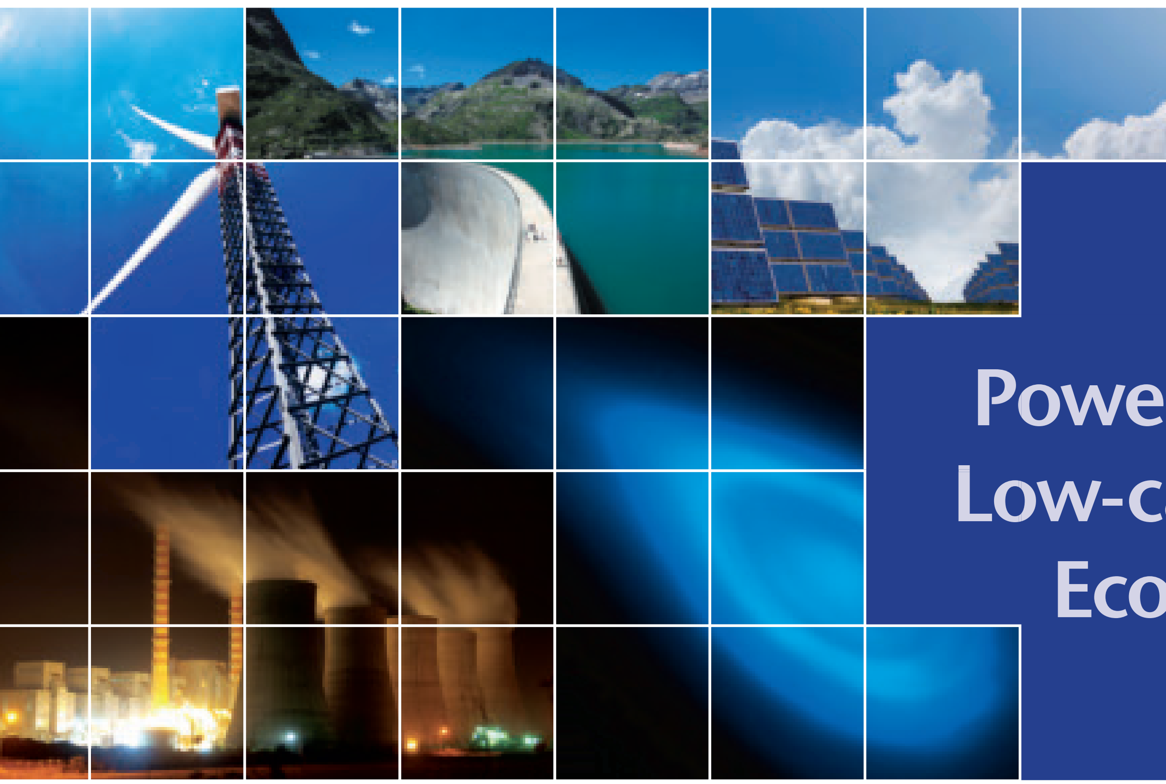
DEDICATED TO MAKING A DIFFERENCE



Powering a Low-carbon Economy

World Business Council for Sustainable Development

Contents

Introduction

In order to address the global climate change challenge, the electricity sector recognizes the need for more efficient electricity consumption and less carbon-intensive electricity supply. This shift will require the use of all technology and energy use management options available today, as well as those future solutions that currently face technological or commercial barriers to deployment.

This document has been developed as part of the WBCSD Electric Utilities Sector report, *Power to Change: A business contribution to a low-carbon electricity future*. This part of the report focuses on policies and measures for nine key energy technology solutions:[1]

- End-use energy efficiency
- Hydropower
- Non-hydro renewables
- Nuclear power
- Natural gas
- Generation efficiency
- Advanced coal technologies
- Carbon capture and storage
- Transmission and distribution

To illustrate our analysis, we refer to the International Energy Agency ACT Map and BLUE Map scenarios.[2] For each technology and measure, we provide a focus on the following issues:

- The wedge potential
- How this wedge contributes to emissions reductions
- Technology status
- Challenges that prevent the technology from meeting its potential
- Policy measures

FIGURE 1

CO_2 reduction within the power generation sector by contributing factor based on ACT Map and BLUE Map scenarios

End-use energy efficiency

Wedge: End-use energy efficiency

End-use energy efficiency can be defined as the efficiency with which energy is consumed by end-users within the commercial, industrial and residential sectors. Energy efficiency within utility operations is treated separately in the document "Generation efficiency" section, page 18.

Wedge potential

According to the IEA ACT Map and BLUE Map scenarios, end-use energy efficiency respectively results in 21 % and 15 % reduction in electricity demand compared to the baseline scenario by 2050. To achieve the more aggressive CO_2 emission reductions within the BLUE scenario, additional CO_2-free electrification is required, which accounts for the higher demand for electricity as compared to the ACT Map scenario. Energy efficient technologies provide many cost-effective and near-term options and are thus expected to play a key role in contributing to emissions reductions.

How this wedge contributes to emissions reductions

Through end-use energy efficiency improvements, the same economic benefits are achieved with less energy, meaning that fewer resources are consumed per unit of economic activity, and emissions are avoided.

In terms of potential reductions in electricity demand, integrated building design, together with the development and deployment of high-efficiency cooling and heating electric devices, lighting systems and electric appliances, for example, improvements could buy time for cleaner, more efficient generation technologies to come on line.

End-use efficiency brings other benefits:

- Increases energy security by avoiding consumption of imported fossil fuels
- Potentially reduces energy costs for customers
- Reduces the incremental investment required to meet energy demand growth
- Provides opportunities for new energy service provision to end-users

Technology status

An array of technologies and designs has been developed to support the more efficient use of electricity. These can be classified as follows

- **Mature and competitive technologies:** New and efficient building designs and various energy-efficient end-use technologies like housing insulation for new buildings, attic insulation in existing buildings, double glazed windows, or solar water heating in certain countries are mature and competitive (i.e., cost-effective). Some, such as compact fluorescent lamps (CFLs) for lighting even allow substantial long-term cost savings (they are 4-5 times more efficient than incandescent lamps).

- **In early deployment:** Other highly energy-efficient technologies such as heating and cooling heat pump technologies (which take heat from air, water or the ground and transfer it to another place for the purpose of cooling or heating) are mature and in an early deployment phase. Their substitution for conventional on site heating and cooling direct fossil fuel combustion technologies will result in substantial savings in primary energy and CO_2 emissions reductions. In addition, new "green" buildings and zero net energy houses are increasingly entering the market.
- **Require further R&D:** Other technologies like high-temperature heat pump systems (used for steam production in industrial processes) require further R&D in order to achieve commercial deployment. With regards to lighting technologies, solid state lighting technologies that include light emitting diodes (LEDs) and organic light emitting diodes (OLEDs) see their efficiency and lifespan growing rapidly, but are still more costly than conventional solutions.

Challenges that prevent this wedge from meeting its potential

Energy efficiency measures have not only been proven the most cost effective in terms of CO_2 mitigation, but also possess significant potential.High transaction costs, market and behavioral barriers have proven challenging to overcome.

They include:

- **Lack and cost of information** among customers with respect to the options and benefits of efficient end-use technologies
- **Time preference** – while most efficient end-use technologies currently bear a higher up-front cost, long-term savings are incurred through reduced energy consumption; many consumers are either not aware of these facts or prefer the present value of consumption
- **Rebound effect** – when energy efficiency measures are implemented, the "rebound effect," by which customers increase their level of comfort (and thus of energy consumption) when they are provided with more energy efficient equipment, may undermine the benefits
- **Split-incentive problem** – for construction projects both in industry and for commercial and residential buildings, those who make decisions about energy efficiency are not the ones that benefit (e.g., between building owners and tenants)
- **Lack of competence** – lack of expertise and experience with the installation of high-efficiency equipment and construction of low-energy houses
- **Business models** – low incentives for utilities as they are not financially rewarded for supporting end-use energy efficiency measures in the same way as is the case for supply-side resource management.

