DEDICATED TO MAKING A DIFFERENCE

Powering a Sustainable Future

Policies and measures to make it happen

An interim report

World Business Council for
Sustainable Development

About the WBCSD

The World Business Council for Sustainable Development (WBCSD) brings together some 200 international companies in a shared commitment to sustainable development through economic growth, ecological balance and social progress. Our members are drawn from more than 30 countries and 20 major industrial sectors. We also benefit from a global network of about 60 national and regional business councils and partner organizations.

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

Our objectives include:

Business Leadership – to be a leading business advocate on sustainable development;

Policy Development – to help develop policies that create framework conditions for the business contribution to sustainable development;

The Business Case – to develop and promote the business case for sustainable development;

Best Practice – to demonstrate the business contribution to sustainable development and share best practices among members;

Global Outreach – to contribute to a sustainable future for developing nations and nations in transition.

www.wbcsd.org

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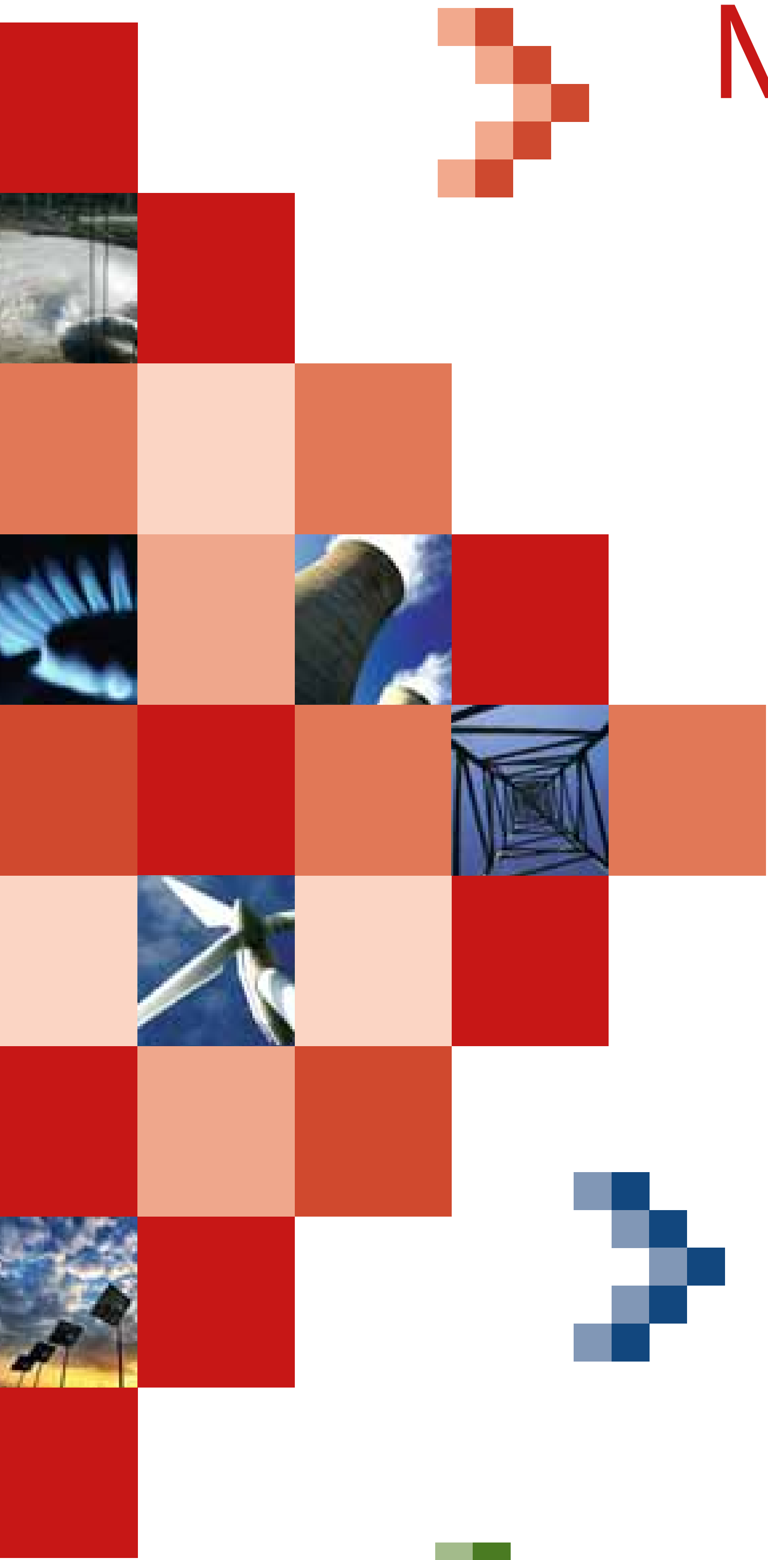
See the inside back cover for our comprehensive booklet on power generation technologies and demand-side management measures.

Message from



We come together as a group of ten global companies within the WBCSD Electricity Utilities Sector Project, working to promote the achievement of a sustainable electricity future. Together, we collectively represent over 405,000 MW of installed generating capacity and touch over 306 million customers every day.

The power sector is currently responsible for 41% of global energy-related CO_2 emissions and projections suggest that electricity demand will double by 2030. It is crucial to meet increased demand for electricity at an affordable price and ensure adequate return while contributing effectively to climate change mitigation. Electricity consumption must therefore be more efficient and supply less carbon intensive. We recognize that this is an enormous and urgent challenge but one that is not out of reach. We are prepared to take action and here, we call on governments to do the same.

Building on our past work, this publication focuses on how we can harness the full potential of low carbon options for both power generation and consumption. We have identified technologies that are mature for commercial implementation, as well as future solutions which currently face technological or commercial barriers to deployment. To both enhance the implementation of existing solutions and ensure the development of promising ones, we highlight the need for new policies, and propose detailed recommendations for individual solutions.

The following points summarize the key actions that we believe will enable our sector to enhance its contribution to addressing the global climate change challenge:

Fred Kindle
Chief Executive Officer
ABB Ltd.

Pierre Gadonneix
Chairman and Chief Executive Officer
EDF Group

Michael Morris
Chairman, President and
Chief Executive Officer
AEP

Andrew Brandler
Chief Executive Officer
CLP Holdings Ltd.

the CEOs

- Immediately establish energy policies that *incentivise investments* in currently available low or zero emission technologies at the end-use and generation levels;
- *Support innovation and R&D efforts* across a wide range of promising technologies to secure that a continuous pipeline of options are brought to the market in the medium and long term;
- *Customize policy interventions* and continually review their effectiveness to make sure they take account of national needs and objectives as well as technological maturity;
- Ensure the *complementary implementation of policy tools* such that they work together in achieving the overarching objectives of CO_2 mitigation, social development and energy security;
- Use an *effective blend of policy tools* that combine market and regulatory instruments and encourage voluntary action;
- *Promote realistic pricing* that reflects investment cost and CO_2 value while addressing social development issues through specific policy measures;
- Realize the *potential of emission reductions along the entire electricity supply chain*, from production to end-use by consumers;
- Fully recognize the *importance of transmission and distribution* and ensure the required investment;
- Establish *strong integrated infrastructure planning* and policy environments which promote coordinated disaster recovery plans and mechanisms, in order to meet existing climate adaptation challenges;
- *Increase developing countries' capacity to adopt climate change related technologies* through enhanced technology transfer supported by policies tailored to the host country needs;
- *Expand the use and effectiveness of the CDM or other future mechanisms* to facilitate the large scale deployment of key technologies.

We are confident that an enabling policy environment, which sets the right framework conditions, will allow us to establish a global, quantifiable, long-term GHG emissions pathway in order to make markets work and attract investments to the most effective projects. In line with these requests, we are committed to acting today to reduce our carbon footprint through accelerated investment in low carbon technology development and deployment; continued work to reduce the carbon intensity of our electricity generation and improve the efficiency of our operations; collaboration with government and other stakeholders to drive R&D; and engagement to improve the end-use energy efficiency of our customer base.

We cannot do this in isolation; we need to work together with all governments and other stakeholders to find the solutions. We realize that this change will take many years, but by leveraging effort, we are in no doubt that a low carbon and sustainable energy future can be achieved. Through this publication, we have outlined some possible options and trust that this will provide a basis for further discussion and engagement.

Jacob Maroga
Chief Executive
Eskom Holdings Ltd.

