas dedicated to conserving biodiversity is nearly as big as the area flooded by the reservoir.

Other programmes include fish hatcheries and aquaculture stations, preserving or reconstituting gallery forests along the lake tributary streams, providing assistance for soil conservation and modern farming techniques, and support for community health care, sanitation and environmental education activities.

Itaipu Binacional has amassed rich and varied experience in the environmental field – and today owns a considerable number of ecological assets, a bequest for future generations. In fact, these assets are already open to be shared with the scientific community, environmental organizations, and people in general.

Much has been done – but more can be accomplished. Itaipu Binacional extends an invitation to all those who can create partnerships and contribute resources – financial and people – to enlarging existing programmes and devising new ones.



Panoramic view of Itaipu's hydro-electric power plant.

Environmental education in the natural resource area of Itaipu.

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whose powerful magnetic fields enable it to contain ionized gases, is one of the most advanced experimental thermonuclear fusion installations in the world. The reactor, built by the EU, is at Culham, in the United Kingdom. In November 1991, for the first time in the world, JET produced 1.7 megawatts of energy for two seconds using a mixture of deuterium and tritium, demonstrating that thermonuclear fusion energy can be produced on Earth. The EU, Japan, Russia and the United States plan a joint project to build an international thermonuclear experimental reactor.

"Real opportunity"

The World Energy Council says that increased use of renewable energy should be encouraged; that there is now a "real opportunity to achieve a sustainable balance" between fossil fuels and renewables; and that the contribution of renewables will increase over the next 30 years. However, non-renewable energy resources will continue to dominate the world's energy market for the foreseeable future. This will certainly be the case in the industrialized countries. For one thing, there has been too much investment in fossil fuels to abandon them easily or quickly; for another, switching to renewables on a huge scale will take years anyway and, importantly, future projections for prices of fossil fuels may make it difficult for renewables to seize market share.

But the situation could prove quite different in developing countries where there is the greatest need for more energy, and where renewable technologies can be well placed to meet that demand. A major factor in their growth could be the level of financial support from the international funding organizations which are still an important lever, even though their resources are dwarfed by private sector funds.

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