Policy measures

- Systematic and repeated information dissemination to raise public awareness about opportunities to adopt energy-saving measures that can result in economic benefits
- Direct support for energy audits, enabling consumers to identify areas for efficiency improvements
- Energy prices that reflect all costs (including CO_2 costs), with schemes to support low-income customers
- Financial mechanisms that reduce the initial capital burden related to the purchase of efficient end-use technologies (i.e., tax credits, mortgage discounts, rebates, preferential loans)

- Tax credits or equivalent financial incentives (including incentives for early retirement of lower efficiency equipment) to increase the speed and scale of deployment of highly efficient technologies that need to descend the learning-by-doing curve (e.g., heat pump technologies)
- Minimum performance standards and labeling schemes, especially for building design and mass-produced equipment/appliances
- Minimal and clearly defined energy savings targets, providing incentives to undertake energy efficiency measures; their impacts in terms of greenhouse gas (GHG) mitigation should be clearly monitored
- Public procurement schemes that include energy-efficiency criteria for the selection of products and services
- Proper training for building professionals and installation personnel
- Financial support for utilities to enable the implementation of comprehensive energyefficiency programs for customers.

UK new housing development targets: Zero carbon by 2016

In 2006, the UK announced their target for all new homes to be carbon neutral by 2016. With the domestic housing sector representing 27% of overall emissions in 2004, this goal aims to take a significant step in achieving the UK's overall climate change targets. To support this goal, they have proposed a set of policy measures including:

- The tightening of building regulations over the next decade to improve the energy efficiency of new homes
- The publication of a Code for Sustainable Homes that includes a green star rating for properties
- A draft Planning Policy Statement on climate change that will take carbon emissions into account.

These measures are outlined in *Building a Greener Future: Towards Zero Carbon Development*.

Thailand: Demand-side management

The 1992 Energy Conservation Promotion Act is the primary legislation guiding Thailand's energy conservation and renewable energy policy. The Act outlines major areas for energy conservation programs including a compulsory program for designated large commercial and industrial facilities and a voluntary program for small to medium sized enterprises.

In January 2003, Thailand established the Energy Efficiency Revolving Fund to encourage involvement from financial institutions in energy efficiency projects, with initial funds of US$ 50 million. This government contribution provides capital at no cost to Thai banks to fund energy efficiency projects, and the banks in turn provide low-cost loans to project proponents. Owners of any commercial or industrial facility, whether or not it is a government-designated facility, are eligible to apply for loans from the fund. The payback period has been from less than a year to 4 years.

Although the government's policy support is strong, its intervention in the actual financing process is small. The major risks on loan defaults fall mainly on the loan applicant and the financial institutions, and most administrative costs incurred are covered by the financial institutions and project proponents.

Hydropower

Wedge: Hydropower

Hydropower in electricity generation refers to large and small-scale power production from river flows and dams. Ocean and tidal power are included in the "non-hydro renewables" document.

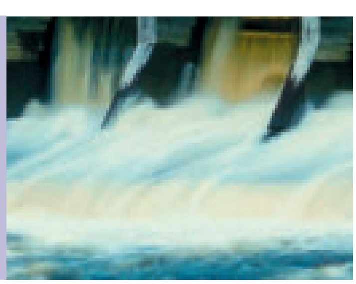
Wedge potential

According to the IEA ACT Map and BLUE Map scenarios, hydropower would account for 0.3 and 0.4 Gt CO_2 emissions reductions below the baseline scenario by 2050 respectively. In addition, hydropower production by 2050 would double.

Today, hydropower produces about 16% of global power generation, whereas only about one-third of potential has been exploited.

How this wedge contributes to emissions reductions

Hydropower can help stabilize and reduce CO_2 emissions because during operation, it generates power with virtually no such emissions. UNESCO is leading an international research effort to further study the impact of hydropower in tropical areas.



Hydropower brings other benefits:

- Increases energy security when substituted for imported fossil fuels
- Enhances security of supply due to high flexibility of storage and pump storage hydro with regards to system regulation
- Offers service beyond the energy sector by enabling multipurpose usage of water which could not be financed without the revenue from electricity sales, such as improved irrigation, water-based transport, tourism, industrial and municipal water supply, flood and drought protection possibilities
- Fosters regional cooperation, especially in developing countries through the development of power pools and regional water management initiatives.

Technology status

• Hydropower is a mature technology with efficiency reaching 95%. It is competitive in many locations with appropriate hydro resources. These primarily include Asia, Africa, Eastern Europe and South America.

• Some development on system improvements for smaller-scale hydro, including standardized production of turbines and new and simpler control systems, are in progress and hope to reduce technology cost.

• Most R&D projects focus on reducing the ecological impacts of plant operations and optimizing operation modalities.

Challenges that prevent this wedge from reaching its potential

- Public acceptance for hydropower in some areas – while hydropower is a clean technology from an emissions perspective, some argue that the environmental and social impacts outweigh its benefits in terms of emissions reductions
- Long lead times for the permitting and construction of hydropower plants (in particular compared to more carbon-intensive alternatives) due to the complex and multifaceted decision-making process
- In some areas a lack of harmonization and coordination of jurisdictions and government departments also creates an additional regulatory burden
- Some developing countries have less-developed infrastructure and often lack adequate regulatory and institutional frameworks for the development of hydropower plants, creating investment uncertainly and thereby increasing risk
- Some countries have limited capacity to finance the high initial capital cost of large hydro power projects, and international funding is needed to enable their development; however, there are difficulties in obtaining loans and financing from international lending institutions and banks. Uncertainties about receiving and trading carbon credits from hydropower projects could so far not contribute much to ease this important financing hurdle
- In some remote areas, a lack of transmission grid optimization presents an obstacle to unlocking hydro potential
- Untapped potential of plant upgrades – potential efficiency upgrades of older hydro power plants are often unrealized; focus falls on minimal plant maintenance or complete plant replacement.

Policy measures

Government policy to facilitate the development of hydropower projects including:

- The establishment of a reliable regulatory and institutional framework for investments by putting forth clear objectives by developing:
  - A predictable, transparent, harmonized, participatory and time-bound permitting process
  - A balanced assessment of social, environmental and economic costs and benefits supported by public debates, with the establishment of sustainability requirements to address issues related to ecological impacts and population displacement
- Being counterpart in power purchase agreements.
- Provision of investment subsidies for developing countries
- Cooperation and engagement with governments and stakeholders to improve public acceptance
- The development of international financial mechanisms through lending institutions or direct funds to support hydro power projects in developing countries (notably provide guarantees to the developer)
- Inclusion of large hydropower within the Clean Development Mechanism (CDM).

A large-scale hydro dam/Nam Theun

Nam Theun 2 is a hydropower project under construction on the Nam Theun river in Laos. Upon completion, 95% of the electricity generated will be sold to neighboring Thailand. Nam Theun 2 represents a major milestone for a large hydropower project receiving financing assistance from international financial institutions, including the World Bank and Asian Development Bank, among others. The decision to provide the financing was largely based on the net environmental benefit for the region, improved living standards and economic development for the local population that the project would bring.

The project is carried out by Nam Theun 2 Power Company (NTPC), of which EDF is the primary shareholder (35%), and other partners, including CLP. Construction began in 2005 and the dam is expected to start operation at the end of 2009. Investment amounts to US$ 1.25 billion, constituting the largest foreign capital investment ever made in Laos.
The project is expected to add 3.2% to Laos's GDP per year over its concession period, principally through the export of power.

IHA Sustainability Assessment Protocol

The International Hydropower Association (IHA) published Sustainability Guidelines in 2003 to promote greater consideration of environmental, social, and economic sustainability in the assessment of new energy supply options, new hydro projects and the management and operation of existing hydropower facilities. Convinced that the hydropower sector should be able in the future to prove that its performance meets high sustainability standards, the IHA went further in 2006, in partnership with other international organizations, to develop a simple tool for objective assessment of each proposed hydro project or existing scheme, the Sustainability Assessment Protocol (SAP).

The purpose is to have an independent and documented auditing review as to whether a project is needed, whether it is correctly located, whether it is acceptable from a social and environmental perspective, and whether its proposed financing, planning and management are adequate to meet sustainability criteria. Assessments rely on objective evidence to support a sustainability score against each of twenty sustainability aspects.

These two IHA sustainability assessment tools are currently being reviewed by the Hydropower Sustainability Assessment Forum, a multi-stakeholder forum with a view towards a future sustainability standard for the sector.

Non-hydro renewables

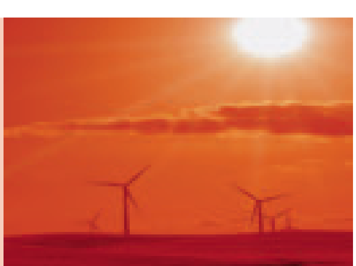
Wedge: Non-hydro renewables

Non-hydro renewables include geothermal, solar, wind, tide, wave energy, osmotic power and commercial biomass for electricity generation.

