ROADMAP FOR A LOW-CARBON POWER SECTOR BY 2050

EEI

esaa
energy supply association of australia

eurelectric
ELECTRICITY FOR EUROPE

Canadian Electricity Association
Association canadienne de l'électricité

fepc
The Federation of Electric Power Companies / Japan

At the International Electricity Chief Executive Summit held in Atlanta, Georgia, USA in October 2008, electricity leaders formed an International Electricity Partnership (IEP) to deliver advanced electric technologies to create a global low-carbon future. They stated: “The industry leaders believe that electricity can be the solution to climate change”.   It was agreed that “new technology, with an adequate transition period, can accommodate the objective of stabilizing of carbon emissions from all sources; and, with aggressive application of technology, carbon emissions reductions of 60 to 80 percent can be achieved by 2050”.

This Roadmap report examines the technologies and policies that are required to deliver this low-carbon future.

It was written by staff at the electricity associations under whose aegis the International Electricity Summit is held –namely ESAA (Australia), CEA (Canada), EEI (US), EURELECTRIC (Europe) and FEPC (Japan), together with EPRI (US). They would like to place on record their sincere thanks to Bill Kyte, OBE, who undertook the arduous task of managing and editing the report.

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1. Executive Summary

Electricity is the lifeblood of our modern world. Indeed, it is hard to find a single aspect of life that has not been transformed by electric power. Many advances in medicine, transportation, manufacturing, communications, and information technology were attainable because of electricity. In societies around the globe, electrification is a fundamental catalyst for economic growth and the means to improve living conditions.

This report examines the present structure of the power sector in Australia, Canada, European Union, Japan and United States and the technologies that are used for the generation and transmission of electricity.

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In line with this statement, this report examines the technologies and policies that are required to deliver this low-carbon future.

The analysis has shown that it is possible to deliver low- carbon power by 2050:

- through intelligent and efficient electricity generation, transmission, distribution and use
- with significantly increased intelligent electricity use as the driver for a secure, low-carbon energy future
- at a lower long-term total energy cost than under a business as usual scenario
- provided that policy action is taken to incentivise very substantial investment in:
    - large-scale uptake of renewable energies, deployment of carbon capture & storage technologies and nuclear power
    - ‘smart’ grids and networks
    - roll-out of electric road vehicles, heat pumps and other efficient electro-technologies
    - widespread energy efficiency in our economy and society

However there will be limited emission reductions before 2020 with the major reductions occurring in the period 2025–2040, and therefore the current political timeframe lacks recognition of the critical timing for commercial deployment of the required low-carbon technologies.

2. Introduction

To meet the global climate challenge any political agreement must take into account both the timescale set by the science of climate change and the timescale for the deployment of the appropriate mitigation technologies, plus the economic and social cost of both action and inaction.

Historically the energy sector, particularly the power industry, has been the largest source of anthropogenic carbon dioxide (CO_2) emissions, the main contributor to climate change. Lowering of the carbon intensity of the power sector, together with increased use of low-carbon electricity in other sectors, can be the key to meeting the challenge of climate change. The rate at which the sector's carbon is reduced will be critically dependant on the technical and economic feasibility of deploying low-carbon electricity generation technology and the rate of improvement of the efficiency of energy utilisation.

At the International Electricity Chief Executive Summit held in Atlanta, Georgia, USA on October 6-7 2008, electricity leaders formed an International Electricity Partnership (IEP) to deliver advanced electric technologies to create a global low-carbon future. They stated: "The industry leaders believe that electricity can be the solution to climate change". It was agreed that "new technology, with an adequate transition period, can accommodate the objective of stabilizing of carbon emissions from all sources; and, with aggressive application of technology, carbon emissions reductions of 60 to 80 percent can be achieved by 2050."

In March 2009, 61 CEOs from 27 European countries signed a declaration which stated: "The power sector, as a significant emitter of greenhouse gases, needs to achieve a carbon-neutral power supply by the middle of this century."

A supportive public policy framework is needed to balance security of energy supply, economic competitiveness and environmental objectives. This political framework must ensure that scientific roadmap to a sustainable climate future and the roadmap for the deployment of low-carbon technology are coherently integrated. At present there is little evidence of such coherence and the two roadmaps are developing independently, which seriously hinders the political process. The political process must bring these two timescales together. It is the objective of the IEP to deliver a coherent roadmap for the electricity sector that delivers an economically efficient low-carbon sector that meets the scientific imperatives.

Meeting scientific reduction targets will only be possible if the generation of electricity is low-carbon by 2050 while other sectors, including the transport and domestic sectors, will also have to make substantial reductions by 2050. Low-carbon electricity can make a substantial contribution to carbon reductions in these sectors.

The timing of the peak and the rate of the subsequent reduction pathway will depend on the rate of deployment of low-carbon technology. If this rate is too slow then the climate objectives will be put at risk. Conversely, lack of an appropriate transition period to deploy these technologies could jeopardise energy security and economic competitiveness while also locking in unsuitable and uneconomic technologies. This is especially important in the power sector, where generation assets and infrastructure are long-lived (50-60 years), permitting and construction times are long (5-20 years) and where the investment required is enormous.

There is a substantial need for very significant investment both to replace the ageing fleet of thermal and nuclear plants and to meet new demand in developed countries. In developing countries the need for new build to meet the rapidly growing energy demands as their economies grow is even more significant. This leads to growth in emissions in developing countries which makes the reduction of global emissions a difficult political issue.

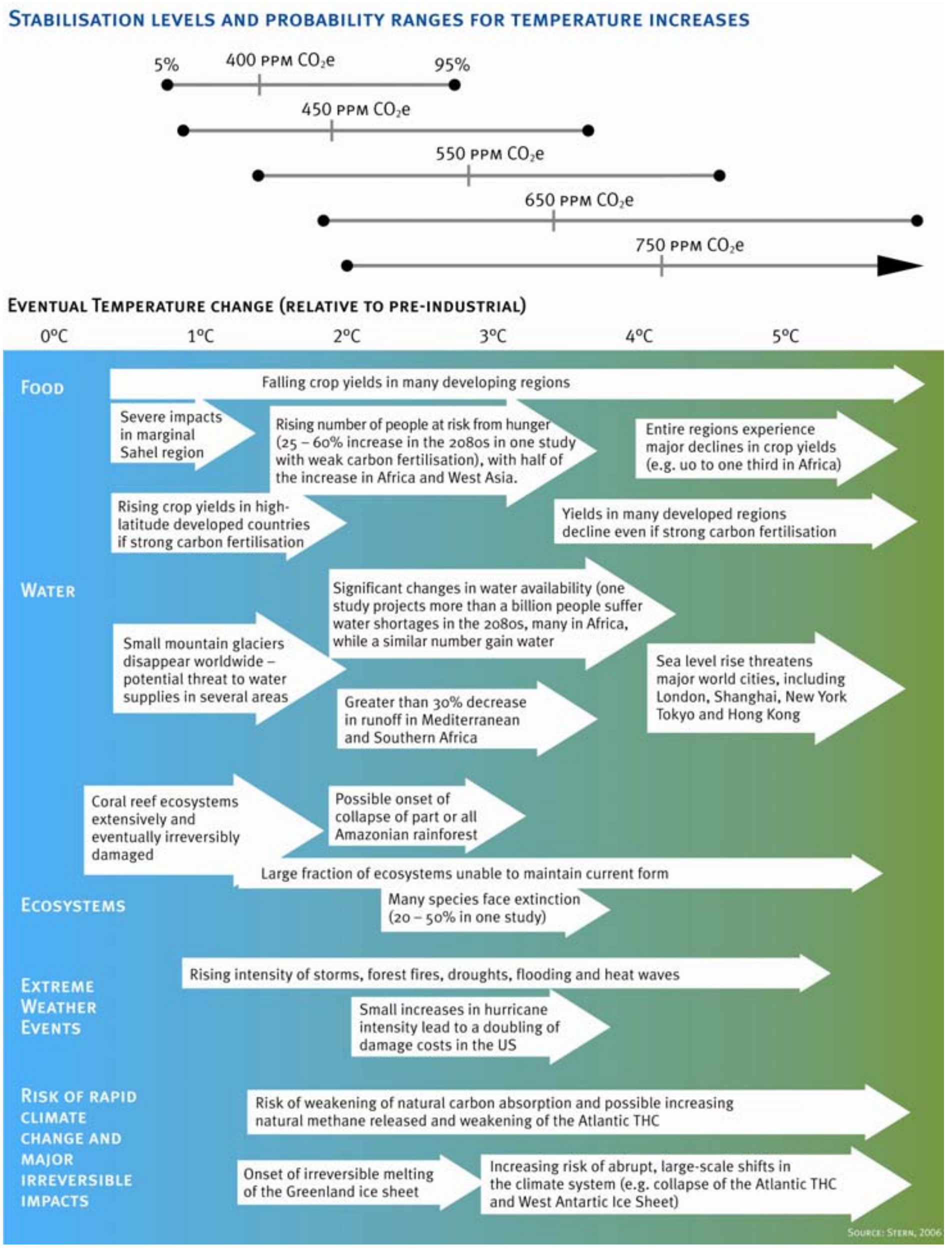
On a superficial analysis the scientific and technology timescales appear to be irreconcilably incompatible, given that emissions need to peak by 2020 while it will not be possible to build any significant low carbon capacity by 2020. Nuclear plants take some 10-20 years to permit and construct and carbon capture & storage (CCS) for coal fired plants will not be commercially available until 2020 at the earliest. It will also need at least a decade to permit and build the transmission and distribution infrastructure to allow the operation of significant quantities of renewables.