Shosuke Mori
President
Kansai Electric Power Company

Gérard Mestrallet
Chairman and Chief Executive Officer
Suez

Jean-François Cirelli
Chairman and Chief Executive Officer
Gaz de France

Bård Mikkelsen
Chief Executive Officer
Statkraft

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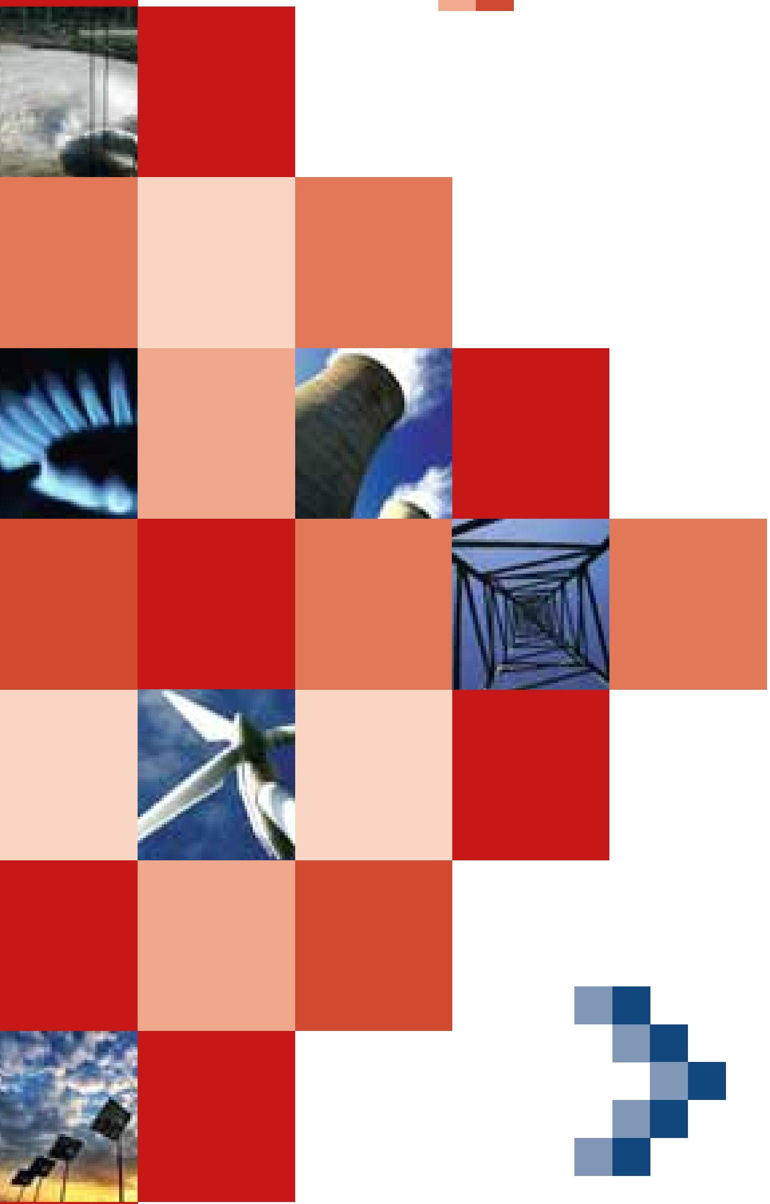
President
Tokyo Electric Power Company



The WBCSD Electricity

This report is issued by the ten member companies of the WBCSD Electricity Utilities Sector Project. This project was initiated within the WBCSD in January 2000, bringing member companies together to develop a deeper and more concrete understanding of the sustainability challenges facing the sector, examine potential business contributions, and explore policy needs.

Sustainability in the electricity utilities sector, a first report published in 2002, details sustainability principles and strategies for the sector. It provides concrete examples of industry activities through case studies, as well as a collection of best practices.

In an October 2006 Phase 2 report entitled *Powering a Sustainable Future: An Agenda for Concerted Action*, the companies identified six urgent needs requiring the efforts of all stakeholders:

1. Secure investment in infrastructure
2. Get more power to more people
3. Use the resource of end-use efficiency
4. Diversify and decarbonize the fuel mix
5. Accelerate research & development
6. Reinforce and smarten the grids

In support of this agenda, the project developed a series of "facts and trends" and "issue briefs" on the technical options available to the electricity utilities sector. The analysis shows that there is enough technological potential to meet the global energy and climate change challenges in the longer term, that all technologies have advantages and drawbacks and that a portfolio approach is needed. Conclusions underscore that policy is required for the technological potential to be fully realized, leading to the work presented within this report. We summarize our current findings in the pages that follow and within the *Powering Sustainable Solutions: Policies and measures* booklet included in the inside back cover of this document. These documents are presented as an interim report to inform a series of international stakeholder dialogues that will take place through 2008.

Utilities Sector Project

Member companies (Phase 3):

ABB
American Electric Power
CLP
EDF
Eskom
Gaz de France
The Kansai Electric Power Co., Inc.
Statkraft
Suez
TEPCO

Project profile: represents total capacity of project members	
Gross generating capacity (MW)	405,500
Number of customers (million)	306
Large hydro capacity (MW)	54,730
Other renewable capacity (MW)	7,240
Nuclear capacity (MW)	104,840
Natural gas capacity (MW)	93,800
Advanced coal capacity (MW)	23,500
Demand management (MW)	170
Transmission & distribution (km)	3,194,650
Transformers (MVA)	939,185
Gas/liquid capacity (MW)	930

Addressing the

global climate change challenge

The electricity utilities industry faces an enormous responsibility in the global fight against climate change. The sector facilitates economic development and growth through the provision of an essential service that can no longer be produced and consumed as in the last century. As the industry is currently responsible for 41% of global energy-related CO_2 emissions, and with projections suggesting that sector emissions might double by 2030, the question of how to meet the increased demand for electricity at an affordable price while effectively contributing to climate change mitigation efforts becomes a crucial challenge.[1]

The positive news is that the electricity sector does have a huge opportunity to contribute to CO_2 emissions reduction.

First, many of the technological solutions exist today to address the challenge:

- As electricity is a flexible energy carrier, switching to lower emitting fuels can substantially reduce sector emissions;
- Carbon-free (hydro, nuclear and wind in some regions) and lower carbon (supercritical pulverized coal (SCPC) plants, combine cycle gas turbine (CCGT)) generation technologies as well as highly efficient end-use technologies (building insulation, lighting, heatpumps, and solar heating in some regions) are currently available to contribute to the reduction of carbon emissions;
- Other promising technologies, like carbon capture & storage (CCS), generation IV nuclear or photovoltaic, have the potential to contribute to the substantial decarbonization of the sector at acceptable cost by 2050.

Second, the sector is presented with an extraordinary window of opportunity given that the current investment needs in terms of capital replacement and additional infrastructure development are projected at US$ 11 trillion in required investments by 2030. This represents a four-fold increase over the investment wave in the second half of the 20th century. These funds will primarily be necessary to meet demand growth requirements in developing countries, and to replace ageing plants in developed countries, providing an opportunity to invest in low-carbon technologies for power generation, delivery, and use.

Acting within this window of investment opportunity is a challenging task. The existing solutions need to be deployed at the scale and speed required to curb the emissions trend and move the electricity sector towards a low-carbon future, in developing as well as industrialized countries. Furthermore, research and development (R&D) of promising technological solutions must be enhanced if we intend to meet the clear need for massive investments from now to 2050 sustainably.

How is the electricity utilities sector contributing to the solution?

The electricity utilities industry is participating actively in climate change mitigation efforts within the framework defined by governments:

- It helps bring to market more efficient and cleaner technologies through a continuous innovation process, as guided by its market understanding and public research, development and deployment (RD&D) incentives;
- It plans to continue investing in climate change related technologies, taking into account the influence of existing policies and regulations on the relative costs of available technologies and local circumstances;
- It is pursuing substantial work on how to adapt its generation and transmission to climate change and prepare for potential impacts on business operations.

How to achieve more?

This important contribution of business could and should be substantially greater. The electricity sector would invest more systematically in climate change-related, best-available technologies, if a more effective policies and measures framework were in place for the sector. This would enable further action in those countries that signed the United Nations Framework Convention on Climate Change (UNFCCC) more than a decade ago.

The two-fold purpose of a policies and measures framework for the sector should be:

- First, to drive investments towards available efficient power delivery and end-use equipment and carbon-free/low-carbon power generation technologies through the two first decades following the renegotiation of an international framework (2013-2025/2030);
- Second, to ensure that the promising technologies researched and developed today are brought to market in the following decades (2025/2030-2050), with a long-term objective of substantial decarbonization of the sector (e.g., halving sectoral GHG emissions worldwide by 2050).

Those policies and measures for the electricity sector may be part of a basket of “sustainable development policies and measures” aiming to achieve development with reduced emissions, without sacrificing economic growth or well-being. As such they are basic elements for the post-Kyoto international climate framework, regardless of how this framework defines common but differentiated responsibilities for countries.

The purpose of this report is to describe the key features of this sectoral policies and measures framework. We have identified nine “wedges” on which to focus policy building efforts. Our analysis illustrates the types of policies and measures that are being used around the world today, or could be used to enable these nine identified wedges to meet their potential. The following pages describes what we have identified as the key features of a policies and measures framework for the sector and our wedge analysis is included within the *Powering Sustainable Solutions: Policies and measures* booklet included in the inside back cover of this document.

We do not advocate any one approach in particular. We recognize that all of the approaches have potential merits, and that their effectiveness depends to a large extent on the jurisdictional context. We believe that a portfolio of policies and measures is needed, and recognize that ideal combinations will vary from place to place depending on national or regional circumstances.

Powering Sustainable Solutions: Policies and measures

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

Shaping a policies and measures framework for the electricity sector

The following statements are built on the premise that for the deployment of appropriate technologies to occur at the required scale, collaboration between the power sector, government and societal actors is key, and must be underpinned by sound public policy.

Powering a Sustainable Future: An Agenda for Concerted Action previously examined the broad scope of sustainability opportunities and challenges facing the electricity sector and the enormous benefits electrification provides to developing countries for social and economic development. Without undermining the importance of all sustainable development issues facing the sector, this report focuses on climate change mitigation policies and measures, which provides an opportunity to focus on these urgent policy needs.

A two-fold objective

To stabilize and then reduce GHG emissions from the electricity sector with the long-term objective of substantial decarbonization, we need:

1. On the demand (or end-use) side:
   - Dramatic energy savings through energy conservation as well as efficiency improvements that provide comparable or better energy services with less consumption;
   - Acceleration of end-use electrification by displacing some stationary uses of fossil fuels.
2. On the supply side:
   - Transformation of electricity infrastructure toward low-carbon electricity generation;
   - Smart and robust grid to deliver this power efficiently, and to serve an increasingly complex network with many distributed sources of power.

Such efficiency and decarbonization objectives imply a dramatic departure from current "business as usual" electricity generation and emissions trends. The International Energy Agency (IEA) Baseline scenario projects that electricity output will triple between 2003 and 2050 and that emissions will increase from about 10 to 26 Gt CO_2. Their alternative, "Tech Plus" scenario suggests a potential decrease of sector emissions in 2050 to 5 Gt CO_2 with only a doubling of electricity output.[2] This estimates that the sector has the capacity to achieve an approximate 21 Gt CO_2 reduction in emissions as compared to the "business as usual" projections by 2050. Our "wedge" documents have based their policy analysis on this mitigation potential scenario.