Wedge potential

Non-hydro renewables have the potential to play a significant role in CO_2 reduction, amounting to 20.9% and 36.6% as per IEA's ACT Map and BLUE Map scenarios respectively as shown in the table below.

Renewables	CO_2 Reduction ACT Map (Gt CO_2yr)	CO_2 Reduction BLUE Map (Gt CO_2/yr)
Power Generation	13.9	18.3
Wind	1.3	2.1
Solar – PV	0.7	1.3
Solar – CSP	0.6	1.2
BIGCC and biomass co-combustion	0.2	1.5
Geothermal	0.1	0.6



To realize this level of CO_2 reduction requires a significant increase in the share of non-hydro renewable output in total electricity generation to 2050. Achieving this depends on the development of significant enabling policies around the world. Generally, the prospects of non-hydro renewables will depend greatly on the levels of carbon constraints agreed, fossil fuel prices, the reduction of their incremental cost and the level of R&D. In addition, direct consumer demand for "premium" renewable power is beginning to play a role in driving the growth of renewable power in some regions.

How this wedge contributes to emissions reductions

With the exception of biomass, during operation non-hydro renewables enable the production of electricity with virtually no GHG emissions. Over the life cycle of the systems, some emissions occur, but these are very low in comparison to fossil fuel generation. In particular, the carbon mitigation potential of biomass as a renewable electricity generation source is linked to its sustainable production.

Another benefit of Non hydro renewables:

As a local energy resource substituted for imported fossil fuels, it increases energy security.

Technology status

The status of existing renewable energy technologies varies and their technical potential relies on local resource availability.

- On-shore wind, geo-hydrothermal and biomass combustion-based power generation technologies are technologically mature and can be competitive in some cases (e.g., on-shore wind in the best locations).
- Deep water offshore wind, hot dry rock geothermal, concentrating solar thermal, solar photovoltaic, osmotic power and ocean energy (wave, tide, current, ocean thermal energy conversion, salinity gradients) are still far from competitive and need further R&D.

For a more detailed account of the status of non-hydro renewable technology status, see our *Non-hydro Renewables Issue Brief.*

Challenges that prevent this wedge from reaching its potential

The challenges related to the uptake of renewable technologies vary by location and technology type. There are a number of crosscutting issues that act as barriers, such as:

- With some exceptions (e.g., wind power in the best locations and solar photovoltaic in some isolated rural areas), the generation of electricity from renewable sources typically costs more than from fossil fuel based generation.
- The NIMBY ("not in my back yard") syndrome can make facility site permitting difficult.
- Reduced resource accessibility results in increased development costs (e.g., the most economic onshore sites have already been developed in some regions).
- The requirement for substantial investment in power grid infrastructure (network reinforcements and investments in back-up capacity and/or storage) to accommodate the distant location of renewable resources (often far from load centers where the transmission network is weak) and generation intermittency.
- Low market value of electric output due to low availability and predictability.
- Unidentified or underestimated risks (i.e., uncertainty related to hot dry rock geothermal seismicity and health impacts).

China renewable energy law

China's renewable energy law provides for a beneficial tariff to be given to renewable projects to promote the development and utilization of renewable energy while being economic and reasonable.

New wind power projects, for example, typically receive a significantly higher tariff than conventional power in China. The law also obliges grid enterprises to buy renewable power generated by grid connected facilities, and allows them to pass along the extra costs, including the cost of grid connection, through the selling price of electricity. The law went into effect in January 2006.

Policy measures

1. The adoption of financial mechanisms and policy measures to aggressively deploy the technologies that are mature and suitable from a resource location perspective and enable them to descend the cost learning curve:

- Feed-in tariffs (i.e., absolute or incremental payment per kWh of renewable energy supplied to the grid)
- The setting of practical targets for renewable obligations by taking into account technical capacity, commercial viability and resource availability in each country/region (portfolio standard, mandatory market shares, etc.)
- Investment and production incentives to offset the higher cost of renewable power (i.e., capital subsidy, rebates, capital or production tax credits, facilitated permitting)
- The establishment of mechanisms through which "end-users" can participate voluntarily in the deployment of renewable electricity (i.e., "green certificates" in Japan)
- Differentiated support according to the type of resource (availability, predictability and market value of electricity) and local operating conditions, avoiding "over compensation".

2. R&D and investment subsidies for the technologies that are still in development and whose costs are substantially above market prices (e.g., solar photovoltaic in average quality locations).

3. In order to ensure that mass-subsidy schemes are effective, provide:

- Information related to the geography of potential sites and the designation of development zones
- Defined schemes to organize sharing of the renewable resource among various users (i.e., biomass, ocean, etc.)

Renewables obligation[3]

Many countries have renewable energy targets, and in some countries these targets are mandatory. For instance, the UK government's 2006 Energy Review has set a target of 15% renewable energy target by 2020 (originally 10% by 2010). In Australia the national Renewable Energy Target is 20% by 2020. The targets are phased in over time, with intermediate targets to be met in the intervening years.

The compliance mechanism for renewable energy obligations is typically a certificate system such as Renewable Energy Certificates (RECs) or Renewable Obligation Certificates (ROCs). Certificates are created by electricity generators whose facilities meet the criteria for the certificate program. Certificates are only issued after power is generated, each certificate typically representing one megawatt-hour of renewable energy. RECs are tradable, and are often sold under a long-term agreement made before the renewable project was built. By assuring revenue over and above income from power sales, the renewable obligation helps to incentivize investments in new renewable energy plants.

In the UK and Australia for example, compliance with the obligations falls on the electricity seller. Compliance is achieved by submitting ROCs or RECs representing the required share each year, in proportion to total sales. In Australia, if a party has RECs beyond the amount needed for compliance, these can be sold to customers as government accredited green power to customers, often at a premium price. Thus green power customers also contribute to growth in renewable energy.

- Financing of network reinforcements and investment in back-up generation units, necessary for power grids to accommodate a high percentage of intermittent renewables
- Adapted support schemes in developing countries where public funding is scarce and most customers cannot bear cost pass-through to electricity prices
- Public support for R&D on utility-scale electric energy storage, which would increase resource dispatchability and allow intermittent renewable resources to operate during periods of maximum efficiency
- Develop periodic review and evaluation of policy measures to take into account the evolution of technological maturity and the costs/benefits of implemented policies.

Nuclear power

Wedge: Nuclear power

More than 430 nuclear power plants are operating in the world. They generated 16% of the world's electricity in 2004, at 2,740 TWh. At the end of 2006, 346 reactors were connected to the grid in OECD countries, constituting 23.1% of the total electricity supply.

Wedge potential

According to the IEA ACT Map and BLUE Map scenarios, nuclear energy in power generation would to contribute to reductions of 2 and 2.8 Gt CO_2 emissions respectively. Nuclear energy would thus account for 19-23% of total power generation and for between 14-15% of the industry's CO_2 mitigation potential.

This projection supposes that future investments will take place mostly within countries currently possessing nuclear power experience and adequate enabling regulations (siting, licensing, safety monitoring and waste management).

With available technologies (generation II & III), there is sufficient uranium to build and operate more than four times the number of nuclear plants currently in use. According to the "Red Book" produced jointly by the OECD's Nuclear Energy Agency and the UN's International Atomic Energy Agency, the world's present known economic resources of uranium, exploitable at below US$ 80 per kilogram of uranium, are some 3.5 million tonnes. This amount is therefore enough to last for 50 years at today's rate of usage – a figure higher than for many widely used metals.[4]

Current estimates of all expected uranium resources (including those not yet economically feasible or properly quantified) are four times as great, representing a 200-year supply at today's usage rates. This lifetime could be extended by up to a factor of 50 by using "fast breeder" reactors, which are for the most part generation IV.

How this wedge contributes to emissions reductions

Nuclear energy can help stabilize and reduce GHG emissions because during operation it generates power without any such emissions.

Nuclear energy also contributes to energy security and competitiveness:

- Nuclear power can offer a positive contribution to energy security as most reserves of uranium and thorium used in nuclear technologies are not located in sensitive regions.
- Relatively expensive to build but cheap to operate, nuclear can be competitive with other means of power generation in some countries even without any CO_2 cost.

Without existing nuclear plants, current emissions would be 2.5 Gt CO_2 higher[5] [+9.7% of CO_2 emissions from energy in 2004 (26.1 Gt CO_2), and +24% of emissions from the electricity sector (10.6 Gt CO_2)].