These considerations lead to the conclusion that it will be at least 2020 before there can be significant deployment of low-carbon generating technologies. The construction of significant quantities of new gas-fired CCGTs may enable the short-term CO_2 and generation capacity targets to be met but will cause long term security of supply issues and may require in some countries the fitting of CCS to these plants in the medium term. However since most of the present capacity will need to be replaced before 2050 it may be possible to reach the 2050 target earlier. This later peaking coupled with earlier achievement of the 2050 objective would probably still enable the climate target to be met for the power sector since the later peaking would be offset by the more rapid reduction rate post 2020.

3. What the Science Tells Us

The greenhouse gas effect is caused by the absorption into the atmosphere of long-wave radiation from reflection of solar energy by the earth's surface. Some trace gases, especially carbon dioxide (CO_2), nitrous oxide (N_20), methane (CH_4) and hydro-fluorocarbons (HFC) can absorb part of this infrared radiation and cause heating of the atmosphere. These trace gases are called greenhouse gases (GHG).

The current consensus is set out in the fourth assessment report of the Intergovernmental Panel on Climate Change (IPCC) which concluded that: *"Most of the observed increase in global average temperatures since the mid-20th century is very likely due to the greenhouse gas concentrations"*.



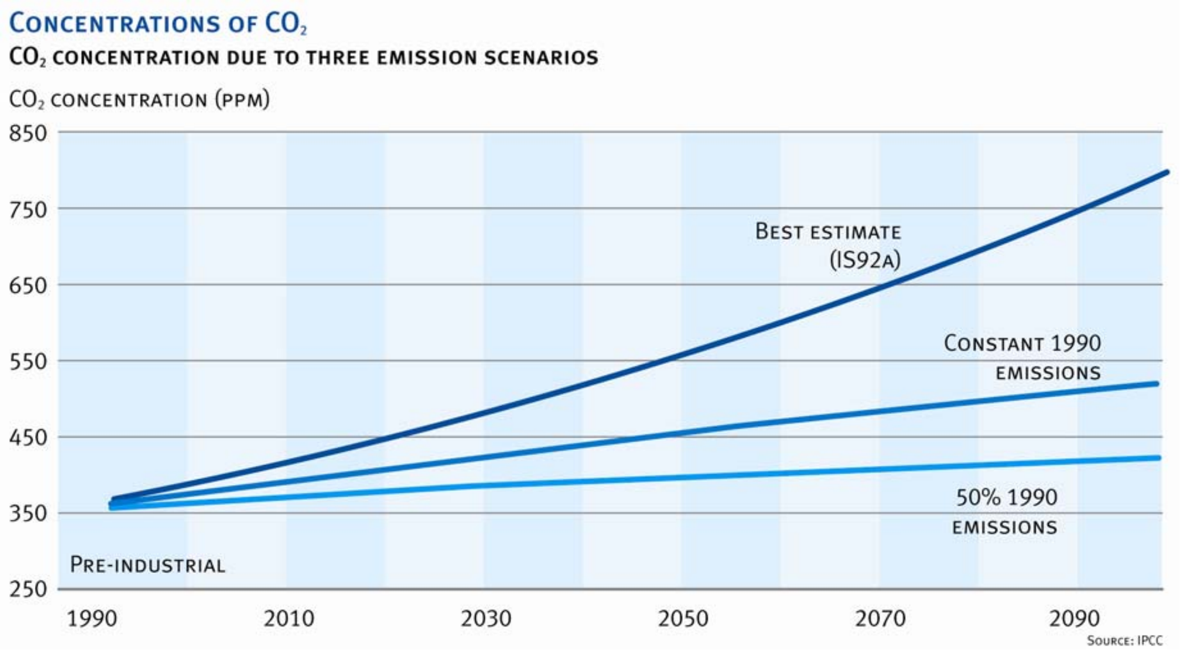
SOURCE: STERN, 2006

Consideration of the scale of impacts has led to the formulation of the 2°C goal for global average temperature rise against the background that this change is of a scale that ecosystems can adapt to. At the Major Economies Forum in L'Aquila, heads of government decided that action needs to be taken to prevent the average global temperature from rising more than 2°C by 2100.

At stabilisation levels around 400 ppm CO_2 equivalent or below, the global mean temperature rise is likely to stay below 2°C while at 450 ppm there is a 50% probability of exceeding a 2°C increase. With the current level of 380 ppm and an annual increase of 2.8 ppm the 450 ppm level will be reached in 25 years. Other forecasts state that the 450 ppm level will be reached in 10 to 15 years. To reach a long-term goal of 450 ppm different abatement paths can be pursued. The general consensus is that global emissions will need to peak by 2020 and decrease rapidly after 2020.

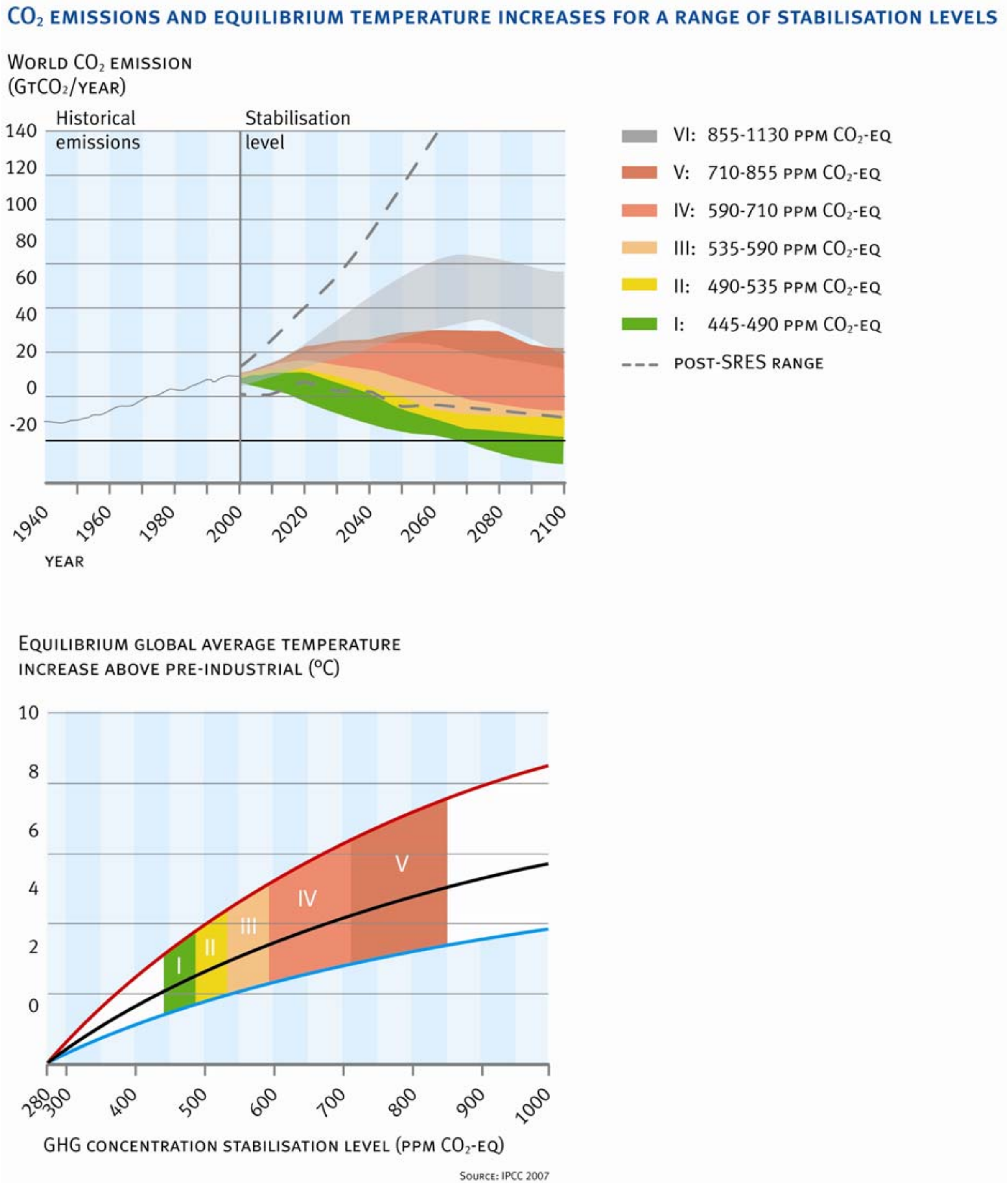
Among the many human activities that produce greenhouse gases the use of energy represents the largest source of emissions. Energy accounts for over 80% of the emissions of global anthropogenic greenhouse gases, with emissions resulting from the production, transformation, handling and consumption of all kinds of fuels. Agriculture, forestry, non-energy industrial processes, waste disposal are the other main sources. In addition, deforestation plays a major role in the carbon balance between emissions and sinks.

