WADE

WORLD ALLIANCE FOR DECENTRALIZED ENERGY

World Survey of Decentralized Energy - 2002/2003

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Decentralized Energy

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About Wade

WADE, the World Alliance for Decentralized Energy, works to bring about change in the way the world makes electricity. It is the worldwide representative organization for those parties seeking the economic and environmental benefits of decentralized energy (DE) generation – including high efficiency cogeneration (also known as combined heat and power, CHP) and decentralized renewable energy technologies.

WADE was established in June 2002. Founding WADE members include national cogeneration and DE organizations in Europe (including COGEN Europe), the USA, China, India and Brazil. Founding company supporters include Solar Turbines (a division of Caterpillar), Wärtsilä, Private Power and FuelCell Energy. In total, WADE's direct and indirect membership support includes over 200 corporations around the world.

WADE defines decentralized energy (DE) as the high efficiency production of electricity (and heating/cooling where possible) near the point of use, irrespective of size, fuel or technology. Proven DE generation spans a wide range of technology, capacity and energy sources. Two key divisions of DE are:

- High efficiency CHP with capacities from 1 kilowatt to over 400 megawatts (and which include reciprocating engines, gas turbines, steam turbines, Stirling engines, fuel cells and microturbines);
- On-site renewable energy systems and energy recycling technologies that capture otherwise wasted energy. These can include photovoltaic and biomass systems, on-site wind and water turbine generators.

WADE believes that the world's electricity systems are in need of significant modernization and development along more sustainable and cost-effective lines. Its **Five Point Blueprint** to achieve this is as follows:

1. Grid access on fair and transparent terms for all DE systems;
2. Innovative market-based rules that encourage greater efficiency of electricity and heat generation;
3. Full price recognition for both the locational value (the fact that DE systems produce energy where it is needed) and environmental benefits of DE;
4. New incentives for incumbent monopoly electricity companies to reduce fuel use and improve efficiency;
5. The establishment of well-resourced DE promotion organizations in every country**.**

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Executive Summary

A FIRST WORLD SURVEY OF DECENTRALIZED ENERGY

This *World Survey of Decentralized Energy – 2002* has been produced by WADE in order to give policymakers, the energy industry and the financial community a clear snapshot of where the world is now at in respect of the much discussed shift in the balance of power from central to decentralized electricity (DE) generation (also known as, among other things, distributed generation)[1].

The survey shows that this shift, sometimes known as 'the transformation of electricity' has barely started. This is emphatically not because of the immaturity or the high cost of DE technologies, as the survey makes clear, but rather through the persistence of various barriers to efficiency.

It is becoming increasingly important that these barriers be addressed. To show why, consider this fact:

> *Including losses from T&D systems, the worldwide waste of energy arising from central power is about the same as the total amount of energy consumed by the global transportation sector.*

In addition, with the recent conclusion of the World Summit for Sustainable Development in Johannesburg, the issues of poverty alleviation and access to electricity are now more important than ever. One key hallmark of development is the expansion of access to electricity, and WADE is convinced that the most cost-effective route to the achievement of this goal is through the accelerated introduction of decentralized electricity generation systems.

In short, DE holds a key to poverty alleviation on a massive scale.

PERSISTENT BARRIERS

The survey includes national profiles of nine major countries (Brazil, Canada, China, Germany, India, Japan, Russia, UK, USA) and summarises the current status of DE development, barriers and promotional policies, and prospects for market development in the future.

The assessment of market barriers reveals the persistence of long-standing market, regulatory and policy barriers which tend to favour incumbent utility companies and the maintenance of the status quo – in particular, central power.

Examples of these barriers, which occur in one form or another in most countries in the world, include:

- Unduly awkward and costly arrangements for grid interconnection;
- Restrictive regulatory arrangements for non-utility generators of electricity and/or supply of electricity to the grid and/or third parties;
- No or little recognition of the locational value of DE, for example through transmission and distribution (T&D) system capital deferral, grid reinforcement and reduction of grid losses;
- Power sector reform strategies which largely ignore the opportunity for DE and which frequently present price and market uncertainty for investors.

Most of these barriers are directly associated with the lack of effective and fair competition in national electricity markets and a lack of understanding among regulators and policymakers.

WHAT GOVERNMENTS CAN DO

In summary, the survey makes clear that there are two key strategies that governments need to take forward if DE technologies are to make inroads into today's electricity systems, which remain dominated by central power:

- First, governments should be encouraged to understand that the level of energy waste from central power generation systems can be avoided by making decentralized energy (DE) solutions a priority model for new electrical capacity development. There are abundant and growing commercial opportunities for on-site cogeneration, based on fossil or renewable fuels, in addition to PV, wind power and small-scale hydro. The best thing that governments can do in the short-term is to eliminate the many regulatory and monopoly-based barriers to DE that exist in almost every country in the world.

- Second, power sector reform must be done in a way which does not inhibit DE. A 2002 report from the World Resources Institute[2] confirms the WADE view that *"electricity restructuring provides a rare opportunity to spur the transition to a micropower future based on small-scale distributed generation."* Yet the report concludes that *"closed political processes and politically powerful groups constrain attention to sustainable development objectives."* In other words, power sector reform is derailing the opportunity for DE to cut energy waste and improve social and economic conditions in developing countries.

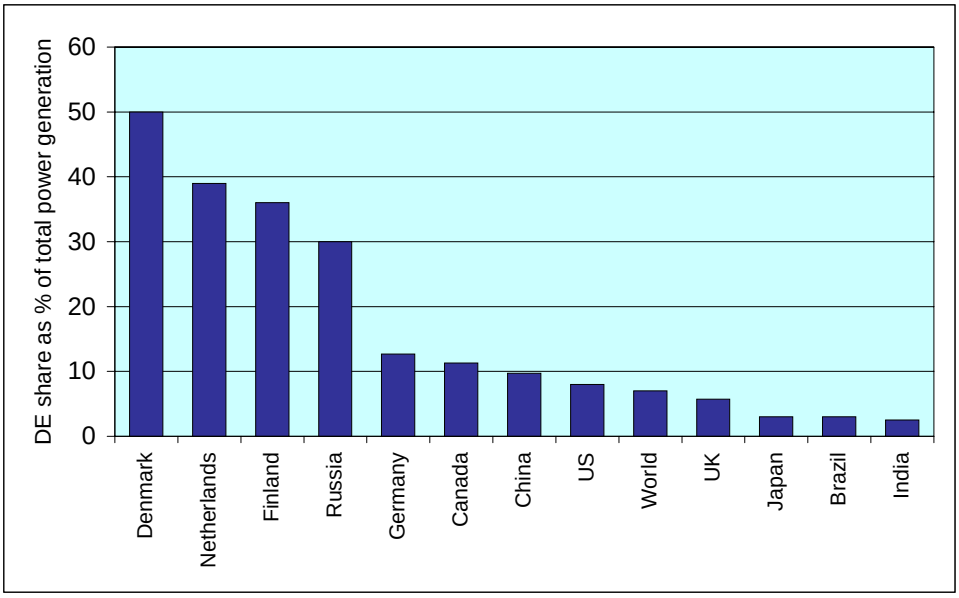
Despite the pervasive nature of long-standing barriers, there are nonetheless emerging examples of national policies for DE, which have proved effective in stimulating markets at particular times. For example, regulatory arrangements which provide a premium price for power from DE systems, renewable energy supply obligations and emissions trading can all be highly efficient tools for policymakers. However, the priority for legislators should be to eliminate barriers by reforming and restructuring energy markets.

Up to now, no government can claim to have taken this challenge seriously.

NEW DATA

Based on analysis of data from the countries profiled, which account for about two thirds of total global installed capacity, WADE estimates that there is no more than 7% of total annual global generation based on DE – leaving 93% based on central power.

FIGURE 1. DE development worldwide as % of total power generation



We have found that obtaining data on DE development is fraught with uncertainty. Different countries collect data in different ways and, while figures for DE generation (in MWh) are more useful than installed capacity (MWe), it is the latter which is more commonly available.

With The Netherlands, Denmark and Finland all holding at least a 40% DE share of the generation market, the scope for global growth of DE is clearly substantial.

MARKET PROJECTIONS

In preparing the survey, WADE has generated three scenarios (‘*Business-as-usual*’, ‘*Growth I*’ and ‘*Growth II*’), which would deliver specific DE market

shares at given points in the future. The survey associates each scenario with different policy approaches to give an indicative view of what may be necessary to achieve a substantial growth in DE market share.

WADE believes that its goal of achieving a doubling of the present share of DE in global power generation is a modest goal compared to what can be accomplished through the wholesale removal of persistent market barriers and the introduction of market based mechanisms to achieve climate change objectives.

This is particularly relevant to the European cogeneration market experience, which has been poor for the last four years and where prospects remain bleak.

SUBSTANTIAL CARBON EMISSION REDUCTIONS

Finally, the survey assesses the potential carbon dioxide emission benefits arising from DE market growth. Under the Growth II scenario, an achievement of a 16% DE share of the global power generation market by 2010 (from 7% in 2000) would deliver at least 25 % of the total emission reductions required to achieve the international Kyoto objectives in full.