Technology status

Nuclear power generation technologies can be broadly separated into three categories. Generation II (existing plants) and generation III technologies are mature for deployment. The lifetime of existing plants could be extended from the initial 40 years to up to 60, depending on the type and use of the power plant.

Generation IV technologies are under research and development. The industrial deployment horizon for this new generation is currently estimated around 2040.

For additional detail on technology status, see our *Nuclear Issue Brief*.

Challenges that prevent this wedge from reaching its potential

- Safety has to remain at the forefront through the establishment of independent safety authorities with the requisite competencies, and by ensuring a culture of safety by responsible operators with peer review processes (World Association of Nuclear Operators or the IAEA's Operational Safety Review Team).
- Competitiveness through technology standardization is a key goal: standardization allows for synergies, which improves process efficiencies and reduces construction time and cost. Harnessing past experiences can thus contribute significantly to the reduction of construction and process efficiencies.
- Public acceptance through stakeholder engagement and industry transparency is required to enhance public understanding of the industry. Concerns related to waste management and disposal, safety and cost, must be addressed through open dialogue.
- Safeguards against possible nuclear weapons proliferation must be effective, under the umbrella of the treaty on the nonproliferation of nuclear weapons.

Policy measures

- **Clear legal framework:** nuclear power deployment requires an adapted legal structure within which roles and responsibilities are clearly defined in order to ensure accountability and transparency. From this perspective, the powers and responsibilities of an independent safety agency are fundamental. This requirement also applies to the establishment of an appropriate process for waste management.
- **Clear licensing process:** the required economic competitiveness of nuclear energy supposes political and regulatory environment stability and predictability, especially regarding licensing processes.
- **Deployment incentives:** in countries with successful past experience, maintaining the existing nuclear regulatory framework and allowing utilities to use viable industrial models (diversified business portfolio, long-term contracts with customers, risk-sharing industrial consortia) should be sufficient in the context of an implicit or explicit CO_2 price.

In other countries, a strong political commitment to climate change mitigation will be key through the establishment of appropriate penalties for CO_2 emissions. However, incentives for "first movers" will also be necessary, such as tax credits and loan guarantees.

- **Ensure stakeholder participation:** stakeholder engagement and industry transparency are required to enhance public understanding of the industry. Public policies should set up conditions for the establishment of an efficient dialogue process to address concerns related to waste management and disposal, safety and cost.
- **In cost-of-service regulated jurisdiction or nation**, policies to support the timely and full recovery of all costs with a reasonable return on investment to enable broader deployment and eliminate regulatory lag.

Government's key decisions on policy that drives nuclear power[6]

France

The French parliament adopted a law on energy policy and security in 2005 confirming the important role of nuclear power. The law went through a 2-year public consultation process prior to being adopted. The independence of the National Safety Authority was enshrined in the Nuclear Transparency and Safety Act in 2006, and along with the obligation of stakeholder engagement, with formal responsibilities conferred by this Act to Local Information Committees (CLI) representing communities living in the vicinity of nuclear plants. Legislation on the management of radioactive waste was also adopted in 2006, confirming deep geological storage as the country's preferred long-term option and setting deadlines for choices on location and construction of a repository. This law also provides that a prototype generation IV fast breeder reactor enabling the transmutation of radioactive waste should start operation by the end of 2020. The legal foundations for the development and acceptability of nuclear power in France have thus been thoroughly renewed, granting long-term stability and visibility to investors.

China

The Chinese government amplified its policy direction on nuclear power through its Nuclear Power Medium- and Long-term Development Plan (2005 – 2020) drafted by the National Development and Reform Commission to increase nuclear generating capacity. In June 2008 the China Electrical Council projected 60 GWe (gigawatt electrical) in nuclear capacity by 2020.

Japan

In October 2005 the Japanese government established the "Framework for Nuclear Energy Policy" which delivers its basic view on nuclear energy policy in the next decade.

Adopted by the Cabinet, it includes fundamental principles such as (a) continuing to meet at least 30 to 40% of electricity supply even after 2030 by nuclear power generation, (b) further promoting the nuclear fuel cycle, and (c) aiming at commercializing a practical fast breeder reactor (FBR) cycle.

In August 2006, the government drew up its "Nuclear Energy National Plan", which provides a ten-item concrete policy package, including "appropriate use of existing nuclear power plants, and appropriate use of existing nuclear power plants with assuring safety as a key prerequisite", namely improvement of the rate of operation, in order to realize the basic principle of the Framework for Nuclear Energy Policy.

South Africa

The Nuclear Energy Policy of South Africa was developed by the Department of Minerals and Energy. The draft Policy, published for comment in August 2007, was updated and approved by the South African Cabinet in June 2008.

The Policy serves as an embodiment of the South African government's commitment to the further development and expansion of the existing nuclear energy sector in a coordinated manner. It presents the government's vision for nuclear energy and proposes a framework within which this vision can be attained. This vision is premised on Article IV of the Treaty on the Non-Proliferation of Nuclear Weapons which affirms South Africa's inalienable right to research, develop, produce and use nuclear energy for peaceful purposes.

The Policy articulates South Africa's long-term vision for the use of innovative technology for the design, manufacture and deployment of state of the art nuclear energy systems and power reactors and the nuclear fuel cycle.

Finland

The Finnish government amended the Nuclear Energy Act in 1994 to stipulate that all nuclear waste produced in Finland must be disposed of in Finland. Finding an appropriate location for the disposal site spanned over twenty years, covering site selection, safety analyses and environment impact assessment. Finland was the first country in the world to move forward with a site for the construction of a high level waste repository. This policy is an important example in resolving a nation's growing need to safely dispose of high-level radioactive waste and spent nuclear fuel.

USA

The Energy Policy Act of 2005 contains three key provisions that provide critical incentives for building new nuclear plants and offers risk protection for companies pursuing the first new reactors:

1) Standby support or risk insurance for new reactor delays

2) Production tax credit of 1.8 US cents per kWh for the first 6,000 megawatts during the first eight years of operation

3) Government loan guarantees to support the development of innovative energy technologies that reduce greenhouse gas emissions.

Natural gas

Wedge: Natural gas

Natural gas is the cleanest fossil fuel. A switch from coal to gas achieves emission reductions from this less carbon intensive fuel. This section explores the use of natural gas in power generation, with an overview of the resource potential, and technologies and costs for resource use (i.e., upstream and downstream processing).

Wedge potential

A general change in the fossil fuel mix, which includes the substitution of coal for natural gas (among others), can contribute to a reduction of 3.8 Gt CO_2 in the electricity sector's overall reduction potential of 13.9 Gt CO_2 by 2050 under the IEA's ACT Map scenario, and 1.8 Gt CO_2 in 18.3 Gt CO_2 under the BLUE Map scenario respectively. Under both scenarios, there is a sharp decrease from coal fired generation from 52% in the baseline scenario to 14% and 13% in the ACT Map and BLUE Map scenarios respectively. A significant part of this decrease is attributed to switching from coal to natural gas. Although there is an increase in the use of natural gas for power generation under the ACT Map scenario, overall CO_2 emissions are reduced due to the fuel switch.

How this wedge contributes to emissions reductions

By switching from coal to natural gas, emissions reductions are achieved as natural gas is a less carbon-intensive fuel. Natural gas plants can also achieve higher efficiencies than other forms of fossil fuel-based generation. For example, a natural gas combined cycle (NGCC) plant emits approximately 400 grams of CO_2 per kWh output, whereas coal technology plants emit between 780 and 900 grams of CO_2 per kWh output. By increasing the efficiency of natural gas-fired generation, gas-fired steam cycles could be replaced by more efficient combined-cycle plants.

The key challenge of a fuel switch from coal to natural gas is price and availability. As fuel cost in NGCC plants accounts for 60% to 70% of total generation costs, natural gas plants are more sensitive to fuel cost and are much more volatile than for coal. Rises in gas prices in the US and EU in recent years have resulted in a switch from gas to coal-fired generation. A swift switch from coal to gas could strain gas production, be constrained by lack of pipeline capacity, and lead to further natural gas price increases. Various countries are building liquefied natural gas (LNG) terminals in order to have better access to natural gas, but the dependency on a limited number of countries for supply results in energy security concerns. Coal-fired facilities on the other hand are generally more capital intensive and therefore less susceptible to fuel cost than natural gas plants.

Other benefits of this wedge:

Lower local air pollution: natural gas combustion generates fewer emissions from substances with a local impact like NOx or SO_2.

Technology status

The development of the gas turbine and its adaptation for stationary use revolutionized gas-fired power generation in the mid-1980s. Since this time, the technology has evolved significantly.