Worldwide economic stability and development requires energy. In 2005 fossil sources accounted for 81% of the total global primary energy supply. The energy sector is largely dominated by the direct combustion of fuels, a process leading to significant emissions of CO_2.

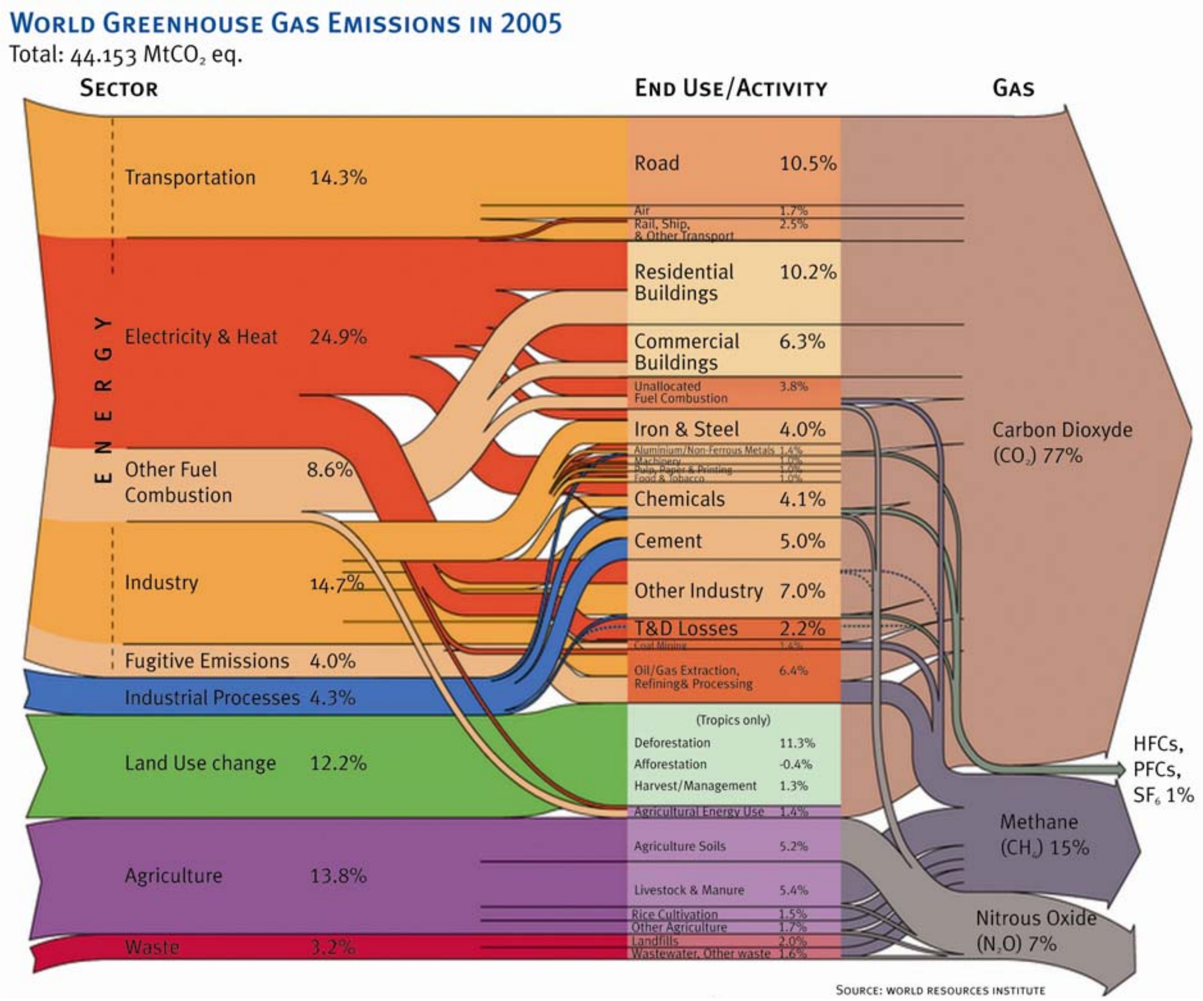


Source: IPCC

The IPCC has shown that global emissions need to peak in the next two decades and then decline by 60-80% by 2050 in order to stabilise greenhouse gas (GHG) concentrations in the atmosphere at 450-550 ppm CO_{2eq} corresponding to an average global temperature rise of 2-3°C.



SOURCE: IPCC 2007


WORLD GREENHOUSE GAS EMISSIONS IN 2005

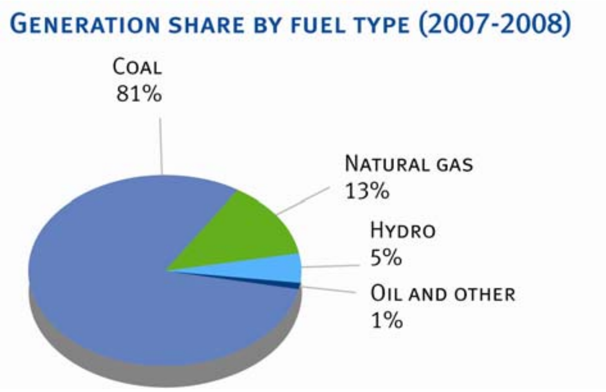
Total: 44.153 $MtCO_2$ eq.

SOURCE: WORLD RESOURCES INSTITUTE

In 2005, global CO_2 emissions from fuel combustion accounted for 85% of total CO_2 emissions and for 63% of total greenhouse gas emissions world-wide while CO_2 emissions from industrial processes and from other sources contributed 11%. Methane and the other greenhouse gases contributed 26%.

4. Electricity Structure in Australia, Canada, EU, Japan and US

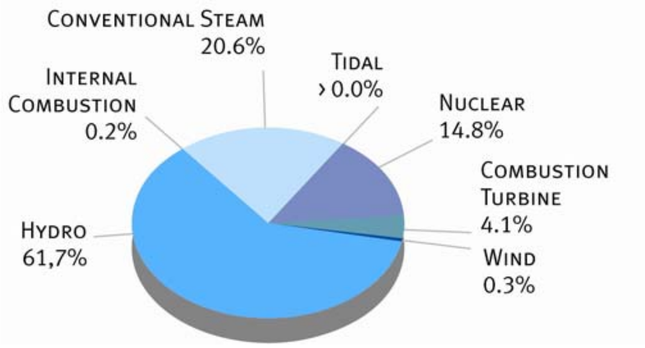
Australia



The Australian electricity system is characterised by three separate networks, aligning with the geographical dispersion of the population: one spanning the densely populated eastern and southern states of Queensland, New South Wales, Victoria, Tasmania and South Australia; one in the south-west of the state of Western Australia and a small network concentrated around the north of the Northern Territory. Australia has a total installed grid-connected generation capacity of 48,500 MW. Total 2007-08 power generation was 228TWh which was delivered over nearly 900,000 circuit kilometres of network. There are 9.9 million customers.