This two-fold objective, while seemingly clear, is complex in its realization. Achieving them will require a combination of policy instruments designed and implemented with consideration of technology characteristics, national circumstances and, eventually, the coordination of nationally developed policies at the international level.

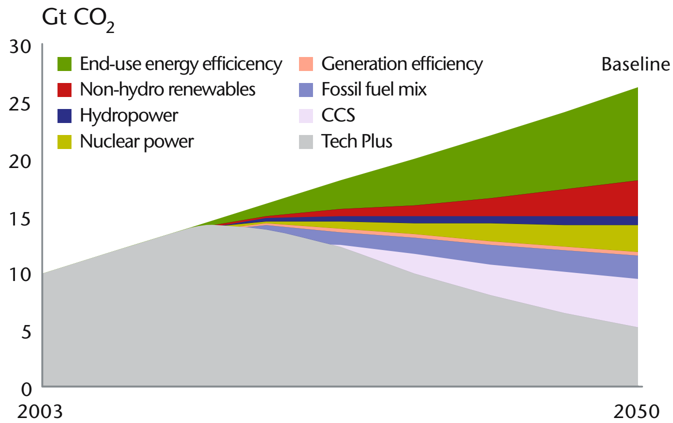


Figure 1: CO_2 reduction potential within the power generation sector by contributing factor (adapted from IEA, 2006).

Policies catered to

technological maturity

A variety of technological solutions are available for the electricity utilities sector today, each with different carbon mitigation potentials, and each at different stages of development and deployment. This calls for different types of policy intervention, as indicated in the table below and described in the next four paragraphs.

Technology situation 1

Some end-use or carbon-free generation technologies, such as housing insulation, hydro or nuclear power generation (in certain countries) are mature and competitive. They urgently require regulation that builds public acceptance and fosters successful implementation. Some may also require incremental financing to bridge the affordability gap. Such regulations should be technology and country-specific, and could for instance:

- Provide for the assessment of hydro projects according to the International Hydropower Assocation (IHA) Sustainability Assessment Protocol (see box);
- Ensure that clear and transparent licensing and safety procedures are in place for nuclear power.

Technology situation 2

Some technologies like ultra supercritical pulverized coal (USCPC)[3] power generation and wind power in optimal locations are mature and would be competitive were the value of CO_2 emissions internalized into electricity prices. This could be done through mandatory performance standards, carbon taxes or cap & trade systems.

Technology situation 3

Some technologies, like wind power in average quality locations or heat pumps for cooling & heating, are mature or quasi-mature and not far from competitiveness. The main issue relates to ensuring their large-scale deployment to enable them to descend learning curves quickly and obtain wide-scale uptake. They will need mass-deployment support through, for example, feed-in tariffs or financial incentives.[4]

In addition, defining development zones for wind power will be important to minimize the "not in my backyard" syndrome (NIMBYism) and ensure that mass-deployment schemes result in the required investment in the most geographically suitable locations.

Technology situation 4

Other technologies like CCS or generation IV nuclear are promising but not yet mature. The basic need for these technologies is to accelerate research and development and boost large-scale demonstrations necessary to prove their commercial viability and eventually make them competitive in the market. This will require direct public RD&D support, and moreover the successful organization and coordination of public-private partnerships with international participation.

Clearly, a given technology is often not in a single maturity/competitiveness class in every country and for every application. Its position along the development and

Table 1: Technology situations

Technology situations	Level of maturity and competitiveness	Main policy response	Technology example
1	Mature and competitive	• Enabling deployment regulations	• Housing insulation • Compact fluorescent lamps (CFL) • Large hydro • CCGT • Generation II & III nuclear
2	Mature and competitive if carbon is valued	• Carbon valuation tools (cap & trade or carbon tax systems, mandatory performance standard systems)	• USCPC power generation • Wind power in best locations
3	Close to maturity and near a competitive stage	• Mass-deployment schemes (feed-in tariffs, tradable green certificates...)	• Wind power in average quality locations • Heat pumps
4	Promising but far from being mature and competitive	• Organize and support direct RD&D • Public-private partnerships	• CCS • generation IV nuclear

deployment path depends on the country of deployment and the way in which the equipment incorporating the technology is designed and used. While heat pumps are generally considered to be near a competitive stage in many locations, they are already competitive in Japan. Solar water heating equipment in China is designed for a simple application, and is thus competitive. The more complex design and application in many developed countries limits the competitiveness of this technology.

Policies must also take into account the fact that technology systems may require the deployment of individual technologies which are at difference stages of maturity. Such is the case for CCS: while CO_2 transport technologies are mature, carbon capture technologies at the power generation level are at various stages of demonstration or technically unproven for certain types of coal. Geological carbon storage is still in a very early testing phase. An important element of the policy response is to accelerate the development of the technological elements of the system that are lagging.

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 idea is to have independent and documented auditing look at whether a project is needed, whether it is rightly located, whether it is acceptable from a social and environmental point of view, 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:

1. Political risk and regulatory approval;
2. Economic viability;
3. Additional benefits;
4. Planned operational efficiency and reliability;
5. Project management plan;
6. Site selection and design optimization;
7. Community and stakeholder consultation and support;
8. Social impact assessment and management plan;
9. Predicted extent and severity of economic and social impacts on directly affected stakeholders;
10. Enhancement of public health and minimization of public health risks;
11. Safety;
12. Cultural heritage;
13. Environmental impact assessment and management plan;
14. Threshold and cumulative environmental or social impacts;
15. Construction and associated infrastructure impacts;
16. Land management and rehabilitation;
17. Aquatic biodiversity;
18. Environmental flows and reservoir management;
19. Reservoir and downstream sedimentation and erosion risks;
20. Water quality.

The IHA is studying the possibility of accrediting independent auditing companies for performing such an assessment in order to use a common and valuable tool worldwide.

Building consistent and

effective policy packages

To ensure meaningful and effective implementation of technologies, consistent and effective policy packages will have to be developed, using an appropriate combination of mechanisms and instruments.

Different types of mechanisms are available to build public policies:

- Market-based mechanisms (such as tradable allowances, credits and taxes), which establish a value for carbon emissions or reductions, are important to promote existing solutions that are competitive or nearly so but not being deployed rapidly enough.
- "Command and control" regulations (such as performance standards, portfolio requirements, siting procedures or voluntary programs under "pledge & review") are are indispensable tools for implementing policies aimed at reducing emissions.

The effectiveness of a mechanism depends critically on the quality of its design, as highlighted in the box on cap & trade on page 12.

Public policies will also have to use a combination of the different types of instruments, with consistent integration and coordination.

For instance:

- Tax credit systems and mandatory performance standards and labeling schemes in the case of, for example, energy-efficient solutions like CFLs or housing insulation whose diffusion require substantial front-end consumer investment and have high transaction costs.
- Cap & trade systems associated with regulations that facilitate market access and foster successful deployment for mature power generation technologies. Such supportive regulations are, for example, those that provide more predictable and reasonable timelines for siting and licensing of base load (coal-fired, gas-fired, nuclear) power plants, or define development maps for wind power.

Policy instruments must be combined with regard for complexity, cost and global effectiveness:

- The combination of tax credits with advanced but robust technology standards is for instance successful in boosting the deployment of high-efficiency products like heating and cooling heat pumps systems. Adding a white certificate system to this framework (where a mandatory energy savings objective borne by energy suppliers is attainable through certified actions that bring tradable certificates to the market) may increase flexibility for the participants, but also lead to increased complexity and higher transaction costs for both participants and regulators (see box on page 13 for more details about white certificates).
- A support scheme for mass-deployment for mature or quasi-mature renewable energy is appropriate. This scheme should minimize the total need for financial support, and minimize the negative environmental consequences. It should also secure the right investment incentives at the lowest possible cost, be robust against changing framework conditions, and create an attractive and stable framework for investors and suppliers. Applying this principle is all the more important as deployment targets become increasingly ambitious.

The EU has for instance adopted a binding 2020 target of 20% renewable energy sources, which could mean as much as a 34% share for renewables in the electricity mix. The current support system, which consists of non-harmonized national schemes, most of them based on feed-in tariffs, some on tradable renewable certificates (see box below), is not considered adequate to meet the target at an acceptable total cost. An EU-wide system, which selects a specific instrument (whether it be feed-in tariffs or renewable certificate instruments) for all countries, appears a more a cost-effective option as it would allow the optimization of EU resource potential across borders.

ROC Policy

A Renewables Obligation Certificate (ROC) is a green certificate issued to an accredited generator for eligible renewable electricity generated within the United Kingdom and supplied to customers within the UK by a licensed electricity supplier. The ROC is the main support scheme for renewable electricity projects in the UK. It places an obligation on UK electricity suppliers to source an increasing proportion of their electricity from renewable sources.

Making cap & trade work

A cap & trade (C&T) system (i.e., setting a GHG emissions absolute target and allowing subsequent trading of emissions permits between the players that have binding emissions targets), is one possible mechanism with which to attribute a market value to emission reductions, otherwise unaccounted for in traditional markets. C&T systems have had some success, for example, the North American acid rain program. Other price mechanisms such as taxes, for instance, can set a regulated price for emissions. Mandatory performance standards are further (non-price) means of carbon emissions valuation.