NGCC plants account for 38% of global gas-fired capacity, while 26% are open-cycle turbine. Gas boilers make up 36% of global gas-fired capacity, and internal-combustion accounts for less than 1%.

NGCC is a mature technology. The efficiency of NGCC technology using the latest turbine design (the H-class) is now 60% on a lower heating value. In comparison, the world average efficiency of gas-fired power plants was just 42% in 2003.

Furthermore, it is estimated that advanced NGCCs, compared to today's technology, will bring a further reduction of 3 to 6% in CO_2 emissions per kWh of electricity generated. Further efficiency gains are possible in the longer term if fuel cells are integrated into the design or if a bottoming cycle using waste heat is added.

In terms of downstream processing through cogeneration using combined heat and power (CHP) systems, various technologies are mature. The current industry standard can achieve efficiencies of 34-40% for electrical generation, and it is expected that the efficiency of aero-derivative and industrial turbines can be increased by 45% by 2010. The total efficiency (heat + electricity) can reach 90%.

TABLE 1

Net electricity efficiency of natural gas plants in 2003

United States	43%
Western Europe	49%
Japan	44%
China	44%
Russia	33%
World	42%

Source: IEA, 2006.

Challenges that prevent this wedge from meeting its potential

- Uncertainty about future natural gas prices: A rapid increase in the use of NGCCs could lead to higher prices for natural gas. Fuel costs currently account for 60 to 85% of total generation costs, compared to zero for renewables, 5% for nuclear and 40% for coal.
- Energy security and diversification: A rapid increase in the use of NGCCs would raise concerns over energy security and diversification in some countries as gas production is concentrated in politically sensitive areas.
- Uncertainty about domestic supply infrastructure:
  - "Not in my backyard" syndrome on gas pipelines
  - Pipeline infrastructure needs to be greatly expanded
  - Ability to site and permit LNG terminals.

Policy measures

- Policy guidelines for LNG infrastructure: Policies and measures leading to the liberalization of capacity-contracting for LNG terminals (investors need long-term visibility and security).
- Incentives for investment in production, transport and storage that can facilitate the use of natural gas until CCS technologies are ready and can be associated with coal-based electricity generation.

DK6: A large scale, effcient and flexible system

The DK6 converts blast furnace gases and natural gas into electricity to provide an additional power generation capacity of 535 MW to the Arecelor Groups Sollac Atlantique steelworks plant. As a result of its technical and economic performance and the use of natural gas, the DK6 plant contributes to environmental protection by substantially reducing emissions per MWh generated: a plant efficiency of about 50% is achieved, which is 40% higher than that of a steam turbine power station; the use of low NOx technology for boilers and gas turbines enables atmospheric releases below regulatory limits.

The capacity of the combined cycle power station is 790 MW. A 165 MW gas turbine, a heat recovery boiler with post combustion and a 230 MW steam turbine is installed in each of the two 395 MW units. The gas turbines are supplied with natural gas by GDF SUEZ. The boilers burn fatal steelworks gases produced by the Arcelor Mittal plant, with the possibility of natural gas as a back-up. The excellent flexibility of production capacities comes from the different operating methods (combined or simple cycle mode) and the ability to continuously burn the flow of steelwork gases.

Generation efficiency

Wedge: Generation efficiency

Generation efficiency relates to either the implementation of best available, efficient technology (BAT) in the development of new power plants or improvement in the operational efficiency of existing plants.

Wedge potential

According to the ACT Map and BLUE Map scenarios, energy efficiency in power generation has the potential to contribute to 0.8 and 0.4 Gt CO_2 reductions respectively. This figure takes efficiency improvements to existing plants into account, but the implementation of BAT in new plants also plays an important role in ensuring optimal power generation efficiency.

In particular, with electricity demand expected to double over the next 25 years and with the existing generation stock in OECD countries in need of replacement within the next 10 to 20 years, a significant opportunity to move towards more efficient plants exists within the sector.

How this wedge contributes to emissions reductions

Plant energy efficiency has the potential to increase per unit productivity of resource input, thereby contributing to the stabilization of resource demand. For example, if Chinese coal plants were as efficient as the average Japanese plant, China would consume 21 % less coal (IEA, 2008).

Increasing the efficiency of non fossil-fuels based technologies will also help contribute to the reduction of CO_2 emissions. In an integrated electricity system, increased productivity (e.g., from nuclear or hydropower) will increase their capacity to replace demand for fossil fuel-based production, and thereby contribute positively to CO_2 emissions reductions.

Combined heat and power (CHP), for example, offers the opportunity to capture and use heat at the cost of losing some efficiency of electricity generation. As less fuel is needed to produce the same amount of useful energy, the overall efficiency of the plant is increased compared with the case when power and heat are generated separately. CHP represents a small niche market but can be effective when used on site in parallel to power plants. Since efficiency of CHP generally depends on the balance of demand of power and heat, consideration of such a condition would be needed for design.

Hospitals and industrial facilities can often take advantage of CHP plants of a smaller scale. These smaller scale, on site CHP plants are most efficient if the thermal loads match well with the heat available from the CHP system. Large scale CHP schemes are often advantageous when a plant is located in an industrial complex or near energy consumers.

Efficiency improvements can be implemented through optimal operations and management, retrofitting and rapid installation of BAT.

Energy efficiency in power generation also:

- Contributes to energy security by saving energy resources
- Helps to build knowledge and skills within the sector through technology transfer.

TABLE 2

Regional evolution in electric efficiency of natural gas and hard coal

	Natural gas			Hard coal		
	1974	1990	2003	1974	1990	2003
United States	37	37	43	34	37	37
Western Europe	39	40	49	32	38	39
Japan	40	42	44	25	39	42
China	–	35	44	27	31	33
Russia	36	33	33	–	–	–
World	36	35	42	30	34	35

Source: *IEA. 2006.*

Technology status

Power generation efficiency and delivery by electric utilities has increased steadily over the years as a result of advances in technology and practice. The following table represents the regional evolution in electric efficiency of natural gas and hard-coal plants between 1974 and 2003. This demonstrates the significant improvement of generation technologies over time.

The development of more efficient technologies and practices is a continuing journey. Advances in instrumentation and monitoring, as well as in operations and maintenance, have and will continue to enable further improvements in utility operation efficiency. At the same time, emerging technologies such as ultra-supercritical coal plants and integrated gasification combined cycle coal plants offer the potential for even higher efficiency in the future.

In addition, the higher uptake of distributed generation offers the potential for higher overall efficiency. Though individual units may not be as efficient as large-scale central power plants, net energy efficiency gains can be realized through the use of what would otherwise be waste heat from power generation, if there is a local need for this heat.

Challenges that prevent this wedge from meeting its potential

- **Improvements in the operational efficiency of existing plants:**
  - Lack of relevant knowledge and skills in some places
  - Inadequate operational and maintenance practices
  - Low cost of some fuel, leading to low incentives for investment in efficiency improvements
  - Life cycle trade-offs between extending the life of older facilities and constructing new ones

- **Installation of BAT in new plants:**
  - Limited manufacturing capacity in relation to growing power demand
  - Slow turnover of long-lived capital stock.
  - In relation to the installation of distributed generation, the "not in my backyard"(NIMBY) syndrome
  - Scarcity of knowledge and skills
  - Slow rate of transfer of technology best practices across facilities through existing mechanisms such as equipment user groups and trade associations.

Dry cooling technology: Water conservation vs. energy efficiency, an adaptive decision

A conventional wet cooled power station uses a circulating system in which cooling takes place via evaporation in an open cooling tower. Approximately 85% of the total quantity of water supplied to a power station evaporates through these open cooling towers.

In contrast, dry cooling technology does not rely on open evaporative cooling for the functioning of the main systems. As a result, overall power station water use is approximately 15 times lower than a conventional wet cooled power station.

In order to meet water conservation targets and adapt power station operations in areas of water scarcity, dry cooling technology has been implemented. This decision has been made despite the fact that dry cooled stations are comparatively less efficient than wet cooled stations and capital and operating costs associated with the technology are approximately 8% higher over its life cycle. This water conservation effort results in an estimated combined savings of over 200 Ml/day, or in excess of 70 million m^3 per year.