Electricity load growth has averaged over 1.7% per annum for the past five years and is projected to continue at or above that level for the next decade. The industry directly employs some 52,000 people, has assets valued at over $120 billion and investment needs of approaching $49 billion in the next 5 years. It contributes 1.6% of Australia's GDP and is owned by both private companies and governments.

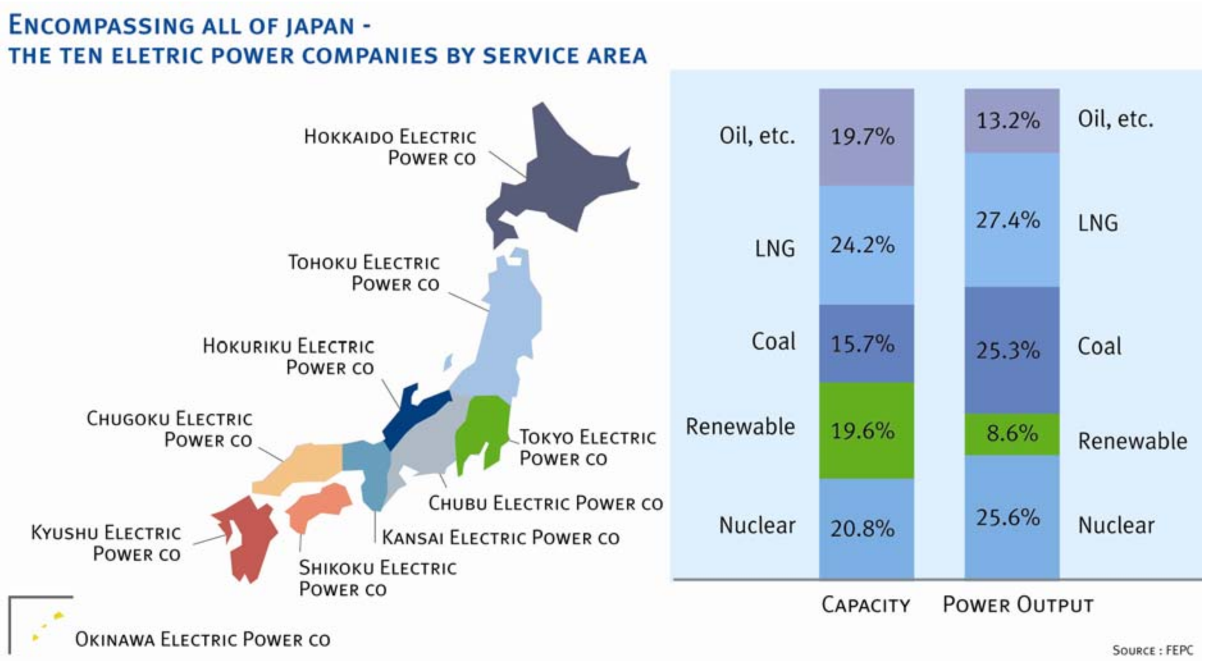
Canada



Canada's demand for electricity continues to rise. Since 1990, total end-use electricity demand has increased by approximately 1.3 percent per year and this rate of growth is expected to remain steady over the coming years. Refurbishment and expansion of the sector's infrastructure is needed to maintain reliability, meet future demand and to accommodate the integration of a greater variety and increasing number of renewable supply sources. Renewal and expansion of infrastructure, the need for greater system efficiency, security and reliability and the increasing desire to provide consumers with options and opportunities to manage their environmental footprint and to control their electricity consumption - and consequently their electricity bills - are all factors which warrant investment in the modernization of the electricity grid.

The current electricity grid is more than 75% non-emitting and is predominantly based on large central power stations connected to transmission and distribution systems.

Japan



SOURCE : FEPC

The total amount of electricity consumption in Japan for fiscal year 2008 was 889TWh, down from 920TWh a year earlier due to the rapid economic recession. The electric utility industry of Japan is working on achieving the best mix of energy sources, balancing the use of nuclear power (as the primary energy source), thermal power, and hydroelectric power among others. Within thermal power, a balanced use of fossil fuels (coal, LNG, and oil) is considered desirable. The best mix of energy sources takes into account security of supply stability, economic, and environmental impacts.

European Union

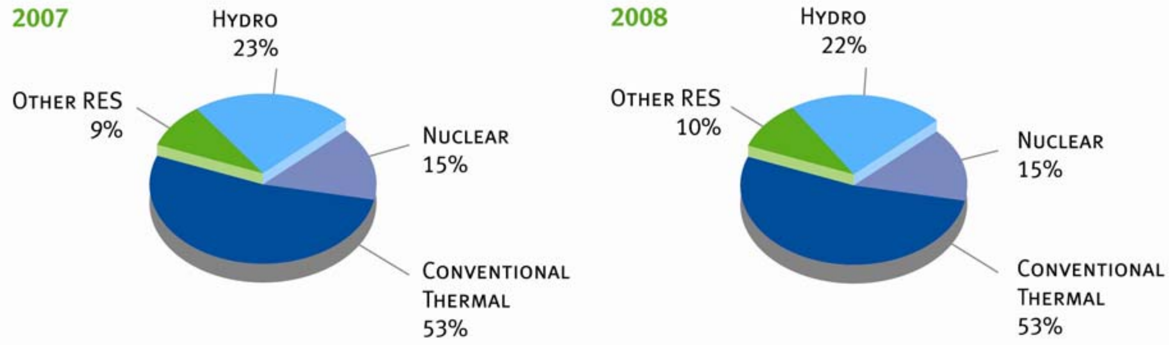
Europe boasts a varied mix of power generation technologies with nearly half of the generation fleet being low-carbon. Such a balanced mix of technologies is indispensable to simultaneously ensure security of supply and the achievement of the strategic objectives laid down in EU energy policy.

From 2007 to 2008, generating capacity increased by slightly more than 2%, with half coming from conventional thermal plant and the other half from renewable energy sources.

Electricity production in Europe (EU + Croatia, FYROM, Iceland, Norway, Switzerland and Turkey) increased slightly between 2007 and 2008 from 3608 TWh to 3635 TWh. Over half (53%) came from conventional thermal production while nuclear power production remained stable and renewable energy increased by some 40 TWh.

The trend towards less CO_2 intensive power production is set to continue under the new EU legislative framework, with an emission cap and newly agreed renewable energy production targets.

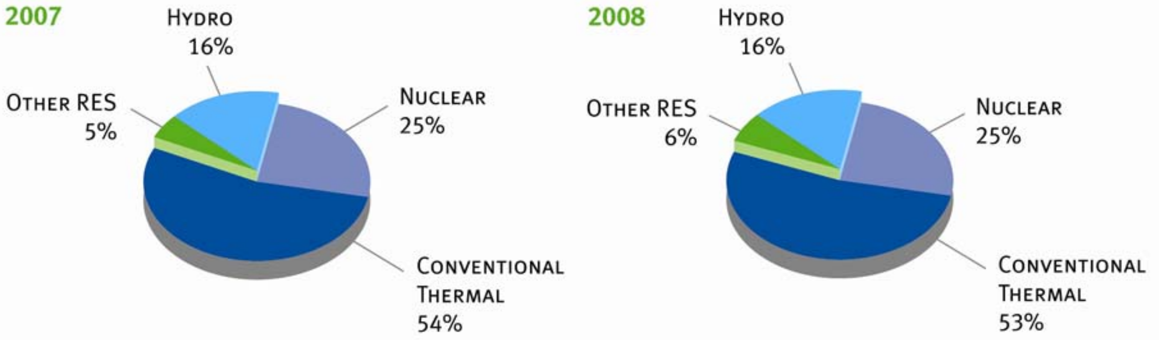
ELECTRICITY GENERATION CAPACITY, MW

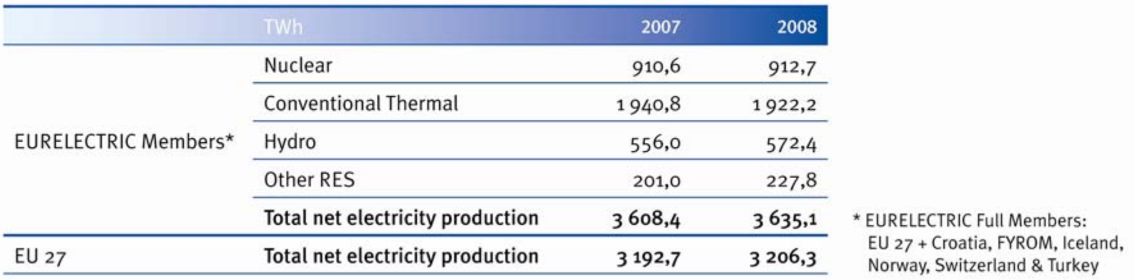


	MW	2007	2008
EURELECTRIC Members*	Nuclear	136 255	135 564
	Conventional Thermal	469 331	480 613
	Hydro	200 124	200 858
	Other RES	79 876	90 831
	Total capacity	**885 586**	**907 866**
EU 27	**Total capacity**	**792 590**	**811 110**