If a C&T system is used, conditions must be met for it to play its expected role, which is among others, to provide incentives for investments in cleaner technologies:

- The rules of the C&T system must provide players with long-term visibility over framework conditions on a time horizon in line with their investment choice. This requires that market rules be defined over at least 15-20 years and that market stability be, to the greatest extent possible, maintained so as to provide certainty to investments in low-carbon technologies;
- The specific details of the market rules should be defined in such a way that they effectively encourage investment in lower carbon and carbon-free technologies. Economic theory, and the example of the US SO_2 market, show that the following rules can lead to such an efficient market:
    - Allowance of permit banking within the operating period;
    - Free allocation of permits to existing plants through "grandfathering" once for all, with a decrease over time according to emissions reduction objectives;
    - Obligation for all new projects to buy their emissions permits;
    - No withdrawal of emission permits when plants are decommissioned.
- Capping emissions and leaving the determination of the carbon price to the free market may appear risky as future abatement costs are fairly uncertain in the short and mid term periods. Several actors therefore request the introduction of a "safety valve" to protect industry against excessive emission price spikes.

In parallel, all direct uses of fossil fuels, including energy services provided at customer sites (such as space or water heating) must bear the cost of the emissions for which they are responsible (possibly through some carbon tax or an "upstream" cap & trade system). Otherwise, the significant CO_2 reduction potential deriving from the substitution of direct fossil-fuel burning by low-carbon electricity will be hindered.

Realizing the potential of
emissions reduction on the demand side

Efficiency improvements and direct emissions reduction through the use of low-carbon end-use systems and appliances represent the greatest global potential for cost-effective emissions reductions, but face a number of specific behavioral and economic barriers:

- The number of individual decision-makers (i.e., customers) is extremely large and consumer preferences are such that the present value of consumption is estimated at a higher value than potential long-term savings (i.e., customers would rather pay less today for an appliance despite the fact that a slightly more expensive alternative is more economical in the long-run due to lower operational costs).
- Those actors making investment decisions are not necessarily those that will reap the benefits, or alternatively those who will bear the cost (i.e., in the case of rental housing, the landlord is responsible for any energy efficiency investments, while it may be the tenant that benefits from the savings; or in the case of leased office space, the tenant may alter behavior, but it is the building owner or operator who benefits).
- Finally, the potential “rebound effect” of energy efficiency improvements is such that some consumers may tend to increase consumption due to the lower cost of electricity, thus undermining any efficiency gains.

Establishing performance standards for end-use energy consumption is an important and effective step, but alone may not achieve sufficient reductions. A specific collection of complementary policy measures is typically necessary:

- Repeated information campaigns to make customers fully aware of cost-economic investments;
- Regulations and incentives to ensure the alignment of multiple players in investment decisions (i.e., landlord and tenant interests in the case of housing);
- Financial mechanisms to address consumer reluctance to make high front-end investment (in exchange for a sequence of future savings over a long period of time);
- The maintenance of tax credits for buyers for some period of time when the technologies embedded in equipment are considered mature and cost-effective;
- Electricity prices reflecting their full cost, including greenhouse gas reduction costs, in order to limit the “rebound effect”;
- Policies allowing electricity utilities to recover investments made in energy efficiency measures, for instance through tariff structures.

“White certificates” in the UK and France

A “white certificate” system is a C&T system: there is a mandatory energy savings objective borne by energy suppliers and attainable through certified actions (which may include, for example insulation improvements or double glazing windows) that introduce tradable certificates to the market. To hold the required volume of certificates, companies can act alone or in partnership to support customer investment in efficiency projects, or buy certificates from registered vendors. Savings are thus expected to be attained at the lowest possible cost.

Such a system was introduced first in the UK, followed by France and Italy. It has given a positive impulse to the energy efficiency improvement process in countries where it was introduced and it promotes consumer awareness.

It adds substantial complexity (there are usually some 50 kinds of measures, generating high transaction costs).

The originally implemented version of the mechanism has been modified in the UK to also ensure effectiveness in reducing GHG emissions.

Fully recognizing the importance of

transmission and distribution

Low investment in transmission and distribution (T&D) in the last two decades and changes in power flows due to market liberalization have resulted in ageing and overloaded networks and increased risk of power failures in industrialized countries. In addition, the need for more integrated and expanded alternating current (AC) and direct current (DC) infrastructure is enormous in many developing countries. Furthermore, network strengthening and development is increasingly complex as a result of the need to connect renewable intermittent power generation plants, decentralized generation, and a number of very large, new base-load plants. The building of T&D lines and interconnections can be problematic in terms of public acceptance and finding suitable routes generally raises fierce opposition.

Policy support to carbon-free and lower-carbon power generation schemes can only be effective if power T&D grids are strengthened and developed to deliver clean energy. As power is mainly delivered through regulated, natural T&D monopolies, this is almost a pure policy and regulatory issue.

Policy-makers should be aware that grid investments are not likely to be a major cause of electricity price increase as high-voltage transmission generally accounts for 7 to 10% of total electricity supply cost. On the other hand, to secure the necessary investment in smartening and reinforcing the grid, regulation of transmission must allow network operators sufficient rate of return on the required investments.

Policies aiming at boosting the development of low-carbon generation schemes must be matched with network development plans that include the reinforcements required to accommodate desired new generation. They must also consider the allocation of new plant connection costs between the generator and the network operator.

Transmission regulation in federal states should be such that authorization for building transmission lines rests with federal regulatory bodies. In regions (such as Western Europe), where interconnections between countries are needed, concerned states should work in cooperation to ensure their development.

Bringing in a

pipeline of breakthrough technologies

Developing breakthrough electrical technologies is integral to achieving global energy objectives. The electricity sector needs technologies to improve energy efficiency and reduce the carbon intensity of the energy mix. Technologies are also required to provide universal access to electricity and a reliable infrastructure to underpin development (although the implementation of existing technologies will also play a significant role). A key condition to ensure the development of a pipeline of technologies, will be the successful leveraging of resources and partnerships.

Business efforts in technology innovation and development need to be supported by national enabling policies and frameworks:

- National technology development strategies that cover fundamental research and innovation as well as emerging and near commercial areas in order to ensure a pipeline of new technologies;
- National research programs targeted at local barrier identification and the recognition and support of opportunities;
- Policies can include positive incentives for R&D, with direct public funding focused on technologies for which commercialization prospects are too uncertain or remote from a business perspective.

For technologies of global importance and high RD&D cost, national programs should be coordinated at the international level and multinational programs should be strengthened and further developed. Such technologies include CCS, solar photovoltaic, generation IV nuclear or fusion.

It is critical that, as a whole, technology development programs cover a wide range of technology options. Given the plethora of national and local conditions, resources and policies, these technologies must be developed in parallel rather than sequentially, in order to bring them to market in time to stabilize emissions.

For instance, setting up a mechanism for the development of 20 CCS pilot plants (with some funding to cover the incremental cost) in key countries around the world would speed up learning and more importantly, the acceptability of the CCS technologies at the local level.

There is a great need for public funding for additional large-scale demonstration projects around the world. The FutureGen global initiative for clean coal, in which public and private sector participants are jointly funding and guiding the research, is one example (in that it is open to foreign partners). These projects should be closely linked to capacity-building initiatives, particularly in developing countries, and allow for wide diffusion of intellectual property.

The FutureGen Project

FutureGen is a public-private partnership between the US Department of Energy (DOE) and the FutureGen Industrial Alliance Inc., a non-profit consortium of 12 leading international energy companies, to build a first-of-its-kind 275 megawatt coal-fueled, near-zero emissions power plant (capable of powering about 150,000 average US homes), at an estimated net project cost of US$ 1.5 billion.

The plant will use cutting-edge technologies (such as IGCC) to generate electricity while capturing and permanently storing CO_2 deep beneath the earth. It will also produce hydrogen and by-products for possible use by other industries.

The integrated use of these technologies is what makes FutureGen unique: while researchers and industry have made great progress in advancing technologies for coal gasification, electricity generation, emissions control, CO_2 capture and storage, and hydrogen production, these technologies have yet to be combined and tested at a single commercial-scale demonstration plant. This is an essential step for technical and commercial viability.

The Alliance comprises seven coal producers and five electricity utilities who are responsible for designing, constructing, and operating the facility. The DOE is responsible for independent oversight and coordinating the participation of international governments. Alliance member companies are dedicating nearly US$400 million toward the project's cost and bringing valuable technical expertise and power plant engineering and construction experience to this effort.

During the first four years of operation, DOE regulations require that a significant amount of the information about plant operations be made public. Most of the intellectual property employed in FutureGen is expected to be owned by the suppliers of the novel equipment (e.g., gasifiers) that are incorporated into the plant.

Increasing developing countries'

capacity to address climate change

A key global policy objective is to encourage developing countries to maintain/improve the efficiency of their existing plants, to invest in best available technologies and to contribute to developing future technologies.

To effectively enable these objectives to be achieved, the following points must be considered:

- Policies and instruments to support technology transfer need to be tailored to the maturity of technologies.
- For technologies that are mature and competitive both in developed and developing countries, effort needs to be focused on sharing knowledge related to project management, operations feedback, regulatory frameworks and best practices.
- For technologies that are mature in developed countries but not yet in developing ones, policies should be aimed at securing and encouraging foreign direct investment (FDI), joint-ventures or investments in CDM projects (that provide developed countries with emissions credits under the Kyoto Protocol), in partnership with local players.
- For future technologies, collaborative research is required to enable *ex ante* definition of intellectual property rights and ensure that developing countries will be able to access future technologies when available.
- Barriers that may prevent technology transfer or deployment must be removed. These barriers may take the form of legal requirements that prevent or limit foreign investment in developing countries or taxes on imports that impede transfer between rapidly industrializing countries and least developed countries. In some circumstances, changes in regulations in a recipient country can accelerate technology transfer. Electricity market restructuring in China, for example, has occurred rapidly and corrected the regulatory flaw of not using merit order dispatch that previously prevented the country from optimizing its power generation.
- It should be recognized that developing countries may also be a source of new technology development, as well as recipients.