Technology	CAPEX (1996 Rands) Majuba (4-6)	CAPEX (2007 Rands) Majuba (4-6)
Indirect dry	R 740 million	R 1,426 million
Direct dry	R 540 million	R 1,040 million
Wet	R 420 million	R 809 million

Policy measures

- Financing mechanism to bridge future benefit and initial capital input
- Financial and institutional assistance for international transfer of technology and leading practices; through voluntary and/or sectoral initiatives
- Technology standards & benchmarking.
- Subsidy of energy audits or other analyses of savings potential
- Public financial support for R&D and large-scale demonstrations of high efficiency technologies for power generation and delivery
- Policies and regulations to ensure that tariffs reflect real costs
- CO_2 emission regulation.

New South Wales, Australia Greenhouse Gas Abatement Scheme

Started in January 2003, the New South Wales Greenhouse Gas Abatement Scheme aims to reduce the per capita greenhouse intensity of energy used in New South Wales. The scheme is based on a benchmark of 8.65 tons per person per year in 2000, with the aim to reduce it to 7.27 tons per person per year in 2007. Under the scheme, energy retailers surrender New South Wales Greenhouse Gas Abatement Certificates for a proportion of the retail load in this state.

Certificates can be created from abatement projects at utility facilities, from low-emission power generation, or by others.

Asia Pacific Partnership on Clean Development and Climate (APP)

The Asia Pacific Partnership on Clean Development and Climate (APP) was established in 2006 as a multilateral public-private partnership on clean technologies. The partnership currently includes seven countries: Australia, China, India, Japan, Korea, the US and Canada (a new member as of 2007). In November 2006, more than 100 action plans were adopted for eight sectors, 18 of which have been identified and approved as flagship projects.

In relation to operational efficiency, under the Power Generation and Transmission Task Force, peer review activity aims to improve the energy efficiency of coal-fired thermal power plants by sharing good practices among engineers on optimal operation and maintenance ages and new plants, as well as facilitating technology implementation.

Activities were successfully held in the US in 2006, Japan in 2007 and India, the US and Australia in 2008, with participation from all member countries.

Advanced coal technologies

Wedge: Advanced coal technologies

Advanced coal technologies include advanced steam cycle, i.e., supercritical, ultra-supercritical, fluidized bed combustion and pulverized coal (PC) technologies and integrated gasification combined cycle (IGCC) technologies.

Wedge potential

Some 85 % of global coal-fired generation installed capacity uses sub-critical PC technology.[7] The use of advanced coal technologies has the potential to raise the average efficiency of coal-fired power plants from 35 % today to more than 50 % by 2050. This could contribute to approximately 0.4 Gt CO_2 emissions reduction per year up to 2050.

How this wedge contributes to emissions reductions

Higher efficiency than with conventional technology (sub-critical PC) means reduced fuel consumption and consequently avoidance of CO_2 emissions. A 10 % efficiency gain, for example, can translate into a 25 % reduction in CO_2 emissions.

Technology status

Supercritical combustion (SC) currently accounts for 11 % of globally installed coal-fired capacity, while ultra-supercritical combustion (USC) and fluidized bed combustion (FBC) each account for 2 %.

The SC PC technology is mature and commercially available, and is used in both developed and developing countries. USC is still in the deployment phase with plants currently in operation in Japan, Denmark and Germany. Units operating at temperatures of 700 °C or higher are still in the R&D and demonstration phase. FBC is a mature technology and there are many FBC plants operating worldwide. Second generation FBC, with improved thermal efficiency, is under development.

Integrated gasification combined cycle (IGCC), which is currently among the cleanest and most efficient of the clean-coal technologies, accounts for less than 0.1 % of global coal-fired installed capacity. IGCC technology is mature but not yet competitive, and only a small number of demonstration plants are operational today. In addition, integrated coal gasification fuel cell combined cycle (IGFC) is under development.

Other benefits of using clean coal are:

- Increases energy security (through energy resources savings)
- Reduces local pollutants (NOx, SOx and particulates)
- Reduces cooling water discharge and service water consumption in IGCC
- Increases feedstock flexibility in IGCC
- Deployment enhances knowledge and skills within the sector

250MW Nakoso IGCC Demonstration Plant [8]

Integrated Gasification Combined Cycle (IGCC) is an advanced coal technology that is widely recognized as an important step towards reducing emissions from coal fired electricity generation. The business risk of IGCC investment is high because the capital cost has been estimated to be 15%-50% higher than a conventional pulverized coal plant. IGCC projects also face technology risk because of the limited experience with the technology. A public private partnership is essential in managing these risks.

The Japanese government's support was a key contribution to the recent successful launch of the first coal-fired IGCC demonstration plant at Nakoso. The Japanese government allocated billions of Japanese yen in its fiscal policy to support technological development.

The Nakoso Coal-fired IGCC demonstration plant illustrates the importance of public-private partnership. Eleven Japanese corporations (nine regional utilities), EPDC (Electric Power Development Company) and CRIEPI (Central Research Institute of Electric Power Industry) have jointly launched this 250 MW plant as a national project with 30% of the total cost subsidized by the government. Without this subsidy, the business risk would otherwise be too high. This project began operation in September 2007 and is scheduled to operate until 2009, aiming to obtain the necessary data for the future construction and dissemination of commercial IGCC plants.

Challenges that prevent this wedge from meeting its potential

- Long-lived capital stock with slow turnover; this is particularly the case in developed countries with substantial coal resources
- Higher capital and full costs of commercially available advanced coal technologies, compared to conventional sub-critical PC
- Lack of effective frameworks to transfer available clean coal technology to developing countries where coal is and will remain the dominant primary energy resource
- The performance variations are unknown for different types of coal and plants, which implies a need for many more expensive IGCC demonstration projects
- Large-scale application of advanced coal with carbon capture and storage (CCS); the integrated technology process has yet to be demonstrated.

Policy measures

- Design of an efficient international enabling framework (notably using the CDM) for advanced technology exchanges between developed and developing countries
- The implementation of performance standards.
- Policies leading to a cost of carbon
- Direct financial support for large-scale demonstrations
- Technology cooperation agreements
- Vendor guarantees for gasifier performance with different coal grades.
- In cost-of-service regulated jurisdictions or nations, policies to support the timely and full recovery of all costs with a reasonable rate of return on investment to enable broader deployment and eliminate regulatory lag.

Carbon capture and storage

Wedge: Carbon capture and storage

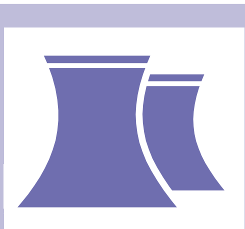
Carbon capture and storage (CCS) is a process consisting of the "separation of CO_2 from industrial and energy-related sources, transport to a storage location and long-term isolation from the atmosphere."[9]

While the various processes involved in carbon capture and storage (capture, transportation and storage) are in use today, the application of these known techniques to a new challenge, by putting together all parts of the process in an integrated and economic whole, will be complex. This document focuses on CCS as applied explicitly to the power generation sector, for the purpose of CO_2 mitigation. For a more detailed account of the technical aspects related CCS, refer to our *Carbon Capture and Storage Issue Brief*.

Wedge potential

According to the IEA ACT Map and BLUE Map scenarios, CCS in the power generation sector would contribute to reductions of 2.9 and 4.8 Gt CO_2 emissions respectively to 2050. The potential for applying CCS technology within the sector hinges on a number of considerations, including: geological storage potential, technological maturity, the development of supportive regulatory frameworks, public acceptance, and the financial implications of technology implementation.

Worldwide capacity for storing the captured CO_2 in geological formations has been estimated to be at least 2,000 Gt CO_2 (with a 66-90% estimate probability), although the capacity may vary across specific regions.[10] Underground storage of the captured CO_2 in deep saline aquifers has been proposed as having the highest potential.



How this wedge contributes to emissions reductions

Simply put, CO_2 is captured, compressed, transported and then stored. The storage site is then monitored in order to detect and calculate any leakage. This process results in the removal of otherwise emitted CO_2 from the atmosphere, thereby contributing to CO_2 reductions. At the individual fossil fuel-fired power generation plant level, CCS has the potential to reduce CO_2 emissions between 85% and 95%.

CCS also fosters energy security and competitiveness

- CCS enables countries with access to coal reserves and markets to continue to exploit these in a carbon constrained world: the omission of CCS from the technology portfolio results in a 23.6% point decrease in the contribution of coal to electricity generation in 2050.
- CCS could also play an enabling role in the further deployment of coal-to-liquid plants, which may allow countries to increase domestic oil consumption in transport and reduce reliance on imported oil supplies but raising the problem of water resources (e.g., China).