* EURELECTRIC Full Members: EU 27 + Croatia, FYROM, Iceland, Norway, Switzerland & Turkey

NET ELECTRICITY PRODUCTION, TWh

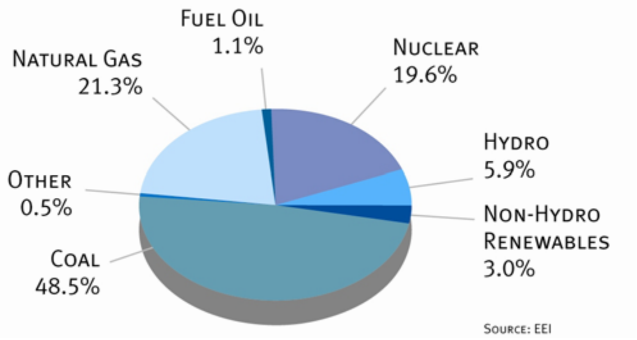




	TWh	2007	2008
EURELECTRIC Members*	Nuclear	910,6	912,7
	Conventional Thermal	1 940,8	1 922,2
	Hydro	556,0	572,4
	Other RES	201,0	227,8
	Total net electricity production	**3 608,4**	**3 635,1**
EU 27	**Total net electricity production**	**3 192,7**	**3 206,3**

* EURELECTRIC Full Members: EU 27 + Croatia, FYROM, Iceland, Norway, Switzerland & Turkey

United States



Source: EEI

There are over 19,000 electricity generators in the United States, representing about 1,100,000 MW of installed capacity. Coal is the predominant fuel source for power generation in the United States, accounting for 48.5% of power generated, followed by natural gas (21.3%), nuclear (19.6%), hydroelectric (6.0%), non-hydro renewables (3.0%) and oil (0.7%). Generation by all fuel types totaled approximately 4,100 TWh in 2008. Along with an expected need to replace aging capacity, the projected electricity supply growth of 21% by 2030 will create many opportunities for installing more efficient and clean generating capacity in the near future. A chart describing the fuel mix of the U.S. electric generation sector is shown below.

5. The Future of Energy

The International Energy Agency (IEA) in its World Energy Outlook 2009 (WEO 2009) makes an in-depth analysis of climate policies and develops a climate scenario consistent with limiting the concentration of greenhouse gases in the atmosphere to 450 ppm CO_2 equivalent. This scenario analyses measures in the energy sector which *might* be taken to fulfil a co-ordinated global 450 ppm commitment. It should be emphasised that neither this global commitment nor the policies to achieve it are in place at the present time.

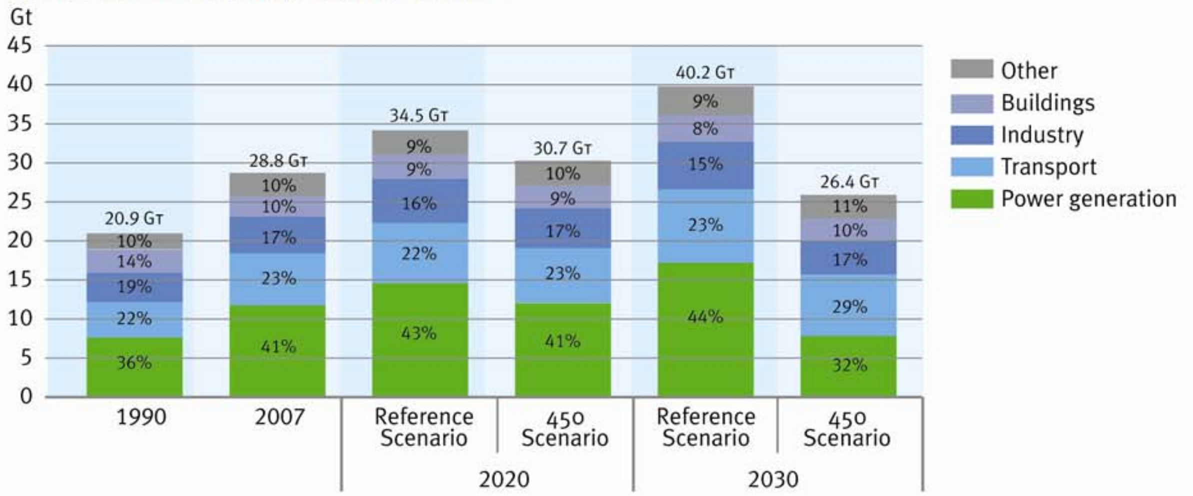
The Reference Scenario in WEO 2009 takes into account government policies and measures adopted by mid-2009, and gives a picture of how global energy markets would evolve if governments were to make no further changes to their existing policies. In this scenario rising global fossil fuel use increases energy-related CO_2 emissions from 29 Gt in 2007 to over 40 Gt in 2030. The Reference Scenario, if projected out to 2050, would result in a long-term CO_2 concentration of about 1000 ppm.

The 450 Scenario uses a combination of policies and commitments including cap and trade, sectoral agreements and national policies most of which have not been agreed at national, regional or international level and it is therefore highly dependent on political developments and investment.

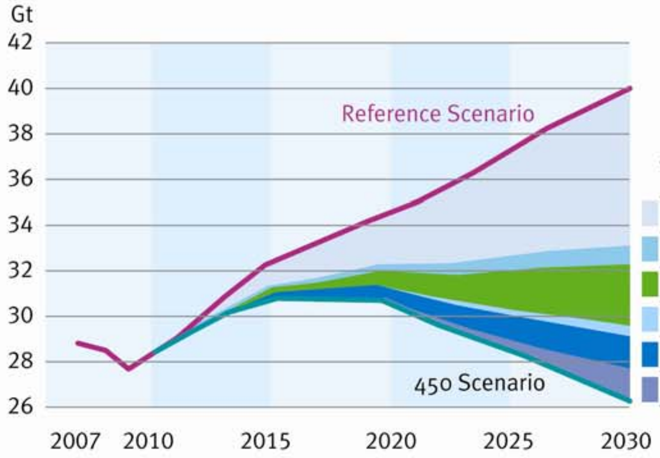
On a global basis the 450 Scenario postulates by 2020 relative to 2007:

- a 6% global increase in energy related CO_2 emissions
- power generation CO_2 intensity decreasing by 23%
- car fleet CO_2 intensity decreasing by 37%
- increase of 3% in emissions from buildings
- increase of 9% in industrial emissions