As many companies have a global reach through markets or supply chains, business has a key role to play in the diffusion of developed technologies worldwide through FDI as well as through the supply chain. This may be possible, provided that the barriers noted above are overcome and the issue of intellectual property is dealt with. The concept of "patient capital" also needs to be considered in order to leverage resources and reduce risk. This would consist of leveraging private equity with other forms of support, such as from the World Bank and other development banks, official development assistance (ODA) and the CDM.

While the CDM is an important mechanism, it is not achieving the large-scale clean energy technology development and emission reductions originally envisaged. Barriers include the low level of capacity to identify and implement projects, high transaction costs (which are prohibitive for many small projects), "excessive" additionality requirements, a project-based approval process that is self-limiting, and the *de facto* exclusion of certain technologies.

At the conclusion of the first commitment period of the Kyoto Protocol in 2012, the CDM should be expanded as follows:

- Streamlining the approval process of small projects, which is currently underway, should be brought rapidly to a successful conclusion.
- All technologies that can result in large scale reductions need to be accommodated within the CDM and future mechanisms of the post-2012 agreement. Specifically, nuclear power and clean coal technologies with carbon capture and storage should be included.
- Enabling rules for the realization of large or programmatic CDM need to be fast tracked to rapidly facilitate learning by doing, and allow large scale deployment of technologies (e.g., an energy efficiency program applying to a city or a city district in a developing country).

The Generation IV International Forum (GIF)

The Generation IV International Forum was established in January 2000 to coordinate international research & development on innovative nuclear energy systems to benefit from comparative advantages that include reduced capital cost, enhanced nuclear safety, minimal generation of nuclear waste and further reduction of the risk of weapon materials proliferation.

It is now a thirteen-member R&D consortium that includes Argentina, Brazil, Canada, China, Euratom, France, Japan, Republic of Korea, Russia, Republic of South Africa, Switzerland, United Kingdom, United States.

After the evaluation of some 100 system concepts through international collaboration, six systems have been selected for further study and cooperative development: gas-cooled fast reactor, very-high-temperature reactor, supercritical-water-cooled-reactor, sodium-cooled fast reactor, lead-cooled fast reactor, molten salt reactor. The technology roadmap published in December 2002 describes the R&D pathways for establishing their technical and commercial viability, demonstration and, potentially, commercialization.

Working extensively on

adaptation

While this report focuses mainly on the new policies necessary to limit the extent of climate change, adaptation to the impacts of unavoidable climate change is a critical issue to consider within the international climate change debate.

Adaptation is not a new issue for electricity utilities. It is embedded in their sustainable development and risk management strategies. Hydropower management is a good example of a field in which utilities have begun work on adaptation to climate change.

The electricity utilities sector has started addressing issues related to adaption by developing a clear understanding of:

- How the science of climate change is advancing and what the physical impacts on facilities and operations will be;
- How risks can be identified, quantified and managed in a proactive manner, including through the development of early warning systems;
- How changes in global climate will affect the sector's stakeholders, (i.e., employees and contract staff, customers and users, lenders and investors, suppliers and service providers);
- How utilities should work with governments and other parts of civil society and business on infrastructure development and disaster management;
- How new climate policies will affect the electricity utility business, and what new policies will be needed to facilitate adaptation of the economy and society;
- What technologies and R&D need to be deployed and developed to limit damage and to increase the sector's ability to adapt.

Electricity utilities are particularly vulnerable to the negative impacts of climate change given that operations are generally geographically widespread and particularly sensitive to meteorological situations (i.e., temperature and rainfall). Strong integrated infrastructure planning and policy environments which promote coordinated disaster recovery plans and mechanisms are necessary. Policies that promote research and innovation into new technologies and predictive capabilities are also key. Collaboration amongst all relevant stakeholders will be critical in improving resilience and response times. Governments need to take the lead in addressing the many social and planning issues and utilities need to work closely with governments (and in some cases more than one government) to understand these issues and plan effectives responses.

Concluding remarks

Through this report, we have tried to outline the policies and measures that, in our view, are required for the full decarbonization potential of the electricity sector to be realized. In the short term, these policies and measures should aim to foster investments in clean technologies at the lowest possible incremental cost. In the longer term, we expect them to help support the development of a pipeline of breakthrough technologies through which we can change our lifestyles and collectively invent a new sustainable energy future. As such, these policies and measures need to be developed in coordination with, and integrated within other public policies, such as those dealing with water resource management, urban planning, and economic development. Public education, awareness raising and the development of new competencies will also be required.

This assumes strong and long-lasting cooperation between all stakeholders, which is a challenge that is not to be underestimated. Only under these conditions will the current sense of urgency related to the climate change challenge be translated into action at the appropriate scale.

This report is presented as an interim piece, proposed as part of an ongoing dialogue, through which we will continue to engage with stakeholders in refining our analysis and policy recommendations.

Glossary

alternating current (AC): An electrical current whose magnitude and direction vary cyclically, as opposed to direct current (DC), whose direction remains constant.

carbon capture and storage (CCS): A long-term alternative to emitting carbon dioxide to the atmosphere is capturing it at its source of emission and storing it. Geological carbon storage involves the injection of CO_2 into subsurface geological formations.

carbon credit/offset: Represents a certificate for avoidance of carbon emissions. It can be used to meet a carbon target.

certified emission reduction (CER): A type of carbon credit/offset that is issued through the Clean Development Mechanism.

clean development mechanism (CDM): An international mechanism put in place by the Kyoto Protocol to facilitate greenhouse gas emissions reductions in developing countries.

combined cycle gas turbine (CCGT): The current state-of-the-art technology for power generation utilizing natural gas, combining steam and gas turbines.

combined heat and power (CHP): A process or technology that uses waste heat from power generation, and significantly raises the efficiency of energy exploitation.

direct current (DC): The constant flow of electrons from low to high potential. In direct current, the electric charges flow in the same direction, distinguishing it from alternating current (AC).

feed-in tariffs: Tariffs that private generators can charge for electricity that they feed into the power grid. Feed-in tariffs are higher than the power price if they are designed as subsidies, e.g., to encourage the installation of renewable energy capacity.

foreign direct investment (FDI): An investment made with the objective of obtaining a lasting interest in an enterprise operating outside of the economy of the investor.

generation II light water reactors: The majority of nuclear reactors that exist today. They include pressurized water reactors and boiling water reactors.

generation III light water reactors: Designed to improve safety and improve economic performance. A small number have been built or are under construction in East Asia, Europe, India and China.

generation IV fast breeder reactors: In the R&D stage. Six different technologies are currently being explored.

greenhouse gases (GHG): Gases in the Earth's atmosphere that absorb and re-emit infrared radiation thus allowing the atmosphere to retain heat. These gases occur through both natural and human-influenced processes. The major GHG is water vapor. Other primary GHGs include carbon dioxide (CO_2), nitrous oxide (N_2O), methane (CH_4), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs) and sulfur hexafluoride (SF_6).

heat pump (HP): An electrical device that takes heat from one location and transfers it to another. A typical refrigerator is a type of heat pump since it removes heat from an interior space and then rejects that heat outside. Heat pumps can work in either direction (i.e., they can take heat out of an interior space for cooling, or put heat into an interior space for heating purposes).

integrated gasification combined cycle (IGCC): This technology involves the gasification of coal to increase the efficiency of coal-fired power plants and provide a basis for pre-combustion carbon capture and storage (CCS).

International Energy Agency (IEA): An intergovernmental body committed to advancing security of energy supply, economic growth and environmental sustainability through energy policy co-operation.

Intergovernmental Panel on Climate Change (IPCC): Established by the World Meteorological Organization (WMO) and the United Nations Environment Programme (UNEP) to assess scientific, technical and socio-economic information relevant for the understanding of climate change, its potential impacts and options for adaptation and mitigation.

kW, MW, GW: kilowatt, megawatt (1,000 kW), gigawatt (1,000 MW). A measure of electrical capacity (e.g., of a power plant).

kWh, MWh, GWh: kilowatt hours, megawatt hours (1,000 KWhs), gigawatt hours (1,000 MWhs). A measure of electrical output or use (energy).

merit dispatch order: The dispatch of generation means based on incremental cost minimization

not in my backyard (NIMBY): Commonly cited term that refers to the resistance of local communities to infrastructure developments.

nuclear fusion: In this reaction, two light atomic nuclei fuse together to form a heavier nucleus and release energy. Nuclear fusion technology for power generation is currently being researched and developed in international experiments.

pulverized coal (PC): This technology, put into widespread use worldwide in the 1960s, involves "pulverizing" coal into very small fragments and then mixing these with air. This mixture is then injected into a boiler where it behaves very much like a gas and burns in a controlled manner.

solar photovoltaic power: Power generated through the conversion of the sun's electromagnetic waves by solar cells.

supercritical pulverized coal (SCPC): A type of advanced coal generation that is considered to be mature and competitive

ultra supercritical pulverized coal (UCSPC): A type of advanced coal generation that is globally considered to be in the deployment phase, while plants are currently in operation in Japan, Denmark and Germany.

United Nations Framework Convention on Climate Change (Conference of the Parties) (UNFCCC (COP)): An international treaty to begin to consider what can be done to reduce global warming and to cope with whatever temperature increases are inevitable. The Conference of the Parties refers to the meeting of those countries that signed the UNFCCC.

white certificates: A market-based mechanism for the promotion of energy efficiency. White certificates allow industry to meet energy efficiency targets through direct investment in efficiency projects or by buying certificates from other organizations that have implemented a project.

Notes and references

1 International Energy Agency (IEA). *World Energy Outlook 2006.* 2006. (According the "Baseline"– i.e., business as usual – Scenario).

2 International Energy Agency (IEA). *Energy Technology Perspectives 2006: Scenarios and Strategies to 2050.* 2006. 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 Tech Plus scenario is currently the most optimistic in terms of both technological innovation and diffusion. It leads to a 16% global reduction below current levels in 2050. Within the power generation sector, it projects a 50% reduction below the 2050 Baseline scenario.