1. Introduction

With the ever-growing need for new electricity capacity and increasing concerns over the emissions of greenhouse gases (GHG's), there is a need for the accelerated application of high efficiency, low emission decentralized energy (DE) technologies which can deliver both economic and environmental benefits.

Most national electricity markets have been, or were, monopoly-based for decades and their performance and efficiencies reflect this. In the US, where large power companies continue to hold considerable control of the market, with relatively little competition, the electrical system's efficiency peaked in 1959 at 33% and has remained relatively constant since[3]. The global thermal efficiency of power generation also stands at around 33%.

The problem is not confined to generation inefficiency.

> *Worldwide transmission and distribution (T&D) losses totaled 1,336 TWh in 1999[4], the equivalent of 11.6% of the world's final electricity consumption – or more than the combined electricity demand of Germany, the UK, France and Spain. Including losses from T&D systems, the worldwide waste of energy arising from central power is very close to the total amount of energy consumed by the global transportation sector.*

One of the most important solutions to this massive waste is decentralized energy (DE), including high efficiency cogeneration systems, on-site renewable energy and energy recycling (the use of energy, which would be otherwise wasted, to generate electricity).

DE, however, remains at the margin of most countries' generation portfolios. There remains a bias towards central power in every country in the world, and associated with this, ongoing regulatory and policy barriers to the wider use of DE. To address this profound challenge, however, policymakers and other stakeholders need core information about the status of DE

development around the world, and some idea about its rate of growth. Until now, such an assessment has not been available.

This report provides the first ever worldwide review of DE. In particular, it examines the level of development of DE today, and how the market might grow in the future.

In addition, it summarises the main DE technologies, the barriers to their wider implementation and the degree to which DE market growth can bring about dramatic worldwide reduction in the emissions of CO_2.

2.
DE Technologies

DECENTRALIZED ENERGY

WADE defines DE as electricity production near the point of use, irrespective of size or technology:

1. High efficiency cogeneration of heat and power – 1 kWe - 400 MWe+ (includes gas turbines, steam turbines, reciprocating engines, fuel cells, microturbines, Stirling engines and power produced with recycled energy from flare gases, high temperature waste heat or pressure drop of gas or steam);
2. Decentralized renewable energy technologies, including photovoltaic (PV) systems, small hydro, on-site wind power and localized geothermal production.

COGENERATION

Cogeneration, also known as combined heat and power (CHP), is the simultaneous production of electricity, heat and/or cooling at or near to the point of consumption. This section summarises the principal prime mover technologies.

GAS TURBINES

Gas turbines have been in use for over 40 years in the power generation market[5]. Liquid or gas fuels are combusted within the turbine creating an expansion of gases. As these gases expand and leave the turbine, they are forced through a system of blades that absorb some of the energy and convert it into mechanical energy.

Gas turbines typically convert 20-45% of the input energy into electrical energy[6]. The gas turbine exhaust can be used to produce steam that drives a condensing steam turbine and achieves up to 58% fuel to electric efficiency. By siting the plant near thermal users and switching to a backpressure steam turbine, combined cycle gas turbine CHP plants achieve efficiencies of 85% to 97%.

STEAM TURBINES

Steam turbines are a more long-standing technology, and anchor both ends of electric generation efficiency. When fuel is combusted or hot exhaust gas is used in a boiler to produce steam at high pressures, that steam pressure can drive a turbine that in turn drives a generator. Almost any fuel can be used.

When the steam is simply condensed at the exit of the steam turbine, between 15% and 38% of the energy in the fuel or exhaust is converted to electricity. This was until recently the dominant technology for all new central generation plants, including nuclear power, and is at the bottom of the efficiency scale among today's technologies.

By contrast, a backpressure steam turbine produces two products, heat and power. The turbine extracts some electricity from the steam, lowering both the pressure and temperature of the steam. The steam is then used to supply thermal energy to a process, or to heat and cool buildings, replacing boiler fuel. The efficiency is measured by the power produced divided by the net change in fuel to meet the thermal load, and often exceeds 85% efficiency. In the many cases where steam condensate is not returned to the boiler, the turbine can produce fuel-free electricity.

RECIPROCATING ENGINES

Also known as internal combustion engines, reciprocating engines are available in sizes that range from 1 kWe – 15 MWe[7]. Cogeneration capability also exists since most of the input energy leaves as heat. Reciprocating engines are also widely used for back-up power and mobile generation, typically generating electricity and not recovering waste heat.

MICROTURBINES

Microturbines are smaller versions of gas turbines. Typically in the 25-500 kWe range, they are capable of electrical efficiencies of 20-30% with the clear possibility for use in cogeneration mode[8]. These systems are now becoming commercially available although there remains ongoing scope for cost reduction and efficiency improvement.

STIRLING ENGINES

Stirling engines are external combustion systems since the fuel does not enter the working cylinders. Instead, it is combusted outside of a cylinder to warm an inert gas, which is sealed within the cylinders. It is this inert gas, typically hydrogen or helium, which does the actual work on the pistons. Currently, Stirling engines are capable of electrical efficiencies of 12-25% in the 1-25 kWe range. Commercial availability is expected by 2005[9].

FUEL CELLS

Fuel cells, ranging in size from 1kWe to 10MWe, are electrochemical energy conversion devices that use hydrogen and oxygen to produce electricity, heat, and water. The electrical production is relatively efficient when hydrogen fuel is used (40-60%) since there is no combustion or large moving parts involved and therefore less energy conversion to heat losses[10].

It is a relatively new technology and capital costs remain high - in the $3,000-$5,000+/kWe range[11].

The future potential for fuel cells as important on-site power plants awaits significant cost reductions, which the leading vendors believe will occur with volume. The molten carbonate technology and the solid oxide technology both achieve close to 50% fuel to electricity efficiency and both have exhaust heat suitable for combined cycle plants and CHP. The current technology has nearly zero emissions of NOx and can achieve comparable efficiency to the largest combined cycle gas turbine (CCGT) central plant.

The current capital costs per kilowatt of capacity and uncertainties about the component lives have limited penetration. At the end of 2001, there was a worldwide total of only 45 MWe of fuel cell capacity with 1 GWe projected for 2006[12].

BIOMASS ENERGY

Biomass is regarded as a renewable fuel and has considerable potential for use in DE cogeneration systems, including those discussed above. For electricity generation, the potential energy stored in biomass is typically extracted in one of the following ways:

- Direct combustion of the biomass within a boiler can produce steam to drive a steam turbine. In this case, only certain biomass materials are used in order to avoid ash buildup, which decreases efficiency and increases costs.

- Processing the biomass through a gasifier, which converts the liquids and solids into a combustible gas. This gas can then be used as a fuel for a gas turbine or (CCGT.

PHOTOVOLTAICS

Photovoltaic (PV) cells are able to produce electricity directly from sunlight. Photons within the sunlight transfer their energy into electrons found in semiconductors that are typically made of single crystal silicon. Currently, PV is capable of efficiencies of 5-15% in the 1-100 kWe range but has relatively high capital costs[13]. The levelized life cycle cost of current PV modules is estimated at $0.27/kWh by the National Renewable Energy Labs of the US Department of Energy. At this cost, grid connected solar PV is seldom economic, but can be a good choice for applications remote from the nearest grid, including most of the underdeveloped world and some applications in industrialized countries.

The levelized life cycle cost has been projected to fall to $0.10/kWh by 2020, which compares favorably with the cost of centrally generated power during peak hours. The expected transition to time of use electric pricing

coupled with value improvements could make rooftop PV economic in much of the world within two decades.

A number of large energy companies, including BP and Shell, have made major commitments to PV, whose market has been growing at 40% per year in generating capacity installed, albeit from a very small base.

SMALL-SCALE HYDROPOWER

Small hydro generating stations, up to 10 MW, utilize the head or gravitational potential energy found in flowing rivers and streams. These small hydro installations utilize 'run of river' and do not require the massive dams or create the ecological threat of large hydro projects. The potential world wide for run of river hydro is significant. The government of Nepal has identified sites capable of generating 80,000 MWe, roughly equal to the present peak load of India.

ON-SITE WIND TURBINE

Wind turbines convert the kinetic energy of wind into electricity. Wind power development is largely focused on 1-5 MWe turbines. However, there are also companies developing wind turbines with outputs ranging from a few to several hundred kWe. As the technology breakthroughs in the large turbines migrate into smaller capacities, DE wind power will become cost-effective in many areas.

The large wind turbines have a current levelized cost of roughly $0.07/kWh, just slightly over the levelized cost of new central power at $0.069/kWh. NREL projects these costs will drop to $0.065/kWh by 2010 and to $0.06/kWh by 2020. The DE versions, by avoiding new T&D, may reach levelized costs of under $0.04/kWh by 2020.

Table 1, on the following page, summarises the main features of key DE technologies.