WORLD ENERGY-RELATED CO_2 EMISSIONS

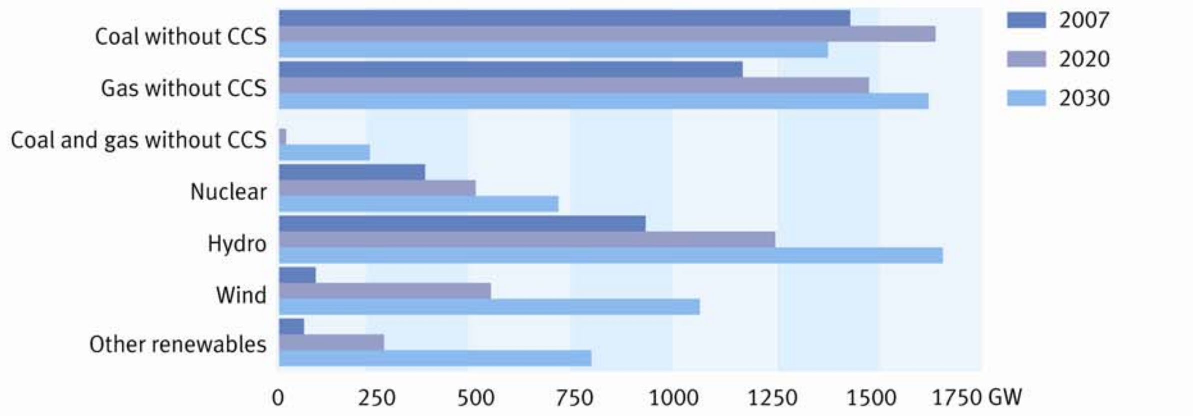


WORLD ENERGY-RELATED CO_2 EMISSIONS ABATEMENT



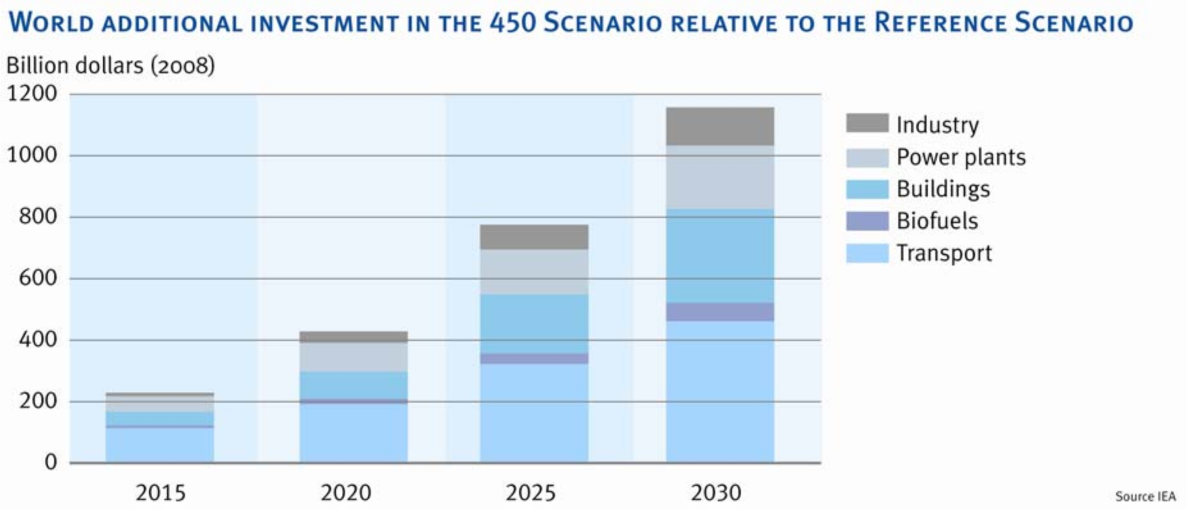
	Abatement ($Mt CO_2$)		Investment ($2008 billion)	
	2020	2030	2010-2020	2021-2030
Efficiency	2517	7880	1999	5586
End-use	*2284*	*7145*	*1933*	*5551*
Power plants	*233*	*735*	*66*	*35*
Renewables	680	2741	527	2260
Biofuels	57	429	27	378
Nuclear	493	1380	125	491
CCS	102	1410	56	646

WORLD POWER GENERATION CAPACITY IN THE 450 SCENARIO



Source: IEA

The *additional* cumulative investment would be $10,500 billion over the period 2010-2030 with a total investment of $6,600 billion in low-carbon generation, mostly in renewables, over the same period.



6. Generic Mitigation Policy Options

There are a plethora of carbon mitigation policies and mechanisms that can be applied at national, regional or global level. Each of these policies has strengths and weaknesses which makes it important that the correct policy is chosen in any particular circumstance. For any policy to be successful and efficient the policy objective must be clear and multiple policy objectives must be avoided. With any policies it is essential to ensure a diversity of energy sources; simultaneous achievement of energy security, economic competitiveness and environmental integrity; consideration of national circumstances and the public acceptance of the policy and its cost recovery mechanism.

Another important part of any policy is how it is monitored, reported and verified and how any non-compliance is dealt with. Adequate monitoring and reporting is an essential prerequisite of any policy and can often indicate the most appropriate and effective type of policy.

Each of the policies can be enacted in a number of different ways with any targets or goals being set in different ways. Targets or goals can be set against differing baselines and can be expressed in differing ways. In any national or international policy it is highly likely that differing combinations will be used to suit particular circumstances. In order to ensure an efficient outcome the need for simplicity and comparability has to be carefully balanced against the complexity created by more tailored mechanisms.

There are three main classes of mechanisms – voluntary agreements, regulation and economic instruments. Again there are advantages and disadvantages to each type of mechanism and, in particular, some activities are best suited to one mechanism, which means that in any area it is highly likely that a mix of the mechanisms will be needed. The success of a particular type of mechanism will often depend on the cultural and legal views in the area where it is being applied.

Emissions cap and trade is one mechanism that has been shown to contribute to reducing emissions from large point sources and has the advantage that the cap is set in advance and is assured provided that appropriate sanctions for non-compliance are in place. The dynamic nature of the system enables participants to identify the marginal abatement cost through the market and thus the cap is met in a cost-efficient manner. It is important to keep in mind that decisions on how to set the cap depend on national circumstances. Such systems can be integrated with other mechanisms through the use of offsets such as those generated by CDM and JI.

A number of new ideas are being mooted in the UNFCCC climate negotiations and elsewhere. These seek to bring together developed and developing nations with their 'common but differentiated responsibilities'. These include sectoral targets, NAMAs, and 'no-lose' targets which could link into a carbon market.

7. Roadmap to Low-Carbon Power

Australia

The Australian government has set economy-wide emission reduction targets of 60% below 2000 levels by 2050 and a minimum 5% and maximum 25% below 2000 levels by 2020, dependent on the nature and extent of the outcome at the December 2009 Copenhagen UNFCCC meeting. In addition, the government has legislated for approximately 20% of delivered electricity to come from renewable generation by 2020. A cap and trade emissions trading scheme is being developed and is expected to commence in mid 2011.

As these initiatives become law, they will progressively provide the policy settings necessary for the Australian electricity sector to make new investment decisions for both generation and networks that include the business impacts of national carbon constraints. As a market based economy with an openly competitive and largely de-regulated electricity sector, Australia’s future electricity system will be the product of mainly private investment responding to regulatory requirements, emission constraints and market opportunities. However, provision of this private sector investment will depend on the government schemes ensuring that energy companies with emissive facilities do not suffer large scale stranding of assets and consequential balance sheet losses.

Industry modelling of the future carbon-constrained Australian electricity industry reveals that it will be characterised by the retirement of between 15% and 20% of existing coal-fired capacity by 2020, replaced with a much greater use of natural gas-fired generation and new large scale renewable generation mainly in the form of wind and, towards the end of the 2010-2020 decade, penetration by new geothermal (hot rocks) generation. Energy efficiency will also contribute to reducing emissions through lower demand.

However beyond 2020, new technology will be necessary to achieve deep emission reductions and replace ageing plant. In conjunction with governments (national and states), the industry is pursuing a range of carbon capture and storage (CCS) projects across the three main variants of this technology. Advanced renewable generation technologies are also being pursued including solar-thermal, concentrated solar PV and several innovative wave energy approaches. Many of these technologies are promising and are expected to come to market between 2020 and 2030.

Canada

The Government of Canada is committed to reducing Canada’s total greenhouse gas emissions by 20 per cent from 2006 levels by 2020 and by 60 to 70 per cent by 2050. Canada has also outlined a goal where 90 percent of Canada’s electricity would be provided by non-emitting sources such as hydro, nuclear, clean coal or wind power by 2020.

In tackling this challenge, the Government of Canada and the Provinces are supporting clean energy technologies. This includes investing over $3 billion in commercial-scale CCS demonstration projects between now and 2015. These projects will be public-private partnerships designed to leverage private investments and reduce the commercial cost of CCS.

Canada's electricity system is already over 75% non-emitting, thanks to hydro and nuclear generation. Only 24% of Canada's electricity fleet is generated from fossil fuels like coal, oil and gas. Hydroelectric projects are either in the planning or construction stages in Labrador, Québec, Ontario, and Manitoba and in BC and Yukon. Electricity generated from wind continues to expand, with generation expected to exceed 3,000 MW this year. Wind and other forms of micro generation will be a key component of grid modernization and emerging "smart grid" technology. Coal-fired electricity is dominant in the Atlantic provinces of Canada, Alberta and Saskatchewan. In Ontario in 2007, coal-fired was 18% of electricity generated or 28.2 TWh of the total 157.9 TWh produced for the province. The Province of Ontario is committed to closing 6,000 MW of coal-fired generation by 2014. Natural gas is the likely bridging fuel to a low carbon future while replacement generation is built.