3 The ultra-super-critical pulverized coal (USCPC) generation technology is in this category because demonstration large-scale plants exist, but the technology still needs some R&D on materials.

4 Photovoltaic (PV) energy features a limit case for present technology generations: the cost of a PV-based MWh is today 10 to 15 times market price. Considering the technology mature enough to be pulled to the market through mass-deployment schemes (as several countries do) is questionable. More support to R&D might appear preferable instead.

Acknowledgements

Project Co-chairs: Fred Kindle (ABB), Pierre Gadonneix (EDF), Jacob Maroga (ESKOM)

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This publication was developed by the Electricity Utilities Sector Project working group, who wishes to thank the WBCSD Secretariat for their contribution.

Photo credits CLP, Flickr (Koert Michiels, Phertronnic, Twentyeight), iStockphotos

ISBN 978-3-940388-17-9

Printer Atar Roto Press SA, Switzerland
Printed on paper containing 50% recycled content and 50% from mainly certified forests (FSC and PEFC) 100% chlorine free. ISO 14001 certified mill.

Ordering publications

WBCSD, c/o Earthprints Limited
wbcsd@earthprints.com
Publications are available at: www.wbcsd.org

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:

- Coal
- Gas
- Carbon capture and storage
- Nuclear
- Hydro
- Non-hydro renewables
- Hydrogen

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

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

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DEDICATED TO MAKING A DIFFERENCE

Powering Sustainable Solutions

Policies and measures

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.

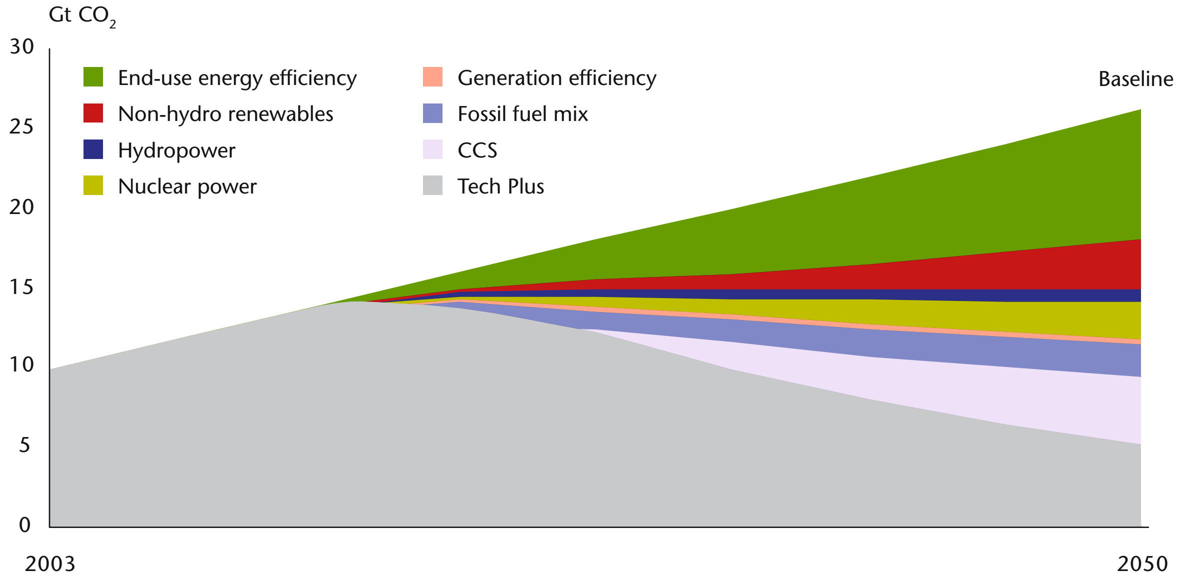
This document has been developed as part of the WBCSD Electric Utilities Sector report, *Powering a Sustainable Future: policies and measures to make it happen*. This part of the report focuses on policies and measures for nine key energy technology solutions:[1]

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

The "wedge" concept has been used to describe their contribution to the electricity sector's CO_2 mitigation potential by 2050.[2] Based on the IEA Tech Plus scenarios, seven of these wedges are illustrated in Figure 1.[3] For each technology and measure, we provide a focus on the following issues:

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

Figure 1: **CO_2 reduction potential within the power generation sector by contributing factor**



Summary of key elements

Electricity Sector Stabilization Wedge	Gt CO_2 Savings Potential in 2050 (Tech Plus)	Lab ⟵⟶ Market Technology Status
End-use Energy Efficiency	**8.2**	heat pump x x plug-in hybrid x zero net emission building
Hydropower	**0.5**	hydroturbines x
Non-hydro Renewables	**3.3**	wind x x solar thermal
Nuclear Power	**2.7**	generation II x x generation III x generation IV
Fossil Fuel Mix (including a switch to Natural Gas)	**2**	gas turbines & combined cycles x
Generation Efficiency	**0.3**	plant optimization x
Advanced Coal Technologies	while not quantified as a separate element within the IEA TechPlus scenario, a focus on these technologies is included	supercritical x ultra-supercritical x IGCC x
Carbon Capture and Storage	**4.4**	x large scale CCS
Transmission and Distribution	T&D is a necessary element for the integration of clean energy technologies and meeting future energy demand	HVDC x

Challenges	Policy Measures
- A complex web of wide ranging options - Low awareness, low priority and low cost of energy - Business model misaligning life-cycle costs and benefits	- Performance standards (e.g., for buildings and appliances) - National targets with financial incentives - Awareness raising and training
- Shared concerns about social and environmental impacts - High capital cost for large hydro in developing countries (which have substantial resource potential)	- Multilateral cooperation for developing countries, enabling them to realize large hydropower potential in line with national energy policies - Establishment of sustainability requirements - Policies and measures leading to the cost of carbon and use of CDM for large hydropower
- High cost of generated power - "Not in my backyard" attitude towards new sites (NIMBY) - Variability and predictability of power generation and its impact on the grid	- Renewable portfolio standards and national targets - Financial incentives such as feed-in tariffs, production credits, rebates for mature technologies and R&D for other technologies - Policies and measures leading to a cost of carbon and use of CDM
- Safety - Public acceptance and NIMBY syndrome - Uncertainty in licensing and procedures leading to excessive construction cost and delay	- Establishment of an independent safety authority and promotion of a safety culture - Promotion of stakeholder engagement and transparency - Clear licensing and permitting procedures
- Rising cost and tight market supply - NIMBY attitude towards new LNG infrastructure	- Incentives for investment in production and transport - Policy guidelines for LNG infrastructure
- Low cost of some fuels - Inadequate operational and maintenance practices - Lack of relevant knowledge and skills in some places	- International partnerships for sharing good practice and technology transfer, such as APP - Performance targets for existing plant & fuel combinations - CO_2 emission regulation
- Need for R&D and technology status improvement - Higher capital cost for advanced coal technologies - Lack of knowledge and technology in some regions	- Performance standards and/or policies leading to a cost of carbon - Direct financial support for large scale demonstrations in connection with CCS technology - Technology cooperation agreements
- High incremental cost for the power generation sector - Undemonstrated use with different plants and fuels; undemonstrated technical storage feasibility, local potential and permanence in all regions - Lack of regulatory framework including liabilities for long term CO_2 storage	- Worldwide direct financial support of R&D and large scale demonstrations - Inclusion of CCS in the CDM and other regulatory frameworks - Regulatory framework development, which includes government liability for long-term storage of CO_2
- Lack of incentive for investment - Unclear division of responsibility for the integration of renewables & distributed resources - NIMBY syndrome towards new T&D infrastructures	- Clear policy supporting investment in T & D infrastructure - Clear roles & responsibilities for integration of renewables & distributed resources

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*.

Wedge potential

According to the IEA Tech Plus scenario, end-use efficiency has the potential to contribute to an 8.2 Gt CO_2 reduction (38%) of the electricity sector's overall reduction potential of 21.4 Gt CO_2 by 2050. 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, could contribute significantly to per-unit CO_2 emissions reductions. By deferring new generation, efficiency improvements 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 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 resources management.

Japan's top runner program

The Top Runner Program was introduced in 1998 in order to curb increasing energy consumption in the commercial and transportation sectors by improving energy efficiency in appliances and vehicles. The program uses a maximum standard value system under which targets are set based on the value of the most energy-efficient products on the market at the time of value setting. The system therefore gives manufacturers incentive to develop more energy-efficient equipment.

Since 1997, the energy efficiency of air-conditioners has improved by 70% and the fuel efficiency of passenger vehicles has already achieved 22% improvement, although the target for 2010 is set at 23%.

The success of the program has been underpinned by the important information dissemination and labeling processes that enable consumers to make an informed choice.

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.

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 regulation 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.*

Eskom: Demand-side management

Eskom is undertaking an aggressive national demand-side management program to effect permanent reductions in demand by 3,000 MW by 2012 and a further 5,000 MW by 2025.

Various initiatives are being implemented including the promotion of efficient lighting; commercial, industrial and residential efficiency measures; public education; a schools program and stakeholder activities including communications and awareness raising.

Eskom's integrated demand-side management strategy seeks to promote the creation of a sustainable energy efficiency market environment in which independent energy service companies implement demand-side management. While creating jobs, this approach has led to the birth or expansion of energy service companies in South Africa.

Further, for every kWh reduced through energy efficiency implementation, there is approximately 1 kg of CO_2 that is not emitted into the atmosphere, and the power plants reduce water intake/consumption by approximately 1.3 liters.

- Minimal and clearly defined energy savings targets, providing incentives to undertake energy efficiency measures; their impacts in terms of 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 energy efficiency programs for customers.

Hydropower

Wedge: Hydropower

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

Wedge potential

According to the IEA Tech Plus scenario, hydropower has the potential to contribute to a 0.4 Gt CO_2 reduction of the electricity sector's overall reduction potential of 21.4 Gt CO_2 by 2050. Hydropower energy would thus account for 16% of global power generation.