TABLE 1. Technological comparison of DE prime movers. Source (in part)[14])

	Electrical Efficiency (%)	Cogeneration Efficiency (%)	Size Range	Fuel
Gas turbine	28-40	80-97	500 kWe-300 MWe	Natural gas, liquid fuels
Steam turbine	25-35	80-90	Extensive	Natural gas, liquid and solid fuels
Reciprocating engines	25-40	50-70	1 kWe – 15 MWe+	Combustible gas, gasoline, diesel
Microturbine	25-30	50-80	25-500 kWe	Natural gas, diesel, propane
Stirling engine	12-20	50-70	1-25 kWe	Natural gas and some liquid fuels
Fuel cell	30-55	70-96	1 kWe-10 MWe	Natural gas, fuel oil, hydrogen
Biomass systems	17	60-80	Extensive	Biomass – gases, liquids, and solids
Photovoltaics	6-19	N/a	1-100 kWe	Sunlight
Small hydro	N/A	N/a	<10 MWe	Water head
On site wind	N/A	N/a	5 kWe-5 MWe	Wind

3.

The Policy and Regulatory Context

For the wider growth of DE to occur, a number of conditions within electricity markets must change to permit a fairer and more competitive market environment.

The bulk of existing market structures and regulations were set in place many decades ago when the goal was rapid electrification and the available technology was limited to coal and hydroelectric generation. Nearly every country in the world granted monopoly protection to a power generation and distribution entity as a way to speed electrification, and then established a price-setting structure that would prevent excessive profits to the monopoly.

Many other regulations were passed, in part at the urging of the local monopoly, that assumed generation would always be from central plants and that all power would flow through T&D wires.

As new technology has been developed that makes on-site generation economically and environmentally superior to central generation, the old rules have become barriers to efficiency. These barriers remain widespread - but innovative policy incentives continue to emerge. This section summarises both.

BARRIERS

MONOPOLY BASED ELECTRICITY MARKETS

Power markets and regulations that are organised on a monopoly-based centralized generation system can and do create significant difficulties for DE. Governments have traditionally regulated electricity production and pricing to allow for costs to be recovered and reasonable profits for generating companies. The typical regulatory approach has not rewarded the monopoly for increasing overall system efficiency, so there has been no real incentive to increase this efficiency.

In addition, in monopoly-based markets, smaller independent generators have tended not to 'fit' comfortably with the single utility model, and a number of the issues raised below are a direct consequence of this. These and other barriers have now been well documented in dozens of countries around the world.

INTERCONNECTION ISSUES

In many countries, monopoly-based distribution companies have final say on DE grid interconnection – an essential service for much DE. There are countless examples around the world - for example, in Ontario, Canada, there have been cases where the local utilities have forced small generators to over-design facilities, resulting in a 5% increase in capital costs[15]. COGEN Europe has also documented this issue in some detail[16].

LITTLE RECOGNITION OF LOCATIONAL VALUE OF ELECTRICITY

Transmitting and distributing electric power from central plants represents 40% or more of the retail cost of power and can increase to 90% of the power cost in dense urban or remote areas. DE plants, located at or near users, avoid this T&D cost, but pay somewhat more for fuel. Since it costs around seven times more to transport electricity than it does to transport a fuel, it makes greater sense to locate power generation near its point of use.

But regulatory rules do not often recognize the locational value of electricity, and almost never set power purchase rates that reflect transmission avoidance savings. DE plants sized to the nearby thermal load with generation in excess of the on-site needs benefit the grid. The excess power, regardless of contract terms, flows to the neighbors and lightens demands on the grid. However, the benefit is not usually recognized or compensated, which makes DE more difficult to finance.

STANDBY POWER COSTS

Standby charges should compensate the grid for supplying electricity at times when DE is unavailable. Most DE plants have failure rates under 2% and planned maintenance of another 2% (which is normally performed during off peak periods). A standby capacity charge based on 5% of the DE capacity would cover the utility's costs and profit. but charges are often based on costs of supply at peak load. This can be 20 times higher. In most countries, the rules forbid backup supply of power from any other entity, so there is no market discipline to moderate the standby charges.

Finally, every country has kept in place rules prohibiting private electric wires that cross any public street. A DE plant cannot procure backup power from a neighbouring DE plant, or from any other electric generator, but must deal with the local utility.

REGULATORY UNCERTAINTY

Uncertainty as to how the electricity and/or gas markets will be regulated in the future can make companies reluctant to invest in their own electricity generation facilities. This is a particular issue in those countries which are undergoing restructuring and liberalization. Not only are investors unsure how future markets will work, but there is also added uncertainty over future power prices – the cornerstone of DE investment.

ENERGY MARKET LIBERALIZATION/RESTRUCTURING

Not only can energy market liberalization create uncertainty (see above), but it can also present other challenges. In some countries, the introduction of competition into the market can increase prices in the long run, through the consolidation of market power within a less regulated environment. This has happened in Germany, for example.

In the UK, the New Electricity Trading Arrangements (NETA) were developed to improve competitiveness and to enable the distribution system more effectively match demand with supply. However, the system penalizes producers that cannot accurately forecast the amount of power they will supply to the grid. This causes substantial problems for small generators, including cogeneration and renewable energy, which can face severe and disproportionate financial penalties if they fail to deliver their committed supply.

DEBT RETIREMENT TAXES (STRANDED ASSETS)

A debt retirement tax is often imposed on DE generators to cover the costs of assets developed in a period of monopoly control, but which now face more competitive markets.

FUEL AVAILABILITY

For some fossil fuel-based DE technologies, fuel availability is a critical issue. Gas turbines, for example, typically run on natural gas and fuel cells ideally require hydrogen. If these fuels are unavailable, it eliminates some, but not all, alternatives.

Sweden, Finland, Greece, China, India and many developing countries are all examples of nations that lack a complete piped natural gas network, severely limiting the scope for cogeneration development, though perhaps enhancing the opportunity for renewable DE systems.

ENVIRONMENTAL RULES

Clean air policies have usually assumed that central generation will always be the norm and typically opt for two methodologies that severely penalize DE. First, the regulations assume all power plants are roughly equal and set pollutant allowances relative to the fuel input. Such allowances are usually expressed in parts per million of the pollutant in the exhaust. Since exhaust volume is a function of the fuel burned, the amount of pollutant allowed ties

to the fuel burned. Efficiency is penalized, since less efficient plant is granted more allowance to pollute than the efficient plant. DE that avoids T&D losses and recycles normally wasted heat often has double the efficiency of central power, but gains no credit from the environmental rules for reducing pollution.

The second issue is the granting of permits based on the time a plant was built and the technology then in use, and then 'grandfathering' that right to pollute. In the US, for example, new plants that will emit less than 2% of the pollution per kWh of the worst existing plants are denied air permits unless they install expensive control technology to reduce their emissions to 1% of existing plants. This approach gives old central plants an invaluable right to pollute and prevents the turnover of capital stock. It is particularly hard on DE plants because their efficiency is not recognized and the cost of 'end-of-pipe controls' does not scale.

A system of pollution allowances based on useful energy produced, including allowances per kWh of thermal energy, would level the playing field. It would create added revenue streams for clean DE from sale of excess allowances and increase the cost of operating old plants, due to the cost of purchasing pollution allowances or adding more controls.

BEST PRACTICE DE POLICY

FISCAL INCENTIVES

Tax incentives from governments can be used effectively to promote the development and diffusion of DE, especially where initial costs are high.

In the USA, Congress may endorse a 10% tax credit for all cogeneration investments as part of President Bush's alternative to the ratification of the Kyoto Protocol. Through this, the plant's owners may take a credit against all federal taxes they owe, or will owe, over the next 15 years equal to 10% of the capital cost of the CHP plant. This has the effect of reducing the plant's cost by 10%.

GAS TARIFF INCENTIVES

In most energy markets, the price per unit of natural gas decreases as consumption increases. This can put smaller cogenerators at a disadvantage. Some countries have tried to overcome this problem by ensuring more competitively priced gas is available to smaller power producers. Other interventions are also possible. In 1987, for example, cogeneration projects in the Netherlands were exempted from the energy tax on all purchased natural gas[17].

Most local gas distribution companies experience low load factors, with customers purchasing peak gas for the coldest day of the winter, but only purchasing gas for domestic hot water heating in the warmer months. Rates are set to recover the distribution system capital assuming this low load

factor. CHP plants, by contrast, have steady demand for gas all year, and essentially overpay their share of the capacity without special cogeneration rates. Some US states have adopted cogeneration rates that recognize this load factor gain and cut gas costs by as much as $4.00/MWh of gas.

RENEWABLE ENERGY OBLIGATIONS AND CERTIFICATES

An increasingly popular market mechanism for promoting renewable DE is the trading of 'renewable energy certificates', in which electricity suppliers are given obligations to provide a given proportion of their total supply through renewable energy. For example, the Australian Renewable Energy Act consists of new legislation that obliges wholesale energy distributors to buy a certain fraction of their power from renewable sources, which can include cogeneration.