Nuclear will play a key role in Canada's clean energy strategy.The refurbishment of nuclear reactors in Ontario and New Brunswick is underway with more planned in Ontario and Québec. New reactors are to be built in Ontario and possibly in New Brunswick and in Western Canada. Wind, tidal and geo-thermal projects are at various stages across the country as alternative generating options are considered.

Total electricity generation in Canada increased about 28% from 1990 to 2008. On the demand side, between 1990 and 2007, overall electricity demand increased by 24%. Demand continues to grow in spite of energy efficiency gains and conservation efforts.

European Union

The EU, in its energy-climate legislative package, has set legally binding targets of a unilateral 20% reduction of greenhouse gases from a 1990 base by 2020 and a 20% renewables share of total energy by 2020, plus an indicative target of a 20% improvement in energy efficiency. The 20% GHG target will be increased to 30% if a satisfactory agreement is reached in Copenhagen in December 2009.

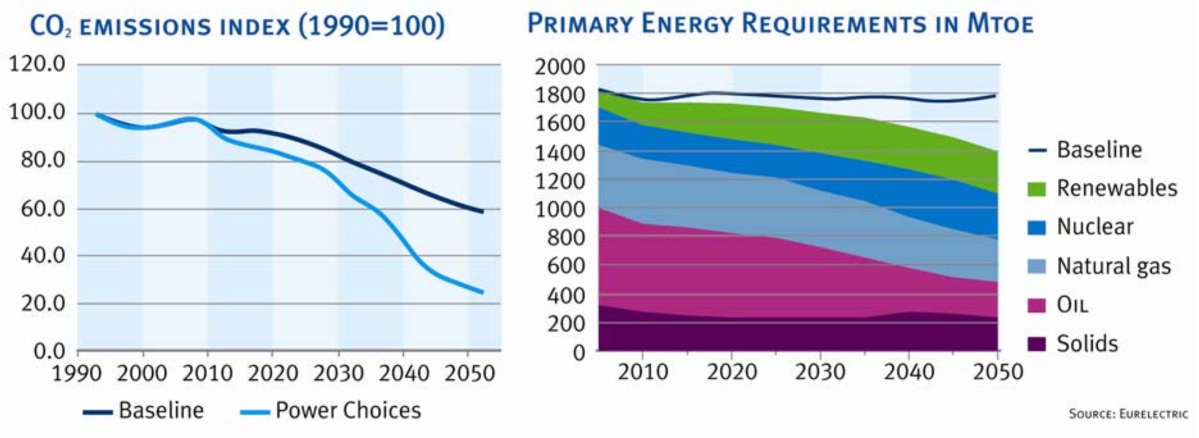
Recognising its responsibilities as a major emitter of greenhouse gas, the European power sector made a public commitment in March 2009 to achieve low-carbon power generation by mid-century.

The EURELECTRIC *Power Choices* study was set up to examine how this vision can be made reality. Setting an EU economy-wide domestic reduction goal of 75%, *Power Choices* looks into the technological developments that will be needed in the coming decades and examines some of the policy options that will have to be put in place.

The *Power Choices* study uses the PRIMES energy model developed and run by Athens Technical University by a team under Professor Capros - also used by the European Commission for its energy scenario work - to examine scenarios to 2050. For this project, the model has been updated as regards macroeconomic and power-sector data and assumptions.

The study develops two alternative scenarios for the EU-27 countries during the 1990-2050 period: *Baseline*, assuming all existing policies are pursued; and *Power Choices*, which sets a domestic 75% CO_2 reduction target across the entire EU economy.

The results show that a low-carbon power sector is feasible in the EU by 2050 provided that all generation options are used together with an increased emphasis on demand-side energy efficiency. The *Power Choices* scenario demonstrates that this can be achieved through increased intelligent use of electricity resulting in savings in primary energy consumption, a major decrease in import dependency and a lower overall energy cost in the EU economy.



SOURCE: EURELECTRIC

Japan

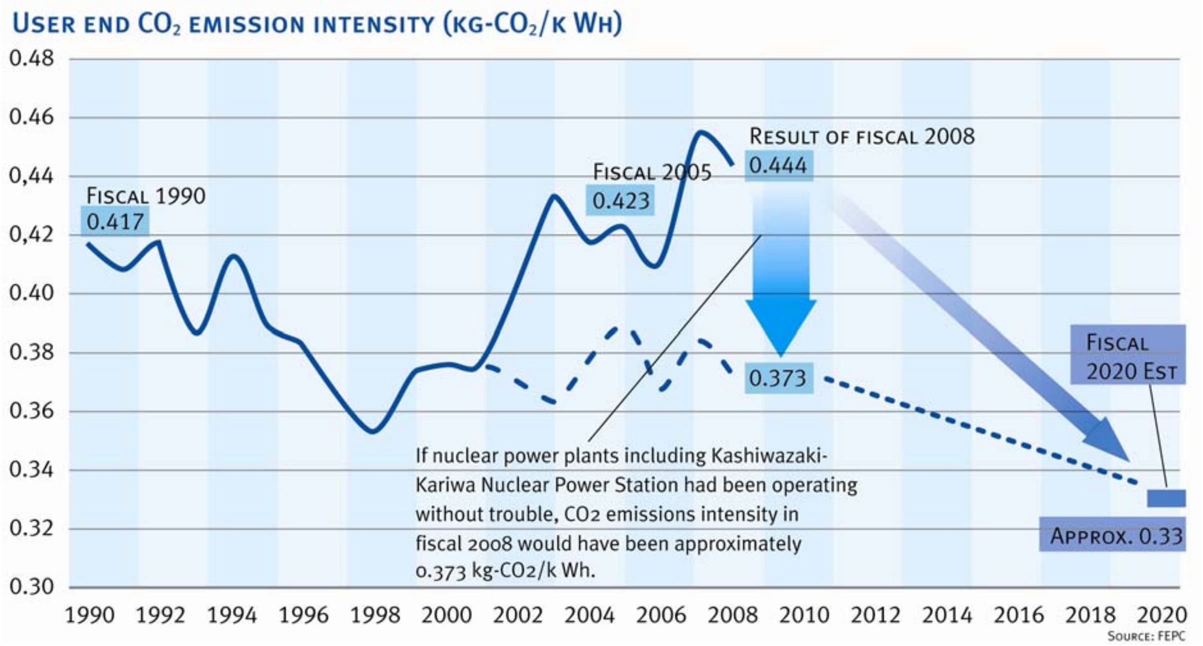
At the UN Summit on Climate Change held in New York on September 22, 2009, Prime Minister Hatoyama announced a new mid-term target of reducing national emissions by 25% compared to 1990 levels by 2020, premised on an agreement on ambitious targets by all major economies.

The Japanese electric utility industry strives to further lower its CO_2 emission intensity with an economically efficient energy supply that fosters environmental conservation and sustainable development.

Since it takes 10 to 20 years to build facilities such as power plants, the Japanese midterm target for 2020 is based on the current state of the electric utility industry. The supply plan reflects the actual electricity demand and aims to fulfil the responsibility of providing a stable supply generated by the best mix of power sources. According to this plan, an emission intensity target has been set at 0.33 $kgCO_2/kWh$ throughout all ten electric companies by 2020.

On the supply side, efforts will be targeted to realize a 50% non-fossil fuel energy supply by 2020, using mainly nuclear power, to increase efforts for mega solar power generation and cooperation for the new solar power purchase system and to realize highly efficient use of fossil fuels (introduction of the world highest efficiency combined cycle power generation and development of coal gasification combined power).

On the demand side, electrification will be promoted through the introduction and expanded use of heat pumps using CO_2 as a refrigerant to realize a low-carbon society.



The Japanese government aims to reduce greenhouse gas emissions in the country by 60%-80% by 2050. The electric utility industry regards promotion of electrification as the key to realizing a low-carbon society. The power sector will maximize efforts to bring about further low-carbon grid power and a transformation of the energy supply-demand structure to boost electricity reliance for 2050, thus drastically reducing CO_2 emissions throughout society.