Technology status

The technology status of the specific components included in the CCS process – carbon capture (through post-combustion, pre-combustion or oxyfuel combustion); transport (through pipelines or shipping) and storage (geological, ocean, mineral carbonation) – are described in detail within our *Carbon Capture and Storage Issue Brief.* Figure 2 depicts the various technological options.

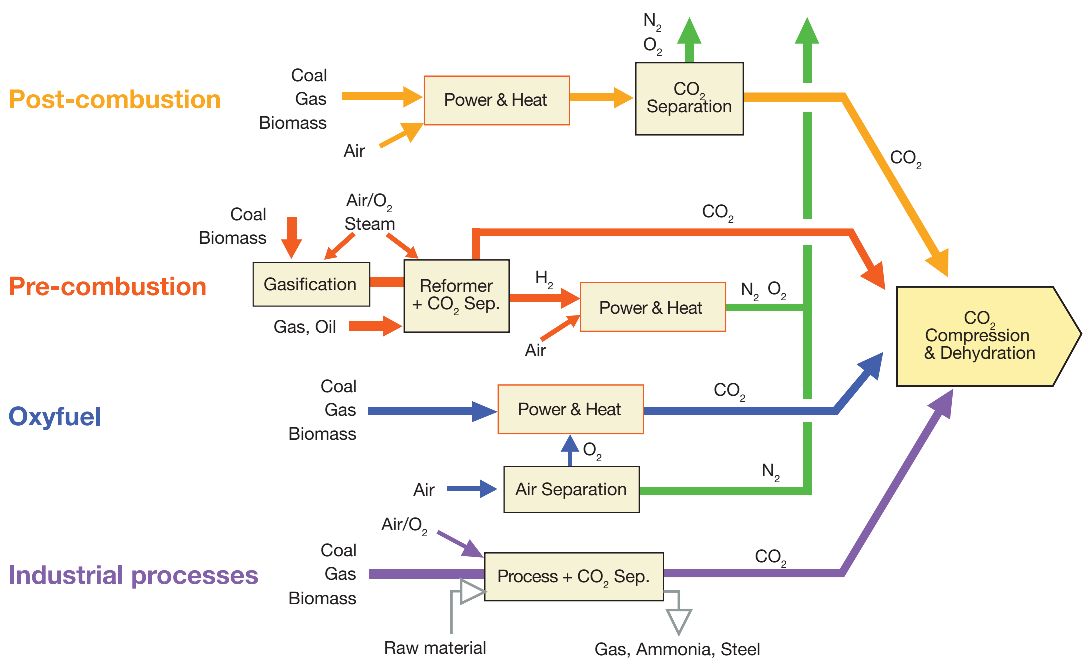
CO_2 capture is currently deployed in various industrial processes and for natural gas processing, although its application within the power generation sector has not yet moved beyond demonstration.

CO_2 has been transported in pipelines and injected underground through enhanced oil recovery and acid gas injection. A number of small-scale injection projects are underway to assess geological storage capacities. Numerous additional pilot plants and demonstration projects have been proposed to test capture from various combustion configurations, with start dates expected as early as late 2008 (e.g., a UK demo plant by 2014, EU plans for 10-12 commercial demo plants by 2015).

Cost estimates for oxyfuel combustion are at about 7,000 €/kW. This is not significant because the technology is still at a very early stage of maturity. For more mature technologies, current estimates run at about €30-35/t CO_2 avoided for capture, and €20-25/t CO_2 for transport and storage. These costs are expected to decrease with technical advances.

The large scale application of the integrated technology process has thus yet to be demonstrated, but deployment could begin in the next decade in the most advanced countries, if R&D and demonstration projects are successful and if there are appropriate incentives.

FIGURE 2



Source: Intergovernmental Panel on Climate Change, *Special Report on Carbon Dioxide Capture and Storage,* 2005.

Challenges that prevent this wedge from meeting its potential

- The fact that large scale application of the integrated technology process has yet to be demonstrated, in particular the storage component
- Performance variations (in terms of efficiency impacts) remain unknown for different types of coal and power plants
- The large additional cost relative to conventional coal power generation (an optimistic estimate of approximately 50% additional cost with the inclusion of carbon capture).
- Skills and costs required for geological storage site characterization (an essential component of full technology implementation)
- The fact that long-term storage at large- scale injection rates is still a scientific/ technological uncertainty due to, in particular, possible non-linear geological behaviors with respect to small-scale injection rates.
- Public acceptance, which requires an understanding of the:
  - Level of integrity of storage reservoirs
  - Relative risks and information/management requirements to detect and/or minimize potential leaks
  - Necessity and potential of CCS technology, without detracting from the necessity and potential for renewable technology development
- A current lack of government support to the scale required for full technology development and deployment.
- The cancellation of a number of projects for various reasons during 2007 and 2008, including the Huntley project in New York, the SaskPower carbon capture project in Canada, and the Miller-Peterhead project in Scotland; the FutureGen IGCC plant with CCS has been cancelled and restructured to support a number of clean coal projects
- In most regions, a current lack of integrated regulatory frameworks to support the implementation and development of CCS technologies in power generation, and in particular a lack of regulatory frameworks to delineate the long-term storage liability of carbon.

Policy-supported CCS[11]

Some governments are providing policy and fiscal support to carbon capture projects that are progressing well.

ZeroGen project – Australia

The Australian Queensland government is the key driver for the ZeroGen project. ZeroGen Pty Ltd is owned by the Australian Queensland government. It announced in March 2008 a two-stage plan for the ZeroGen project. Stage one will develop an 80 MW net coal gasification demonstration plant near Rockhampton in Central Queensland. CO_2 emissions will be captured by up to 75% and transported for injection in deep underground reservoirs in the Northern Denison Trough. Stage two of the project, to be developed concurrently with stage one, will involve the deployment of a 300 MW net coal gasification plant with carbon capture and storage facilities. The capture rate at the large-scale plant will be up to 90% of carbon emissions. Both stages of the project will employ pre-combustion carbon capture technology. The demonstration plant is now expected to be developed by 2012 and the large-scale plant by 2017. As at 2008, the Queensland Government has contributed AUD102.5 million to the project.

Australian Government's Low Emissions Technology Demonstration Fund

The Australian Government established the AUS$ 500 million Low Emissions Technology Demonstration Fund to help Australian firms bring low-emissions technologies to commercialization. The Fund aims to assist companies in demonstrating the commercial potential of new energy technologies in Australia that could lead to large-scale greenhouse gas emission reductions.

AUS$ 50 million (US $42 million) has been funded to the Hazelwood 2030 project where International Power will retrofit an existing coal-fired power plant to include post-combustion capture of 0.1 million tonnes of CO_2 per year.

GreenGen Project China

GreenGen Project will develop an IGCC plant with pre-combustion capture in China. The program was initiated by China Huaneng Corporation in 2004. China Huaneng Corporation and its partners will build two 400-MW IGCC units for Phase II of the green coal power project at Tianjing's Lingang Industry District with 8 other partners. Total investment will be about US$ 675 million and land occupation about 40 hectares. The initial 3,000-tonne carbon capture demonstration facility was commissioned in July 2008. It is the first coal-fired CCS demonstration project in China.

This project is listed under the 2007 "Joint Declaration on Climate Change and Energy Issues" between China and Australia. It has received technical support from Australia's Commonwealth Scientific and Industrial Research Organization (CSIRO) and policy support from the Beijing government with the objective of improving China's capability in combating climate change.

Test Centre Mongstad (TCM), Norway

The Norwegian government has, together with industrial partners, established a center to develop and test new CO_2 capture technologies in order to reduce the costs and risks associated with large-scale CO_2 capture plants. TCM will focus on reduction in both operating and capital expenditure, improvement within health, safety and environment and performance and reliability. The start of the facility is set for 2011, following the start of a gas-fired combined head and power station.

TCM plans to test two technologies – a carbonate technology and an amine technology – through the project. The test facility will increase the knowledge and experience about effect, operation, cost and impact on the environment of these different technologies.

The Norwegian government will also develop a transport and storage solution for 100,000 tonnes of CO_2 annually from the TCM, using depleted offshore oil fields as the storage facility.

Policy measures

- Worldwide direct financial support for the establishment of effective private/public partnerships for well-designed large scale research, development and demonstration projects to:
  - Accelerate technology development and deployment
  - Develop appropriate regulatory regimes
  - Enhance CCS design in order to diminish the efficiency losses from capture
  - Enhance public awareness and acceptance
  - Establish a database of geological characterizations to enable the identification of appropriate storage sites
- The development of consistent regulatory frameworks with respect to the classification of ownership rights to, and accountabilities for, CO_2 repositories and the stored CO_2
- Industry collaboration and review to determine and maintain best practices
- Due recognition of CCS in emissions trading schemes and recognition of CCS as a valid project under the CDM.