A similar example is the US federal renewable energy portfolio standard (RPS), which was passed by the Senate in April 2002. The RPS requires that an additional 1% of US electricity is generated from new renewable energy sources by 2005 and 10% of US electricity by 2020.

REGULATED ELECTRICITY TARIFFS

Since one of the key variables for determining the economic feasibility of DE is the price of electricity, market uncertainty creates an investment risk. One solution is to assure a predetermined tariff for the electricity generated. One of the drivers for the rapid growth of cogeneration in the Netherlands in the 1990s was regulated feed-in tariffs for electricity, and the same approach has been used, perhaps excessively, for windpower in Germany and other countries.

ENVIRONMENTAL INCENTIVES AND CARBON TRADING

Growing environmental concerns are resulting in an increasing number of government-driven incentives for DE. Carbon trading promises to be one of the most important influences, with schemes already underway in a handful of countries, including the UK. In essence, such mechanisms give a financial value to each tonne of CO_2 reduced through DE generation. In time, WADE expects that the trading of carbon emissions will become a major worldwide driver for high efficiency cogeneration and decentralized renewable technologies.

4.
National Profiles

BRAZIL

CONTEXT

Brazil's electricity system is undergoing significant change – but its central hydropower-based system is proving insufficient to supply the country's growing energy needs. Most cogeneration in Brazil is used in sugar mills. There is considerable potential in other industrial sectors such as pulp and paper and in remote, off-grid communities. Table 3 provides relevant data.

TABLE 3. Electricity and DE data, Brazil[18] (2000)

Total electricity generation	332 TWh
Total electricity capacity	70 GWe *
DE generation	9.8 TWh
DE capacity	2.8 GWe
% DE of total generation	3 %
% DE of total capacity	4 %

* Including the Paraguayan half share of the of Itaipu hydropower system.

KEY DRIVERS TO DE

- Urgent need for capacity due to urbanization and increased demand;
- Hydro generation is falling short of demand;
- New availability of natural gas from Bolivia and Argentina;
- Need for improved efficiency in sugar mills.

KEY BARRIERS TO DE

- Monopoly-based market structure;
- Limited natural gas distribution network;
- Need for updated interconnection rules;
- Unattractive arrangements for sale of excess capacity;

PROSPECTS

Natural gas distribution and use has been increasing since 2000. This is likely to allow for greater cogeneration opportunities. There are special incentives in a 2002 law for small hydro, biomass and geothermal energy. Prospects for DE are therefore potentially bright.

CANADA

CONTEXT

Canada, with a number of individual provincial power systems, relies heavily on hydro, coal and nuclear generation, with DE development so far accounting for about 11 percent of total generation. Some provinces, for example Alberta, have already liberalized their electricity markets only to find that overall power prices are rising[19]. Nevertheless new cogeneration projects are being developed, but generally not serving the needs of cities.

Most DE in Canada is used to supply electricity and heat to industry (larger-scale cogeneration), with pulp and paper being the largest user. The growing heavy oil industry is the largest growth sector for new industrial gas-based cogeneration projects, and some new wind and small hydro projects are developing. Table 4 provides relevant data estimates.

TABLE 4. Electricity and DE data, Canada[20]

Total electricity generation	576 TWh
Total electricity capacity	110 GWe
DE generation	65 TWh*
DE capacity	13.0 GWe*
% DE of total generation	11.3 %
% DE of total capacity	10.9 %

* Includes wind power.

KEY DRIVERS FOR DE

- Tax incentives in the form of accelerated depreciation to encourage investment in high efficiency cogeneration;
- Good supply of natural gas;
- The price of electricity is expected to rise.

KEY BARRIERS TO DE

- Lack of awareness of the multiple benefits of DE;
- Inadequate long term planning in the energy sector;
- Not all markets have yet been deregulated;
- Energy market restructuring does not always consider thermal loads;
- Relatively low price of electricity;
- No national objectives for cogeneration or renewables;
- Some regional focus on CCGT rather than cogeneration.

PROSPECTS

Overall, prospects for cogeneration and renewable DE are good, but limitations to potential growth remain due to the low relative marginal cost of power generation and persistent barriers in some of the power markets. Cogeneration is becoming more attractive within the industrial/commercial sector as electricity prices start to rise. Canada's position in respect of the Kyoto Protocol, as well as need for low air pollution and energy security, will also be medium-term drivers for the sector.

CHINA

CONTEXT

In the 1970's and 1980's, China became concerned about energy-saving for the first time. The government consequently developed an energy saving policy, sparking a relatively rapid development of cogeneration systems in the late 1980's and 1990's. Most DE in China consists of coal-fired cogeneration, supplying heat to municipal district heating systems and industrial sites. Table 5 provides relevant data.

TABLE 5. Electricity and DE data, China[21]

Total electricity generation	1,233 TWh
Total electricity capacity	298 GWe
DE generation	c. 120 TWh (based on 4000 h/yr operation)
DE capacity	c. 30 GWe
% DE of total generation	9.7 %
% DE of total capacity	10.3 %

KEY DRIVERS FOR DE

- An Energy Conservation Law was approved in 1997 aimed at promoting energy conservation, including cogeneration;
- Almost half of the cities in China have some form of centralized steam or hot water distribution system, ideal for cogeneration;
- A World Bank financed programme for rapid renewable energy development;
- Overseas aid initiatives, for example, a recent $15 million grant from the Dutch Government to supply 78,000 household PV systems in remote areas.

KEY BARRIERS TO DE

- The recent ending of a promotion programme for energy efficiency and cogeneration;
- Regulatory uncertainty within the electricity sector due to continuing government control and slow liberalization;
- Interconnection challenges;
- Electricity overcapacity.

PROSPECTS

China's level of cogeneration and DE development is above the global average but could be greatly increased since over 90% of the generation is fossil fuel-based and the country is still rapidly developing. Thermal generation capacity is forecasted to grow at 5% per year between 2001 and 2005, with an estimated potential increase of 3 GWe annually in cogeneration capacity during that period. By 2005, DE cogeneration capacity could reach 43 GWe.

GERMANY

CONTEXT

For several decades, a few large electricity companies and transmission grid operators have expanded their share of the power generation market, constraining decentralized industrial and municipal generation, mainly cogeneration, through strategic pricing. Between 1970 and 1995, the share of industrial generation fell from 18% to 7% of total generation, while that of municipal cogeneration district heating systems rose slightly above 4%, due only to government subsidies for coal fired cogeneration[22]. Table 6 provides relevant data.

TABLE 6. Electricity and DE data, Germany[23]

Total electricity generation	551 TWh
Total electricity capacity	114 GWe
DE generation	70 TWh
DE capacity	11 GWe
% DE of total generation	12.7 %
% DE of total capacity	9.6 %

KEY DRIVERS FOR DE

- Existing non-operational cogeneration plants that can be brought back into use;
- Incentives for municipal cogeneration and sub 2 MWe cogeneration;
- The '100,000' roofs programme which provides soft loans for PV installations above 1 kWe.

KEY BARRIERS TO DE

- The major generating companies have consolidated and continue to hold considerable power and tend to discourage cogeneration and DE;
- Low wholesale electricity prices.

PROSPECTS

There is a technical potential for at least a 50% DE share of the generation market. New incentives are being introduced as Germany makes growing efforts to meet its climate change commitments. The country is rapidly advancing in the renewable field and has had significant success with its wind, biomass and solar programme as target capacities are met ahead of schedule.

INDIA

CONTEXT

The Indian electricity system is in need of urgent investment and development. There has been healthy economic growth which is creating a demand for electricity in excess of available supply. The losses from the T&D system alone are 15-30%. There is tremendous potential for DE in the industrial, sugar cane and renewable energy sectors. India's use of DE is mainly in the form of bagasse-based cogeneration in sugar mills. Table 7 provides relevant data.

TABLE 7. Electricity and DE data, India[24]

Total electricity generation	520 TWh
Total electricity capacity	105 GWe
DE generation	13 TWh
DE capacity	2.6 GWe
% DE of total generation	2.5 %
% DE of total capacity	2.5 %

KEY DRIVERS FOR DE

- High priced and unreliable electricity supply;
- Government capital grants and soft loans;
- Rapid growth in electricity demand.

KEY BARRIERS TO DE

- Lack of adequate policy framework;
- Lack of awareness, technical knowledge and support services;
- Shortage of investment finance;
- Limited natural gas network for cogeneration.

PROSPECTS

Prospects for substantial growth in the DE market are potentially bright. For example, India's 10th Five Year Plan contains plans for 10,000 MWe of new renewable installed capacity by the year 2012. This will include two million solar home lighting systems and one million solar water-heating systems. In September 2001, the Ministry of Power estimated that there was a total potential for some 15,000 MWe of cogeneration capacity, of which 2,000 MWe had been implemented to date.

JAPAN

CONTEXT

The Japanese electricity market became subject to reform and restructuring from the late 1980s. This has allowed for a small degree of DE and cogeneration penetration. The power market remains largely under the control of a few large electricity companies.