Research shows that only 31% of the economic 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.

Hydropower brings other benefits:

- As a local resource substituted for imported fossil fuels, it increases energy security
- Enhanced security of supply due to high flexibility of storage and pump storage hydro with regards to system regulation
- Fosters regional cooperation, especially in developing countries

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.

Challenges that prevent this wedge from reaching its potential

R&D projects on the reduction of ecological impacts

- To minimize the impact of water flow variations on local fish populations, Statkraft is directly stocking fish into the river and installing ladders to enable their movement upstream.
- Statkraft is also performing thorough assessments of the fish biology to minimize impacts on natural reproductive cycles.

- Public acceptance for hydropower in some areas – while hydropower is a clean technology from an emissions perspective, some argue that the environmental and ecological impacts outweigh its benefits in terms of emissions reductions.

Refurbishing effort

Statkraft is performing a comprehensive evaluation of older power plants to assess the potential for plants refurbishment, by replacing parts to increase operational efficiency. Where cost benefit analysis demonstrates that plant replacement is optimal, the necessary steps are then taken. For example, it has been identified that the simple upgrade of the rotor blade wheel can result in a 3% increase in efficiency.

- Long lead times for the permitting and construction of hydropower plants (in particular compared to more carbon-intensive alternatives).
- A lack of transmission grid optimization to reach hydro potential in some remote areas.
- 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.
- Some developing countries have a less developed infrastructure and often lack a supportive regulatory framework for the development of hydropower plants, creating investment uncertainly and thereby increasing risk.
- Developing countries have limited capacity to finance 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.

Policy measures

- Establish sustainability requirements to address issues related to ecological impacts and population displacement.
- Cooperation and engagement with governments and stakeholders to improve public acceptance.
- Government policy to facilitate the development of hydropower projects including:
  - Streamlining the permitting process
  - Being counterpart in power purchase agreements.
- In developing countries, the establishment of a clear legal framework and regulatory transparency where they are not present, in addition to investment subsidies.
- 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).
- Include large hydropower within the CDM.

A large-scale hydro dam/ Nam Theun

The Nam Theun 2 dam, which will supply most of the electricity required for nearby Thailand, will provide electricity to 400,000 people. This project is carried out by Nam Theun 2 Power Company (NTPC) of which EDF is the primary shareholder (35%) with 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 and the project is expected to add 3.2% to Laos's GDP per year over its concession period, principally through the export of power.

NTPC is committed to preventing, reducing and compensating the social and environmental impact resulting from the construction and operation of the facility. During the concession (25 years), US $160 million -about 13% of the total cost of the project- will go to financing socio-environmental measures. These commitments drove the major international backers, including the World Bank, to support the project.

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:

1) Political risk and regulatory approval; 2) Economic viability; 3) Additional benefits; 4) Planned operational efficiency and reliability; 5) Project management plan; 6) Site selection and design optimization; 7) Community and stakeholder consultation and support; 8) Social impact assessment and management plan; 9) Predicted extent and severity of economic and social impacts on directly affected stakeholders; 10) Enhancement of public health and minimization of public health risks; 11) Safety; 12) Cultural heritage; 13) Environmental impact assessment and management plan; 14) Threshold and cumulative environmental or social impacts; 15) Construction and associated infrastructure impacts; 16) Land management and rehabilitation; 17) Aquatic biodiversity; 18) Environmental flows and reservoir management; 19) Reservoir and downstream sedimentation and erosion risks; 20) Water quality.

The IHA is studying the possibility of accrediting independent auditing companies for performing such an assessment in order to support the use of a common and internationally recognized tool.

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

According to the IEA Tech Plus scenario, non-hydro renewables in power generation have the potential to contribute to an approximate 3.3 Gt CO_2 reduction (15.4% of total reduction) of the electricity sector's overall reduction potential of 21.4 Gt CO_2 by 2050. This would require a significant increase in the share of non-hydro renewable output in total electricity generation from 2% in 2003 to 20% in 2050. Achieving this requires 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 lifecycle 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 cross-cutting 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).

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).

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.

    - 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 Certificate (ROC) policy

An ROC is a green certificate issued to an accredited generator for eligible renewable electricity generated within the UK and supplied to customers within the UK by a licensed electricity supplier. The ROC is the main support scheme for renewable electricity projects in the UK. It places an obligation on UK electricity suppliers to source an increasing proportion of their electricity from renewable sources.

- 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 Tech Plus scenario, nuclear energy in power generation has the potential to contribute to reductions of about 2.7 Gt CO_2 of the electricity sector's overall reduction potential of 21.4 Gt CO_2 by 2050. Nuclear energy would thus account for 22.2% of total power generation and for 12.6% 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 (WANO, OSART).
- *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 non-proliferation 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.

The "new" regulatory framework of nuclear power in the 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.

- *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.

Natural gas

Wedge: Natural gas

This document explores the use of natural gas in power generation, with an overview of the resource potential and technologies for resource use (i.e., upstream and downstream processing).

Wedge potential

According to the IEA Tech Plus scenario, natural gas demand is expected to increase by 101% above today's level, and contribute to 19.5% of global electricity generation by 2050. A general change in the fossil fuel mix, which includes the substitution of coal for natural gas (among others) is expected to contribute to a 1.2 Gt CO_2 reduction in the electricity sector's overall reduction potential of 21.4 Gt CO_2 by 2050.

How this wedge contributes to emissions reductions

By switching from coal to natural gas, emission reductions are achieved as natural gas is a less carbon intensive fuel and natural gas plants can 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.

Other benefits of this wedge:

Lower local air pollution: natural gas combustion generates less emissions from substances with a local impact like NO_x 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.

Table 1: Net electricity efficiency of natural gas plants in 2003

	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.

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%.

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, efficient 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 Group's 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 Gaz de France. 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 IEA Tech Plus scenario, energy efficiency in the power generation sector has the potential to contribute to approximately a 0.3 Gt CO_2 (1.4% of total) reduction of the electricity sector's overall reduction potential of 21.4 Gt CO_2 by 2050. 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, 2006).

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.

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.

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.

Table 2: Regional evolution in electric efficiency of natural gas and hard-coal plants between 1974 and 2003

	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.

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 gasifier 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

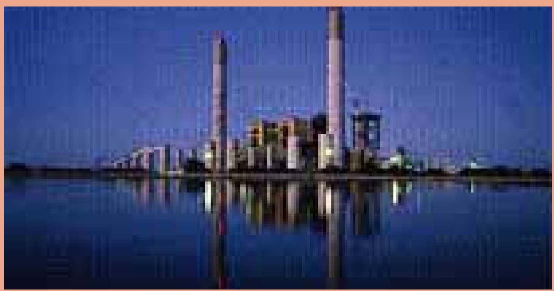
- *Improvements in the operational efficiency of existing plants:*
    - Lack of relevant knowledge and skills in some places.
    - Inadequate operational and maintenance practices.
    - Low cost of some fuel, leading to low incentives for investment in efficiency improvements.
    - Life cycle trade-offs 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 re-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, Eskom has implemented dry-cooling technology wherever feasible. This decision has been made despite the fact that dry cooled stations are comparatively less efficient than wet-cooled stations and there are higher capital and operating costs associated with the technology. This water conservation effort results in an estimated combined savings of over 200 Ml/day, or in excess of 70 million m³ per year.



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.

Asia-Pacific Partnership on Clean Development and Climate (APP)

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 and Japan in 2007 with participation from all member countries. Additional activities are expected to take place in India, followed by activities in other member countries.

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.

Advanced coal technologies

Wedge: Advanced coal technologies

Advanced coal technologies include advanced steam cycle, i.e., supercritical, ultra-supercritical, fluidized bed combustion 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.[6] 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 (NO_x, SO_x 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

As the first in Japan, the Nakoso Coal-fired Integrated Gasification Combined Cycle (IGCC) demonstration plant began operation in September 2007. Eleven Japanese corporations (nine regional utilities, EPDC (Electric Power Development Company) and CRIEPI (Central Research Institute of Electric Power Industry) have jointly launched this 250MW plant as a national project partially supported by governmental subsidy (30% of total cost). This project 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."[7]

While the various processes involved in CCS (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 Tech Plus scenario, CCS in the power generation sector has the potential to contribute to reductions of about 4.4 Gt CO_2 (20.6%) of the sector's overall reduction potential of 21.4 Gt CO_2 by 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.[8] 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%.

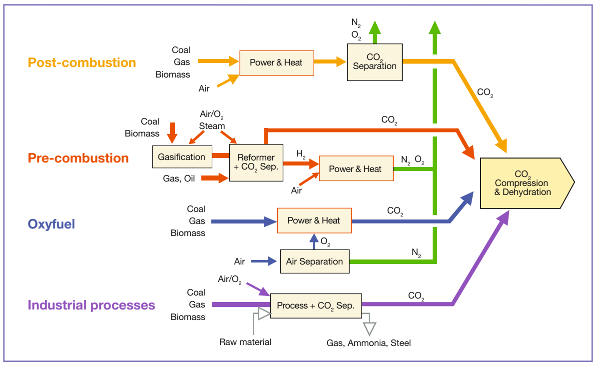
CCS also fosters energy security and competitiveness

- 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.

Figure 2



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

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., FutureGen by 2012, 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 from 2030 in the most advanced countries, *if* R&D and demonstration projects are successful and *if* there are appropriate incentives.

Commercial-scale CO_2 capture

AEP is currently planning the first commercial-scale use of CO_2 capture technology on two existing coal-fired power plants. Beginning in late 2008, AEP will install a CO_2 capture system using a chilled ammonia process (developed by Alstrom) to capture carbon from the flue gas of an approximate 30 MW portion of the 1300 MW Mountaineer Power Plant in New Haven. The project is expected to capture between 100,000 and 200,000 metric tons of CO_2 per year, which will be injected for geological storage in deep saline aquifers at the site. Once this validation project is complete, the technology will be installed at one of the 450 MW coal-fired units at their Northeastern Station in Oklahoma.