Model legislative and regulatory frameworks

In September 2007, state integrated model legislative and regulatory frameworks to support the implementation and development of CCS technologies in power generation were introduced for US states and Canadian provinces. In particular, regulatory frameworks to delineate the long-term storage liability of carbon have been developed in the US with the Department of Energy and the Environmental Protection Agency (EPA). Forty-five states approved these models, to be customized by each one as they enact enabling laws and regulations. As of June 2008, Wyoming had customized the model and many other states are anticipated to take action in 2009. In addition, the EPA has begun to develop federal regulations on storage.

Australia has drafted legislation to establish the world's first framework for carbon dioxide capture and geological storage. The legislation establishes access and property rights for injection and storage of greenhouse gases into a stable sub-surface geological reservoir in commonwealth waters more than three nautical miles offshore. The legislation will provide for appropriate consultation and multiple use rights with other marine users, including fishing and petroleum industries. It ensures pre-existing property and use rights are properly preserved.

On 18 September 2008, the House of Representatives passed the draft legislation and it has now gone to the Senate for approval.

Transmission and distribution

Wedge: Transmission and distribution

Improved transmission and distribution relates to the upgrading of existing electricity grids, the development of new grids, and improved interconnection between electricity grids.

While the upgrading and construction of grids and networks are not directly quantified within our CO_2 sector mitigation wedges, they are essential to enabling the successful integration of many clean energy technologies, and are therefore considered separately here.

Wedge potential

While the IEA states that some US$ 5.2 trillion in investment is required for power generation, US$ 6.1 trillion will be required for transmission and distribution networks between now and 2030. Not only are significant investments in grids required to meet increased demand, but they are necessary to enable the successful deployment of renewable energy technologies and maximize the impacts of energy efficiency measures.

How this wedge contributes to emissions reductions

Adequately developed and interconnected electrical grids (or networks) allow for highly efficient use of generated power:

- The delivery of more efficient power from generation sources to delivery points decreases losses due to reduced resistance within the system (losses account for between 5 and 8% of generation in efficient grids, whereas they can nearly double in less developed ones)
- They enable the use of renewable resources (wind, hydro), which are often located far from load centers
- They drive the broader commercialization of end-use energy efficiency, distributed energy resources and plug-in hybrid electric vehicles, which in turn results in deceases in CO_2 emissions.

Other benefits of grid investment

Adequately developed and interconnected electrical grids contribute to increased energy security.

Technology status

Power grids were historically constructed to transmit and distribute power from a few large-scale power generation units. These were often located close to load centers and as such did not require large scale transmission grids. The grids were not designed to handle the feed-in of power from many smaller-scale power schemes at remote locations, or to cater to a flexible power market with bulk cross-border power exchange. Tomorrow, power grids will need to have the capacity and reliability to operate with a much larger proportion of intermittent renewable sources in specific regions and/or at specific points in time. This will require the creation of grip planning and operations tools, the implementation of special protection schemes and – in the longer term – demonstration of high-voltage direct current (HVDC)/superconductivity.

Advances have been made in power delivery through HVDC transmission, ultra high voltage AC (UHV-AC) transmission, gas-insulated substations, flexible alternative current transmission systems (FACTS) and advanced wide area monitoring of power delivery system operations.

At the same time, emerging technologies such as ultrahigh-voltage DC transmission systems and superconducting cables offer the potential for even greater efficiency in the future. HVDC devices can also be used in environmentally sensitive areas as the cabling can be laid underground or underwater, avoiding the visual intrusion of overhead cables.

The development of higher rated 800 kV DC systems indicates that they will be highly efficient in transporting power blocks of up to 6,400 MW at distances of over 1,000 km, with reduced line losses and improved grid reliability for the host AC system.

ABB ultrahigh-voltage direct current (UHVDC) technology in China

ABB will supply the State Grid Corporation of China and other partners with new ultra-voltage technology for the world's longest power transmission link.

The power superhighway running 2,000 kilometers (1,240 miles) from western China to the highly industrialized coastal area in the east will have a capacity of 64,000 megawatts. The link from the Xiangjiaba hydropower plant to Shanghai is scheduled for completion in 2011.

Breakthrough technology to transmit electricity at ultrahigh voltage (800 kilovolts) will be used, minimizing the amount of power lost in transmission, bringing environmental benefits. With the introduction of China's national reduction targets on energy use and emissions, the incorporation of important energy efficiency components in such major construction projects has increasingly become regular practice.

Lack of investment incentives:

In the US, while the electrical power transmitted each year increased from 2.2 to 3.3 billion kWh between 1980 and 2000, yearly investment in the grid fell from US$ 4.5 billion to US$ 2.6 billion during the same two decades – a decrease in investment per kWh of 6% per year.

Challenges that prevent this wedge from meeting its potential

- **Actual vs. needed investments:** Transmission and distribution (T&D) investments have only recently started to increase moderately in industrialized countries after decades of steady decline resulting in threats to grid reliability and security. In developing countries, investment needs are even greater
- **Grid inefficiencies:** While losses amount to 5-8% of generated power in industrialized countries, the figure can be more than double in less developed grids
- **Lack of supportive investment climate:** Flaws in the public regulation of the business (a low return on investment authorized by regulators and poor or non-existent incentives to invest in grid infrastructure) result in insufficient investment
- **Misperception that grid investments will cause electricity prices to increase significantly:** As transmission only represents a small proportion of electricity cost to the end consumer in the majority of countries, upgrades typically do not add significantly to the retail cost of power
- **Local opposition to transmission line building and wind generation siting**, as a result of a strong "not in my back yard" (NIMBY) syndrome.

Policy measures

- Increase stakeholder engagement and public debate to address problems related to "NIMBYism" around the construction of transmission lines.
- Regulation of the transmission and distribution businesses in order to ensure a sufficient rate of return on investment for operators.
- Regulatory standards by which approved network development plans must include the necessary technical capacity to accommodate generation from renewable energy sources.
- Pairing of the incentive schemes introduced to develop carbon-free and lower carbon generation with network development plans that include the reinforcements required to accommodate desired new generation, taking into account that the cost of connecting a new plant to the network is borne sometimes by the generator, sometimes by the network operator.
- Policies encouraging extra high voltage (765 kV) backbone technology, with many interconnections to lower voltage lines and significantly increase efficiency through reduced energy line losses.

Notes and references

[1] The order in which the technologies are listed in this document does not reflect prioritization of one technology over another.

[2] International Energy Agency (IEA), *Energy Technology Perspectives 2008: Scenarios and Strategies to 2050*, 2008. All scenarios built in this study as an alternative to the "baseline scenario" assume an accelerated development and deployment of low-carbon and carbon-free technological solutions through dedicated public policies. The BLUE Map scenario is the most aggressive in terms of both technological innovation and diffusion, enabling the stabilization of global temperature rise to between 2-2.4°C

[3] *The Guardian*, "Britain set to miss EU renewable energy target", http://www.guardian.co.uk/environment/2008/jun/19/renewableenergy.alternativeenergy?gusrc=rs s&feed=politics

[4] OECD Nuclear Energy Agency (NEA) and International Atomic Energy Agency (IAEA), *Uranium 2005: Resources, Production and Demand* ("Red Book"), 2006.

[5] In 2004, the worldwide mix of fossil fuel plants generated 11,490 TWh and emitted 10.6Gt of CO_2, or 0.92 Mt CO_2/TWh. Assuming the replacement of existing nuclear plants by fossil fuel based generation, based on 2004 figures (2,740 TWh), the elimination of nuclear would add an estimated 2.5 Gt of CO_2 to the atmosphere.

[6] **France:**
World Nuclear Association, "Nuclear Power in France", http://www.world-nuclear.org/info/inf40.html
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Disclaimer

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Technology "issue briefs" and further information

In the second phase of the Electricity Utilities Sector Project, an in depth analysis of the factual context for seven power generation technologies was undertaken on:

1. Coal
2. Gas
3. Carbon capture and storage
4. Nuclear
5. Hydro
6. Non-hydro renewables
7. Hydrogen

The project also produced "issue briefs" on the topics of access to electricity, transmission and distribution and energy efficiency. This analysis provides additional supporting technical detail to the content within this publication.

These are available for download at: www.wbcsd.org/web/electricity.htm.

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