Cogeneration capacity is mainly found in the industrial and commercial sectors with heavy oil and town gas as the primary fuels. There has been limited renewable energy development to now. Table 8 provides relevant data.

TABLE 8. Electricity and DE data, Japan[25]

Total electricity generation	1,092 TWh
Total electricity capacity	259 GWe
DE generation	33 TWh
DE capacity	6.75 GWe
% DE of total generation	3.0 %
% DE of total capacity	2.6 %

KEY DRIVERS FOR DE

- Obligations to reduce GHG emissions following Japan's ratification of the Kyoto Protocol;
- Japan is poor in natural resources, providing significant incentives to reduce energy consumption;
- Soft loans, subsidies, and tax incentives for DE.

KEY BARRIERS TO DE

- Limited availability of high cost natural gas;
- Costly and lengthy interconnection process;
- Deregulation of the power market remains incomplete, with no specific framework for DE.

PROSPECTS

The Japanese General Energy Research Council has produced targets for future energy production, which calls for 4.65 GWe of natural gas cogeneration and 4.82 GWe of solar generation by the year 2010.

RUSSIA

CONTEXT

The Russian energy market creates a potentially ideal opportunity for DE and cogeneration implementation. There is great demand for district heat and electricity demand is growing rapidly. Most of the current capital stock is old and in desperate need for replacement or retrofit. Around 30% of generation is from cogeneration, mostly in association with municipal district heating, and there remains great potential for DE as a whole. Table 9 provides relevant data.

TABLE 9. Electricity and DE data, Russia[26]

Total electricity generation	846 TWh
Total electricity capacity	214 GWe
DE generation	254 TWh
DE capacity	64 GWe
% DE of total generation	30 %*
% DE of total capacity	30 %

* A figure of 30% is used for generation share as a guideline only. Its origin is the 30% capacity share shown in the table. In reality, most Russian CHP capacity does not operate in high efficiency CHP mode at all times.

KEY DRIVERS FOR DE

- Good demand for district heating and industrial steam;
- Good supply of natural gas;
- Much old power generation equipment in need of replacement.

KEY BARRIERS TO DE

- Lack of investment financing, partly because country risk is high;
- Low electricity prices, which are not set at market rates;

PROSPECTS

Russia lacks the opportunity to finance much needed investment in cogeneration and DE. Once this situation changes, there could be rapid market growth based on growing demand and abundant natural resources.

UK

CONTEXT

Prior to the reform of the electricity market in 1989, the power industry was dominated by one large generating and transmission company, the Central Electricity Generating Board (CEGB). A fully competitive market was achieved by 1999, with DE and cogeneration market growth taking place until a further round of market reform and rationalization with the adoption of the New Electricity Trading Arrangements (NETA) in 2001.

Virtually all DE development is based on fossil-fired cogeneration systems. In terms of installed capacity, most of these are in the industrial sector. Table 10 provides relevant data.

TABLE 10 . Electricity and DE data, UK[27]

Total electricity generation	383.4 TWh
Total electricity capacity	79.6 GWe
DE generation	22.2 TWh
DE capacity	4.9 GWe
% DE of total generation	5.7 %
% DE of total capacity	6.2 %

KEY DRIVERS FOR DE

- Strong incentives for renewable energy based on grants programmes and electricity supplier obligations;
- An exemption from the Climate Change Levy for electricity produced in certified ‘good quality’ cogeneration plant and consumed on-site, with a commitment to extend the benefit to exported power;
- Accelerated capital allowances for corporation tax for good quality CHP.

KEY BARRIERS TO DE

- Low electricity prices (and high gas prices for cogeneration);
- NETA subjects small generators to substantial financial penalties, owing to the increased risk profile of these generators under the arrangements.

PROSPECTS

The new UK Government cogeneration strategy (2002) contains several potential incentive measures, including the elimination of the negative impacts of NETA on smaller generators. However, in the specific area of NETA, the independence of the regulatory authority means that the Government has no real power to act without new primarily legislation.

Renewable energy is set for potentially high growth if national GHG emissions and renewable energy targets are to be met.

USA

CONTEXT

The electricity market in the United States has been dominated by large generating and supply companies, with only limited competition. The introduction of the Public Utility Regulatory Policy Act (PURPA) in 1978 allowed specified non-utility owners to operate generating facilities, providing their overall efficiency was 47%. The law stimulated cogeneration, but also incentivised over-sized systems. In 1992, Congress passed the National Energy Policy Act that allowed non-utility companies to build central power plants and compete in the wholesale markets to sell the power. Since then, the DE market has been slow. Industrial cogeneration accounts for over 90% of total DE capacity in the US. Table 11 provides relevant data.

TABLE 11. Electricity and DE data, USA[28]

Total electricity generation	3,800 TWh
Total electricity capacity	787 GWe
DE generation	304 TWh
DE capacity	46 GWe
% DE of total generation	8.0 %
% DE of total capacity	5.8 %

KEY DRIVERS FOR DE

- Need for higher quality power supply;
- Congested T&D lines;
- A possible tax credit for cogeneration and renewable energy projects;
- The development of a new Renewable Energy Portfolio Standard.
- Concerns about system vulnerability to extreme weather events and terrorist actions

KEY BARRIERS TO DE

- Non-standardised grid access arrangements across the USA;
- Continuing monopoly practices by energy utilities;
- Emissions standards that do not reflect the efficiency of cogeneration.
- Continued ban on private wires
- Prohibitions against third party power sales in 15 states

PROSPECTS

Pending legislation and regulatory actions aim at standardised interconnection arrangements for DE, and several major states have enacted interconnection standards. The pending national energy bill encourages time of use pricing, provides a tax credit for CHP, mandates renewables and possibly recycled energy, and otherwise opens the market. However, most of the barriers are State laws and regulations. The energy debate has turned to two main themes, barriers to efficiency and distributed generation. If these debates produce market liberalization, the US market for DE could explode. The US Department of Energy has set a target to double the level of cogeneration to 92 GWe by 2010.

5.

Worldwide DE Data

First and foremost, international DE data remains sparse and national statistics, in those few countries that actually gather them, are collected in very different and often unreliable ways. Nonetheless, WADE has gathered, as far as is possible today, the DE capacity and generation data from selected large countries with a view to extrapolating these figures to derive a global view.

This analysis, based on sources providing figures for 1999 and 2000, is a summary of the data presented in the previous section and is shown in table 12 and figure 1 below (figure 1 also provides data for cogeneration/DE development in Denmark, Netherlands and Finland, the world leaders in the field).

TABLE 12. International DE data (1999/2000)

	Total electricity generation (TWh)	Total electricity capacity (GWe)	DE generation (TWh)	DE capacity (GWe)	% DE generation	% DE capacity
Brazil[29]	332	70	10	2.8	3.0	4.0
Canada[30]	576	110	65	13.0	11.3	10.9
China[31]	1,233	298	120	30.0	9.7	10.3
Germany[32]	551	114	70	11.0	12.7	9.6
India[33]	520	105	13	2.6	2.5	2.5
Japan[34]	1,092	259	33	6.8	3.0	2.6
Russia[35]	846	214	254	64.0	30	30
UK[36]	383	80	22	4.9	5.7	6.2
USA[37]	3,800	787	304	46.0	8.0	5.8
Total	**9,333**	**2,037**	**891**	**181.1**	**9.5**	**8.9**

The data for these nine countries is based on cogeneration capacity and production only. While there are a number of DE technologies currently in use, we believe that cogeneration represents at least 96% of total DE in the selected countries as a whole. For example, according to the US Energy Information Administration, non-cogeneration DE capacity in China makes up no more than 0.2% of total capacity. Data will be included in future surveys as their markets develop and as data collection becomes more thorough[38].

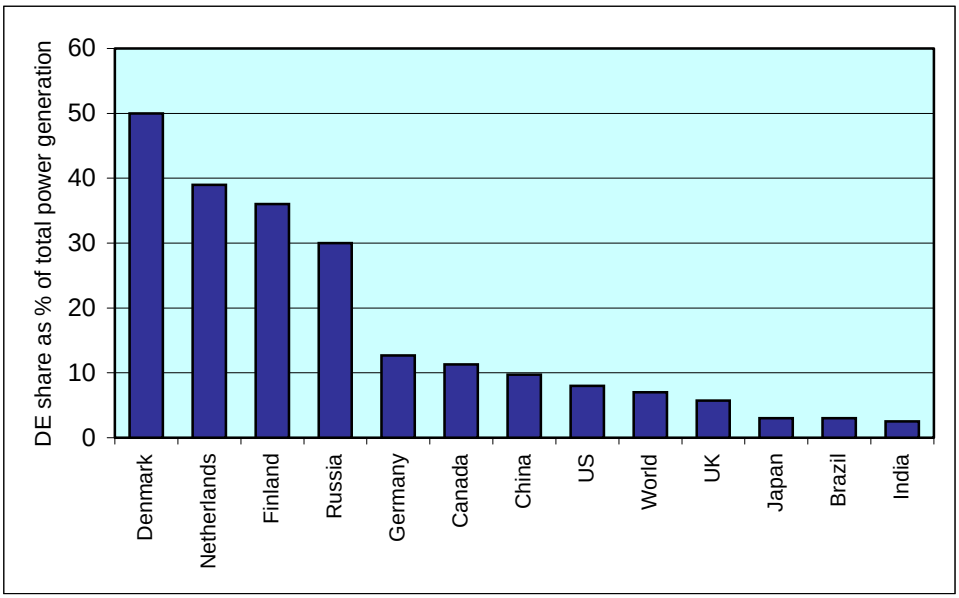
An additional uncertainty within the data relates to power generation produced by a cogeneration system at times of little or no heat recovery. This mainly occurs with larger cogeneration plants linked with district heating systems that have a wide range in heat demand. During the summer months, there is little demand for heat from such systems and cogeneration plants operate largely as conventional power stations. Only that power generation which is linked to heat production qualifies as genuinely cogenerated electricity, as far as WADE is concerned, and therefore is included in the analysis, but it is not at all easy to obtain such distinct data.