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.
- 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 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 Environmental Protection Agency (USEPA). Forty-five states approved these models, to be customized by each one as they enact enabling laws and regulations. In addition, in October 2007, the USEPA announced it would begin developing federal regulations in about a year.

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

ABB HVDC light technology

Introduced in 1997, HVDC Light® is a state-of-the-art power system designed to transmit power underground and underwater over long distances. It offers numerous environmental benefits, including:

- "Invisible" power lines
- Neutral electromagnetic fields
- Oil-free cables
- Compact converter stations.

In addition, the quality of power supply is improved and transmission losses are reduced. A number of underground transmissions of up to 350 MW are in commercial operation and more are being built.

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.

Glossary

alternating current (AC)	An electrical current whose magnitude and direction vary cyclically, as opposed to direct current (DC), whose direction remains constant.
biomass	Biomass is a source of renewable energy and includes forest and mill residues, agricultural crops, wood, animal wastes, livestock operation residues, aquatic plants, fast-growing trees and plants, and the organic component of municipal and industrial wastes.
carbon credit/offset	Represents a certificate for avoidance of carbon emissions. It can be used to meet a carbon target.
centralized generation (CG)	The predominant way of generating electricity today, utilizing a relatively small number of large power plants.
certified emission reduction (CER)	A type of carbon credit/offset that is issued through the Clean Development Mechanism.
clean development mechanism (CDM)	An international mechanism put in place by the Kyoto Protocol to facilitate greenhouse gas emissions reductions in developing countries.
CO_2 intensity	CO_2 emissions per unit of another measure (e.g., energy or output).
coal gasification	Breaks down the coal into its components and produces higher concentrations of carbon dioxide, making carbon capture and storage (CCS) more economical than it otherwise would be. See also integrated gasification combined cycle.
combined cycle gas turbine (CCGT)	The current state-of-the-art technology for power generation utilizing natural gas, combining steam and gas turbines.
combined heat and power (CHP)	A process or technology that uses waste heat from power generation, and significantly raises the efficiency of energy exploitation.
decentralized generation (DG)	Power generation using a large number of small generators (see special section in this report).
direct current (DC)	The constant flow of electrons from low to high potential. In direct current, the electric charges flow in the same direction, distinguishing it from alternating current (AC).
environmental externalities	Costs or benefits to the environment that are not borne or appropriated by the actor who causes them (e.g., pollution caused by a factory).
feed-in tariffs	Tariffs that private generators can charge for electricity that they feed into the power grid. Feed-in tariffs are higher than the power price if they are designed as subsidies, e.g., to encourage the installation of renewable energy capacity.

flue gas desulfurization (FDG)	The current state-of-the art technology used for removing sulfur dioxide (SO_2) from the exhaust flue gases in power plants that burn coal or oil.
fluidized bed combustion (FBC)	In fluidized bed combustion (FBC), coal is burned in a reactor comprised of a bed through which gas is fed to keep the fuel in a turbulent state. This improves combustion efficiency, heat transfer and recovery of waste products.
generation II light water reactors	The majority of nuclear reactors that exist today. They include pressurized water reactors and boiling water reactors.
generation III light water reactors	Designed to improve safety and improve economic performance. A small number have been built or are under construction in East Asia, Europe, India and China.
generation IV fast breeder reactors	In the R&D stage. Six different technologies are currently being explored.
greenhouse gases (GHG)	Gases in the Earth's atmosphere that absorb and re-emit infrared radiation thus allowing the atmosphere to retain heat. These gases occur through both natural and human-influenced processes. The major GHG is water vapor. Other primary GHGs include carbon dioxide (CO_2), nitrous oxide (N_2O), methane (CH_4), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs) and sulfur hexafluoride (SF_6).
heat pump (HP)	An electrical device that takes heat from one location and transfers it to another. A typical refrigerator is a type of heat pump since it removes heat from an interior space and then rejects that heat outside. Heat pumps can work in either direction (i.e., they can take heat out of an interior space for cooling, or put heat into an interior space for heating purposes).
integrated gasification combined cycle (IGCC)	This technology involves the gasification of coal to increase the efficiency of coal-fired power plants and provide a basis for pre-combustion carbon capture and storage (CCS).
International Energy Agency (IEA)	An intergovernmental body committed to advancing security of energy supply, economic growth and environmental sustainability through energy policy co-operation.
Intergovernmental Panel on Climate Change (IPCC)	Established by the World Meteorological Organization (WMO) and the United Nations Environment Programme (UNEP) to assess scientific, technical and socio-economic information relevant for the understanding of climate change, its potential impacts and options for adaptation and mitigation.
kV	kilovolt. A measure of electric potential difference across a conductor (e.g., a power transmission or distribution line)
kW, MW, GW	kilowatt, megawatt (1,000 kW), gigawatt (1,000 MW). A measure of electrical capacity (e.g., of a power plant).

kWh, MWh, GWh	kilowatt hours, megawatt hours (1,000 KWhs), gigawatt hours (1,000 MWhs). A measure of electrical output or use (energy).
Liquefied natural gas (LNG)	Natural gas that has been processed to remove impurities and heavy hydrocarbons and then condensed into a liquid.
not-in-my-backyard (NIMBY)	Commonly cited term that refers to the resistance of local communities to infrastructure developments.
nuclear fusion	In this reaction, two light atomic nuclei fuse together to form a heavier nucleus and release energy. Nuclear fusion technology for power generation is currently being researched and developed in international experiments.
Operational Safety Review Team Program (OSART)	An IAEA program under which international teams of experts conduct three-week in-depth reviews of operational safety performance at individual nuclear power plants. These reviews are conducted at the request of the government of the host country.
pulverized coal (PC)	This technology, put into widespread use worldwide in the 1960s, involves "pulverizing" coal into very small fragments and then mixing these with air. This mixture is then injected into a boiler where it behaves very much like a gas and burns in a controlled manner.
SO_2 (sulfur dioxide)	Coal and petroleum contain various amounts of sulfur compounds; their combustion generates sulfur dioxide, a component of acid rain.
SOx (sulfur oxides)	A general term used to describe the oxides of sulfur - gases formed primarily by the combustion of fossil fuels. Considered major air pollutants.
solar photovoltaic power	Power generated through the conversion of the sun's electromagnetic waves by solar cells.
United Nations Framework Convention on Climate Change (Conference of the Parties) - UNFCCC (COP)	An international treaty to begin to consider what can be done to reduce global warming and to cope with whatever temperature increases are inevitable. The Conference of the Parties refers to the meeting of those countries that signed the UNFCCC.
World Association of Nuclear Operators (WANO)	An independent international organization created to improve the safety of nuclear power plants worldwide. Every organization in the world that operates a nuclear electricity generating plant is a member of WANO.
white certificates	A market-based mechanism for the promotion of energy efficiency. White Certificates allow industry to meet energy efficiency targets through direct investment in efficiency projects or by buying certificates from other organizations that have implemented a project.

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] Adapted from Pascala, S. and R. Socolow. "Stabilization Wedges: Solving the Climate Problem for the Next 50 Years with Current Technologies". *Science.* August 2004. Vol. 305, p. 968. 2004.

[3] International Energy Agency (IEA). *Energy Technology Perspectives 2006: Scenarios and Strategies to 2050.* 2006. The Tech Plus scenario is currently the most optimistic in terms of both technological innovation and energy policy implementation. The diagram has been modified to illustrate CO_2 peaking as well as the later entry of CCS as contributing to CO_2 mitigation.

[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 10.6 Gt 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 CO_2 Gt of CO_2 to the atmosphere.

[6] For all figures for *Advanced coal Technologies*, refer to IEA 2006 in note 3.

[7] Intergovernmental Panel on Climate Change. *IPCC Special Report on Carbon dioxide Capture and Storage: Summary for Policymakers, Technical Summary and Full Report.* 2005.

[8] ibid.

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Fred Kindle (ABB), Pierre Gadonneix (EDF), Jacob Maroga (ESKOM)

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Adam Roscoe (ABB), Dennis Welch (AEP), Gail Kendall (CLP), Jean Paul Bouttes, François Dassa (EDF), Wendy Poulton (ESKOM), Christine Faure-Fedigan (Gaz de France), Masashi Nishikawa (Kansai), Live Dokka, Mette Vagnes Eriksen (Statkraft), Philippe Opdenacker (Suez), Yoshiharu Tachibana, Ikuo Nishimura, Hiroyuki Takahashi, Masahiro Sugimura (TEPCO)

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This publication was developed by the Electricity Utilities Sector Project working group, who wishes to thank the WBCSD Secretariat for their contribution.

Design
www.services-concept.ch

Photo credit
CLP (Generation efficiency)

Printer Atar Roto Press SA, Switzerland
Printed on paper containing 50% recycled content and 50% from mainly certified forests (FSC and PEFC) 100% chlorine free. ISO 14001 certified mill.

Ordering publications
WBCSD, c/o Earthprints Limited
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Publications are available at: www.wbcsd.org

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:

- Coal
- Gas
- Carbon capture and storage
- Nuclear
- Hydro
- Non-hydro renewables
- Hydrogen

The project also produced "issue briefs" on access to electricity, transmission and distribution, and energy efficiency. This analysis provides supportive technical detail to the content within this publication and the briefs are available for download at www.wbcsd.org/web/electricity.htm.

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The World Business Council for Sustainable Development (WBCSD) brings together some 200 international companies in a shared commitment to sustainable development through economic growth, ecological balance and social progress. Our members are drawn from more than 30 countries and 20 major industrial sectors. We also benefit from a global network of about 60 national and regional business councils and partner organizations.

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