The DE share of generation in the ten countries, according to the table, is 9.5%. This is not realistic. Taking into account the potentially substantial amount of DE generation in the data which is *not* associated with heat recovery, particularly in China, Germany and Russia, together with the fact that this group includes some large countries (particularly Russia), which are allocated relatively high DE shares, WADE believes that a figure of around 7% is closer to reality for these countries and serves as a best provisional assessment for the time being. Until WADE is able to secure more complete data, we shall use this figure for 2000 and do not believe that it has moved on significantly since then given what we have observed in the world's main energy markets.

Finally, but importantly, it is clearly not yet possible to collect data from all countries of the world. However, since the countries assessed here collectively generate around 70% of the world's electricity, we have assumed that the figure of 7% stands as a good approximation to a global figure.

On the basis of this 7% figure, this means that the present DE installed capacity worldwide is around 230 GWe and the total generation is about 1,000 TWh (almost equivalent to the total annual power generation of Japan).

FIGURE 1. DE development worldwide as % of total power generation



6.

Future Market Development

WORLD ELECTRICITY CAPACITY GROWTH

There are various projections for global electricity demand growth rates over the next 20 years. The US Energy Information Administration has estimated that the world's electricity demand will grow at a rate of 2.6-2.7% per annum over the next 20 years[39]. This translates into a 67% to 70% increase in world electricity consumption in 2020 over the consumption in 2000. Given recent economic slowdowns, a figure of 2.4% might be more probable, but this still yields a 20 year growth of electric use of 61% over the year 2000.

Using the more conservative figure, on the basis of a 2000 global installed capacity of around 3,250 GWe, this growth rate would equate to an approximate capacity increase of 2,000 GWe in 20 years. Taking into account the decommissioning of older plants, a total of around 4,850 GWe of new capacity will be installed during the next 20 years, providing a clear opportunity to move away from the dominance of central power generation and towards DE.

DE PROJECTIONS

WADE has generated three simple scenarios that demonstrate the potential for DE in the world's electricity markets. The three-fold purpose of these scenarios is to highlight some possible future pathways for DE market growth, to indicate what policy and other changes will be necessary to accelerate market growth and to estimate the degree to which different levels of DE market development will influence future global CO_2 emissions.

For each scenario, WADE has defined shares of the global power generation market that might be taken by DE during the period to 2020. Having determined this overall framework for DE growth, we have made assumptions relating to the relative shares that each DE technology will take of overall DE capacity. There is, inevitably, scope for debate and discussion as to the assumptions (which relate mostly to annual growth rates for newer DE technologies), which we have made for these projections. They are not a WADE view of how the world will be; in particular they are not WADE's

projections for technology share of future power markets. Rather, they are a means of assessing what degree of policy and regulatory change is likely to be necessary, in WADE's view, if growth of the global DE market is to be achieved.

The scenarios are based on the levels of DE development shown in table 13.

TABLE 13. Levels of DE development underlying the three scenarios (DE share as % of total global power generation, excluding cogeneration capacity which is not associated with heat recovery)

	2000	2005	2010	2015	2020
Business-as-usual (%)	7	8.5	10	11.5	13
Growth I (%)	7	10	13	16	19
Growth II (%)	7	11.5	16	20.5	25

1. BUSINESS-AS-USUAL

Under this scenario, it has been assumed that an effective DE market share of 10% of installed capacity will be achieved by 2010 and of 13% by 2020. Installed DE capacity grows from 210 GWe in 2000 to 413 GWe by 2010 and to 681 GWe by 2020. Thus, even under this relatively modest scenario, the global installed capacity of DE will double by 2010.

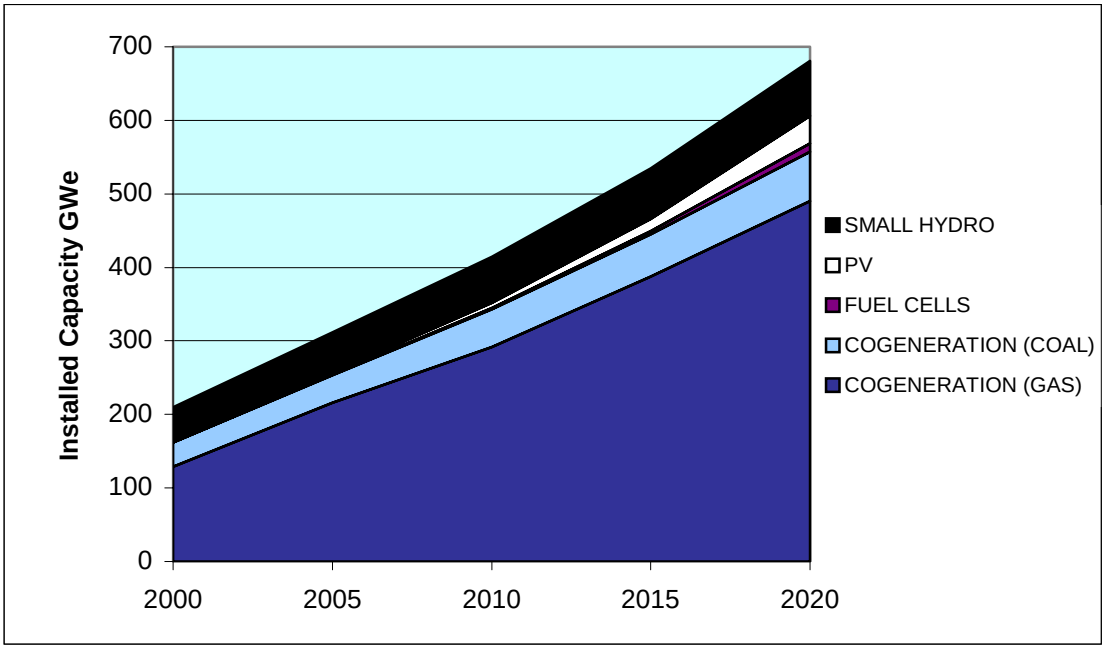
In this scenario, few barriers to DE are removed from the market, with grid access and interconnection issues remaining difficult in most key countries. In addition, few significant measures to reduce GHG emissions are introduced. Most DE continues to be based on larger (>5 MWe) industrial or municipal cogeneration systems using conventional gas engine and gas turbine technologies.

The following summarises additional possible factors underlying this scenario:

- Some industrial and commercial cogeneration growth takes place but is still limited due to interconnection and other regulatory issues;
- Significant PV implementation takes place, through government programmes and subsidies, but not until after 2015 (assumed PV growth rates are 18% pa);
- Fuel cell capital costs remain high, limiting their market penetration (assumed fuel cell growth rates are 50% pa to 2005, 30% pa to 2010, 25% pa to 2015 and 20% pa thereafter).

Figure 2 indicates the growth of the various DE technologies under this scenario.

FIGURE 2. DE BUSINESS-AS-USUAL



2. GROWTH I

Under this scenario, it has been assumed that an effective DE market share of 13% of installed capacity will be achieved by 2010 and of 19% by 2020. Installed DE capacity grows from 210 GWe in 2000 to 537 GWe by 2010 and to 995 GWe by 2020.

This scenario closely reflects the WADE 'DE 2012' challenge of doubling the DE share of the power market from 7% to 14% by 2012.

It is therefore broadly assumed that the overall DE share of total capacity almost doubles between 2000 and 2010. This is based partly on the explicit objectives of certain countries, for example USA, UK and the EU, which have similar targets of doubling cogeneration capacity by 2010.

These targets are achieved through new promotional incentives and the introduction of some effective carbon control policies. It is also assumed that many new DE projects can be implemented through the partial removal of some long-standing regulatory barriers relating to grid access.

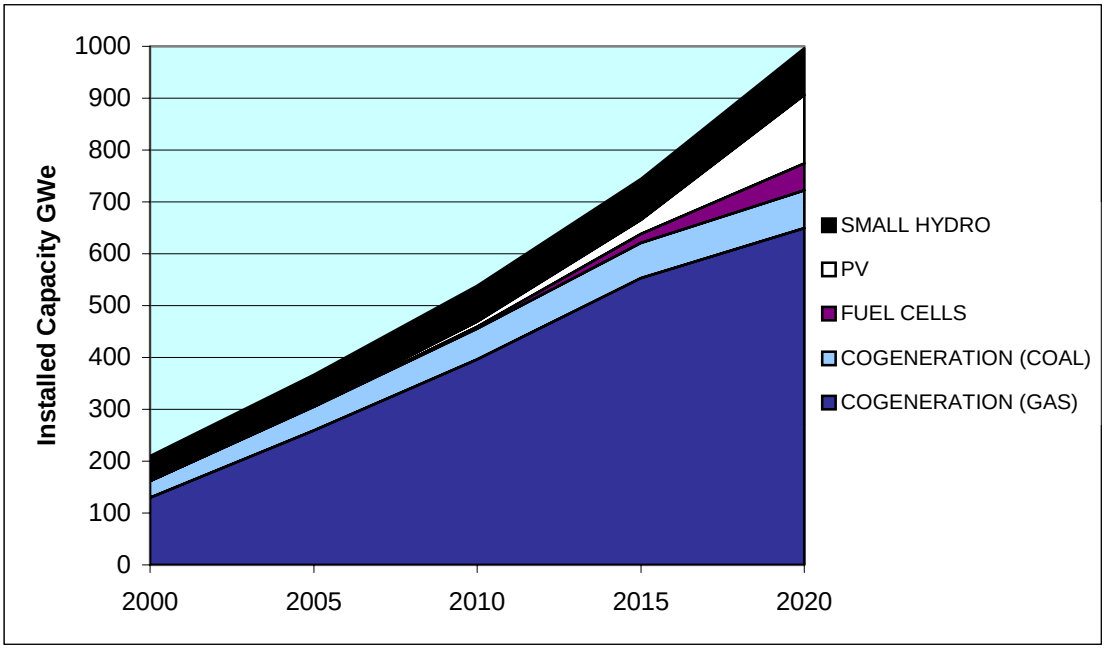
The following summarises additional possible factors underlying this scenario:

- Extended natural gas networks allow for greater use of gas cogeneration in many countries, in particular in developing countries;
- CO_2 trading becomes an effective economic mechanism for tackling climate change in the EU and elsewhere;

- PV capital costs decrease markedly after 2010, creating an increased opportunity for electrifying remote, off-grid communities (assumed PV growth rates are 18% pa to 2005, 25% pa to 2010 and 30% pa thereafter);
- Fuel cell capital costs also decrease more rapidly and applications are found in some significant niche markets after 2015 (assumed fuel cell growth rates are 65% pa to 2005, 45% pa to 2010, 30% pa to 2015 and 25% pa thereafter).

Figure 3 indicates the possible growth trajectories of the various DE technologies under this scenario.

FIGURE 3. DE Growth I Scenario



3. GROWTH II

Under this scenario, it has been assumed that an effective DE market share of 16% of installed capacity will be achieved by 2010 and of 25% by 2020. Installed DE capacity grows from 210 GWe in 2000 to 662 GWe by 2010 and to 1,310 GWe by 2020.

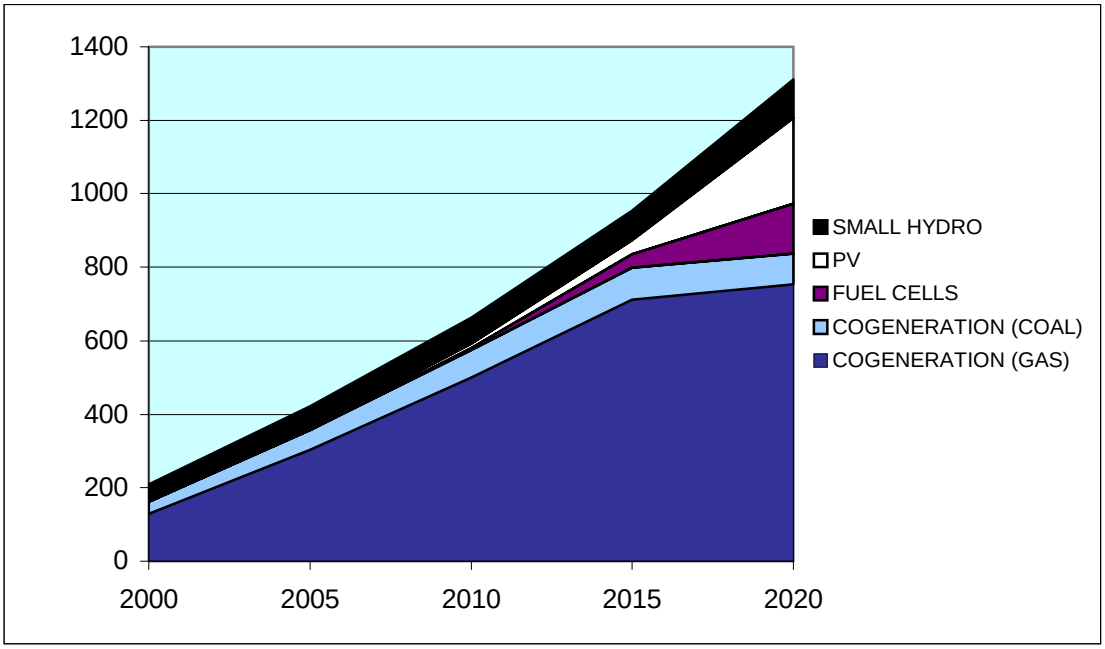
It is therefore generally assumed that the doubling targets of the Growth I scenario are comfortably exceeded. The scenario would come about through substantial removal of the leading regulatory barriers in most countries, and their replacement by widespread market incentives such as global emissions trading and renewable energy obligations.

The following summarises additional possible factors underlying this scenario:

- Gas-based cogeneration systems based on conventional technologies are widely used wherever sufficient heat and steam loads exist;
- Worldwide implementation of carbon emissions trading to enable full compliance with the Kyoto Protocol;
- Rapid decrease in PV costs allowing for widespread on- and off-grid application (assumed PV growth rates are 18% pa to 2005, 30% pa to 2010 and 35% pa thereafter);
- Growth of fuel cell and PV markets slow the development of conventional gas cogeneration dramatically after 2015 (assumed fuel cell growth rates are 65% pa to 2005, 50% pa to 2010, 45% pa to 2015 and 30% pa thereafter).

Figure 4 indicates the possible growth trajectories of the various DE technologies under this scenario.

FIGURE 4. DE Growth II Scenario



POTENTIAL MARKET OUTLOOK

The three scenarios summarized above do not represent market projections, but rather a WADE view on how the DE share of the overall power market might grow under a range of different investment climates. The levels of DE capacity growth shown in the Growth II scenario are clearly achievable, indeed, a 'Growth II +' is feasible. For that to happen, however, barriers must be removed, power sector reform must be introduced in a fully equitable and transparent way and, finally, market based mechanisms to combat climate change should be introduced in the short-term.

This is particularly the case in Europe, where the cogeneration market has been poor for the last four years, with no real prospect for change.

Figures 5 and 6 summarise the three scenarios in terms of growth in installed DE capacities and annual growth rates.

FIGURE 5. Worldwide installed DE capacity (GWe)

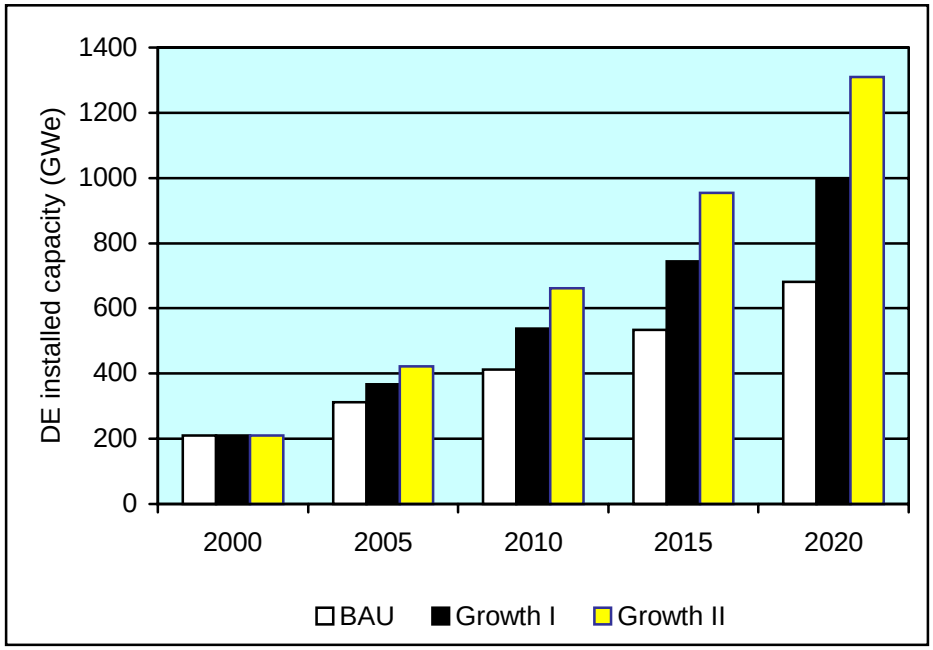


FIGURE 6. DE annual growth in capacity (GWe/yr)

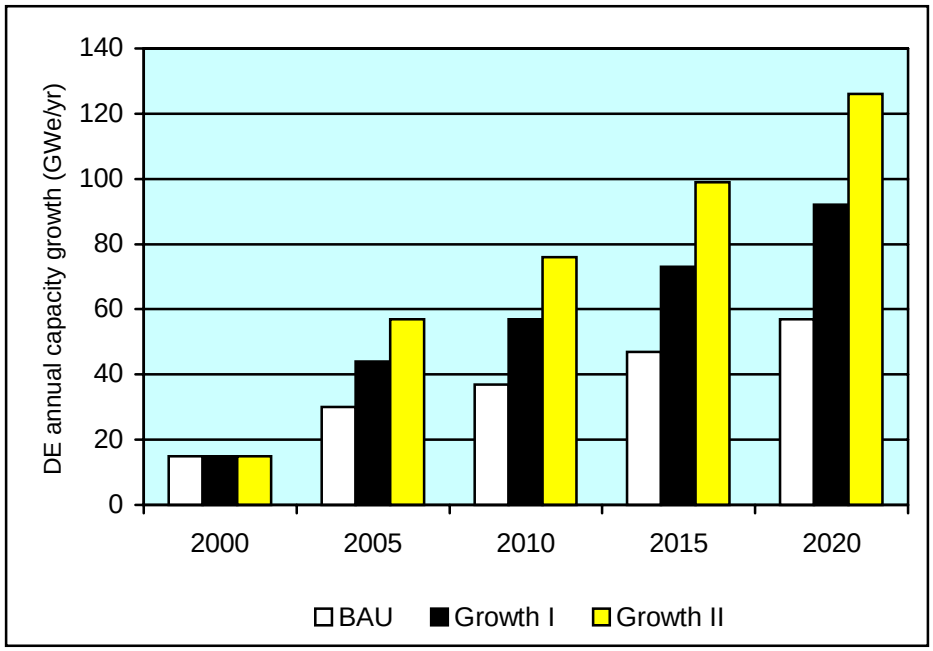


Table 14 summarises the data presented above, and highlights the startling projected growth in global electrical capacity.

TABLE 14. Summary of DE Capacity growth under the three scenarios

	2000	2005	2010	2015	2020
Total global installed capacity (GWe)	3250	3,672	4,135	4,655	5,241
Business-as-usual: DE market share (%)	7.0	8.5	10.0	11.5	13.0
Business-as-usual: DE capacity (GWe)	228	312	414	535	681
Business-as-usual: DE capacity growth (GWe/yr)	c.15	29.8	37.5	46.6	57.3
Growth I: DE market share (%)	7.0	10.0	13.0	16.0	19.0
Growth I: DE capacity (GWe)	228	367	538	745	996
Growth I: DE capacity growth (GWe/yr)	c. 15	43.6	56.9	72.7	91.7
Growth II: DE market share (%)	7.0	11.5	16.0	20.5	25.0
Growth II: DE capacity (GWe)	228	422	662	954	1,310
Growth II: DE capacity growth (GWe/yr)	c.15	57.4	76.2	98.9	126.1

There is no reliable data source for current rates of DE development, but WADE estimates that around 15 GWe of capacity was added in 2000. Under the Business-as-usual scenario, this would increase to 29.8 GWe by 2005 and 37.5 GWe by 2010. Under the Growth II scenario, the respective additions would be 57.4 GWe in 2005 and 76.2 GWe in 2010 – approximately double the rate of Business-as-usual.

Finally, using a simple model developed by COGEN Europe[40], we can estimate the approximate reductions in CO_2 emissions from the three scenarios. For example, the achievement of WADE's target to double DE development to a 14% share by 2012 will result in an annual reduction of around over 720 Mt of CO2 emissions by 2010 – the equivalent of over 25% of the reduction required to achieve Kyoto compliance. Should the Growth II scenario be achieved, the resulting emission reduction of almost 900 Mt/year by 2010 will equate approximately to one third of the global Kyoto objective.

7. Conclusions

Four main conclusions can be drawn from this first WADE World Survey of Decentralized Energy.

Firstly, the extreme paucity of data and statistics on DE makes it very hard to convincingly assess current developments in many key countries. Most OECD countries have data on cogeneration and renewable energy development, but it is only the EU that collects data in a standardised fashion for its 15 member states. For this reason, there needs to be some caution concerning the statistics given in this survey, though the overall picture is clear enough. WADE is already working to ensure that the key raw material of its work, reliable and comparable data, can be gathered and disseminated effectively in the short-term.

Secondly, while the data from some countries may not be strictly reliable, the overall picture conveyed in the survey is plain. The DE share of overall power generation is only around 7% - in other words the development of DE worldwide is marginal. Yet we know that in Europe (for example the Netherlands, Denmark and Finland), levels of DE development of at least 40% are achievable. Some US states, notably Maine, have also achieved DE shares exceeding 30%. More, much more, can be achieved and it is this firm recognition that forms the basis of WADE's commitment to work towards a goal of doubling worldwide DE by 2012.

Thirdly, while the main driver for DE is the economic benefit that it brings to society (outlined in forthcoming DE publications), a valuable secondary benefit is the carbon emission reduction that cogeneration and renewable energy technologies can deliver. This survey has estimated that the achievement of WADE's target to double DE development by 2012 will result in an annual reduction of 720 Mt of CO2 emissions – the equivalent of 25% of the reduction required to achieve Kyoto compliance. As the search for low cost solutions to the challenge of climate change intensify over the coming years, policymakers cannot afford to ignore the potential for DE to deliver the reductions that are becoming ever more necessary.

Finally, this survey has summarised a range of market and other barriers to the development of DE. These have been well documented in recent years and are now familiar to anyone who takes a passing interest in the industry. These barriers are largely generic – they exist in most countries. Policymakers throughout the world, together with decision makers in some of the key global institutions that influence energy policy, must face these challenges head-on. WADE, with the support of its members around the world, will continue to work to ensure that they do so.

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[9] See note 6.
[10] See note 6.
[11] See note 8, p.31.
[12] See note 8, p.32.
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[14] See note 6.
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[21] Various sources give different DE shares of Chinese capacity and generation. All give a range of 9-12%. One of the most detailed sources is 'Market Assessment of Cogeneration in China', China Energy Conservation Investment Corporation; Energy Resources International Inc, 2001.
[22] Klaus Traube 2001, Personal communications and 'Cogeneration in Germany', 'Cogeneration and On-Site Power Production' [Online] volume 2, issue 6, Available: http://www.jxj.com/magsandj/cospp/2001_06/cogeneration_in_germany.html [Accessed June 2002]

[23] See note 22.
[24] DE shares of the electricity market are based on information provided by COGEN India.
[25] Japan Cogeneration Center, Homepage [Online] Available: http://www.cgc-japan.com/english/eng01.html [Accessed June 2002]. Additional information from Professor Koichi Ito.
[26] The estimated share of DE/cogeneration in the Russian energy market comes from the 'Russian Energy Outlook', IEA, 2001. p.191-221.
[27] Digest of United Kingdom Energy Statistics, 2002. Additional sources of information for the UK profile are from Graham Meeks, UK CHP Association.
[28] Various sources, including: US Department of Energy (Energy Information Administration) and PrivatePower.
[29] 'Cogeneration for Brazil', *Cogeneration and On-Site Power Production* [Online], volume 1, issue 2, 2000. Available: http://www.jxj.com/magsandj/cospp/2000_02/cogeneration_for_brazil.html [Accessed June 2002]. See also note 18.
[30] See notes 19 and 20.
[31] See note 21.
[32] See notes 22 and 23.
[33] See note 24.
[34] See note 25.
[35] See note 26.
[36] See note 37.
[37] See note 28.
[38] The GEF has estimated global grid-based renewable electricity generation capacity at around 100 GWe. At the time of writing, it has not been clarified what proportion of this can be classified as 'decentralized' according to WADE definitions. Of the 100 GWe, 93 GWe is made up by small hydro (can be less than 30 MWe), biomass and wind. Much of this is likely to be better described as central power. In addition, much of the biomass is likely to be cogeneration-based and will already be included in the WADE data in this report.
[39] 'International Energy Outlook 2002', US Department of Energy, p.127.
[40] See 'Environmental Aspects of Cogeneration in Europe' in 'Cogeneration & Onsite Power', Volume 2 Issue 6 Nov-Dec 2001, by Simon Minett, COGEN Europe.