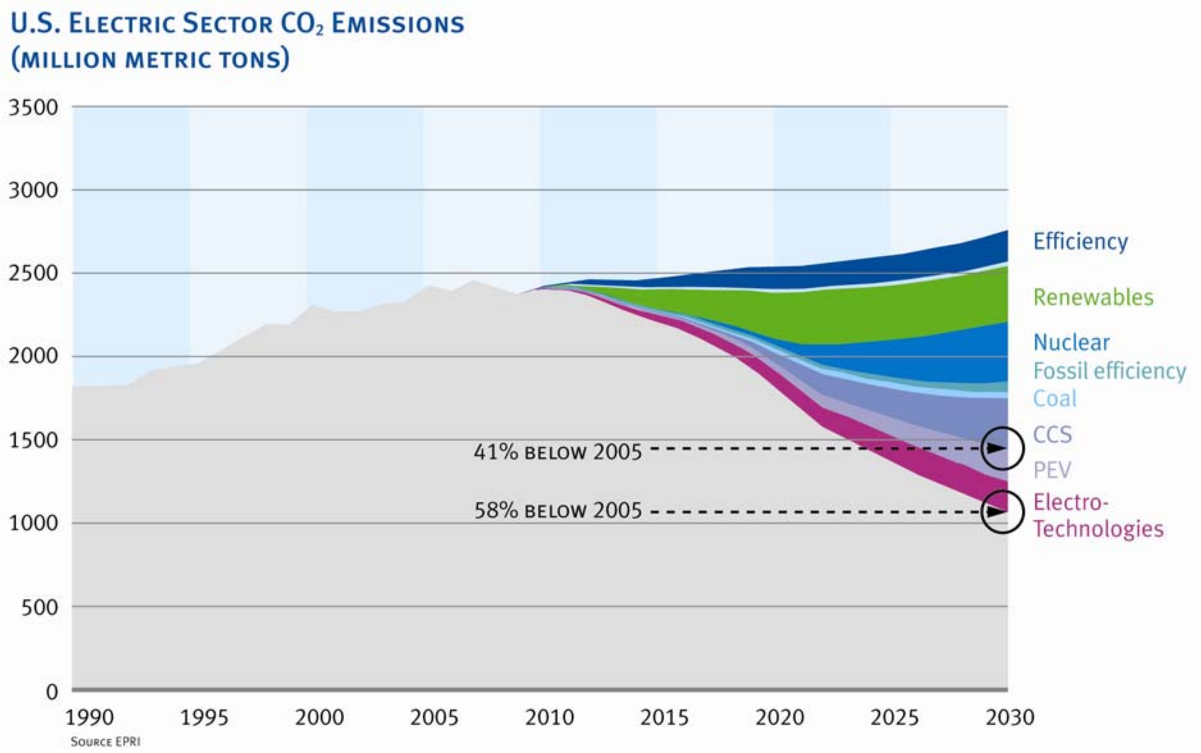
Internationally, efforts will continue to improve the ability of engineers in plant operation and maintenance, and also to maintain and improve facility performances in the developing countries through APP (Asian Pacific Partnership) activities. The sector is committed to technology transfer and capacity building in developing countries to nurture a low-carbon global society.

United States

Any roadmap for a low-carbon power sector must include improvements to current processes and policies to encourage investment in innovative technologies, while continuing to ensure a reliable, affordable supply of electricity. Such an approach needs to address all aspects of power generation, including: improvements in end-use energy efficiency, transmission and distribution efficiency, and generation efficiency; expanded deployment of renewable energy resources and nuclear power; development and deployment of carbon capture and storage technologies; widespread use of plug-in electric vehicles; and, increased use of electro-technologies.

U.S. government funding of energy programs generally reflects this type of approach. For example, the U.S. Department of Energy (DOE) supports a wide variety of programs to improve existing technologies and improve efficiencies in buildings and vehicles, as well as to develop new technologies to generate power from coal, biomass, geothermal, hydropower, wind and solar. DOE is also investing in the development of hydrogen and other innovative fuel cells, as well as electric vehicle research.

Another example of this “full portfolio” type of approach is reflected in the Electric Power Research Institute’s “The Power to Reduce CO2 Emissions: The Full Portfolio, 2009 Technical Report” (Oct. 2009), shown in the figure below. This analysis discusses the technical potential of GHG reductions from the electric power sector from a theoretical standpoint. Enacting such a portfolio approach is highly dependent on the achievement of very ambitious assumptions that would require more aggressive public policies than are currently in place.



8. End-Use Energy Efficiency

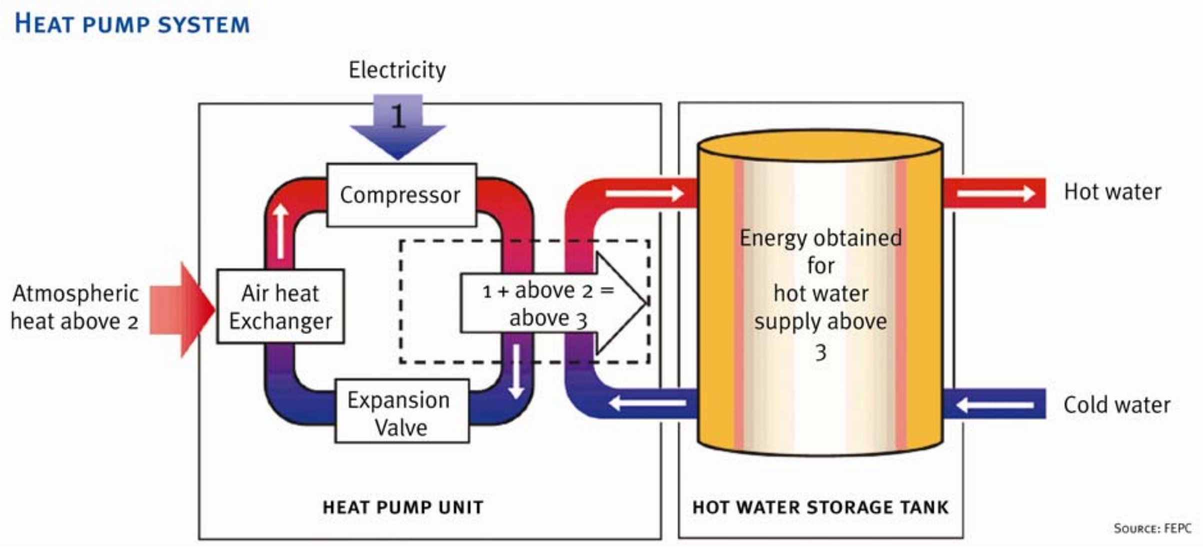
To stabilise and then reduce GHG emissions from the electricity sector, with the long-term objective of substantial decarbonisation, needs not only supply side transformation including development of smart and robust grids for efficient power transmission/distribution and integration of distributed power sources, but also dramatic energy savings through improvements in end-use energy efficiency and reductions in fossil fuel combustion by promoting electrification of the society.

End-use energy efficiency improvements mean that fewer resources are consumed and emissions are avoided. Integrated building design, with the development and deployment of high-efficiency electric cooling and heating devices, lighting systems, and electric appliances will buy time for cleaner, more efficient generation technologies to come on line.

A recent report (WBCSD) shows that in the building sector alone, which accounts for 40% of global energy use and where electrification could play an important role, more than 40% emission reductions are achievable at relatively affordable cost with existing technologies if appropriate policies and measures are introduced or strengthened.

The IEA has shown that higher levels of electrification, particularly in the field of building heating/cooling and transportation where fossil fuel combustion will be displaced by the use of heat pump and hybrid/electric vehicle technologies, can substantially reduce emissions.

Source: Toyota



An array of technologies and designs has been developed to support the more efficient use of electricity. Many of these such as insulation, double glazed windows, solar water heating in certain countries and compact florescent lamps are mature, competitive and cost effective. Other highly energy efficient technologies such as heating and cooling heat pump technologies are in an early deployment phase. Their substitution for conventional heating and cooling combustion technologies will result in substantial saving in primary energy and CO_2 emissions. Zero net energy houses are increasingly entering the market. Other technologies such as high-temperature heat pump systems (used for steam production in industrial processes) require further R&D to achieve commercial deployment. Solid state lighting technologies are rapidly developing in efficiency and lifespan but are still more costly than conventional solutions. The advancement of sensor and control technologies together with smart meters could further enhance energy efficiency.

Energy efficiency measures have not only been proven the most cost effective in terms of CO_2 mitigation but also possess significant potential. Although there are technological challenges for energy efficiency technologies to overcome for further deployment (batteries for plug-in hybrid and electric vehicles, and high-temperature heat pumps), non-technological barriers especially need to be addressed. These include high transaction costs, market and behavioural barriers which have proven to be challenging to overcome.

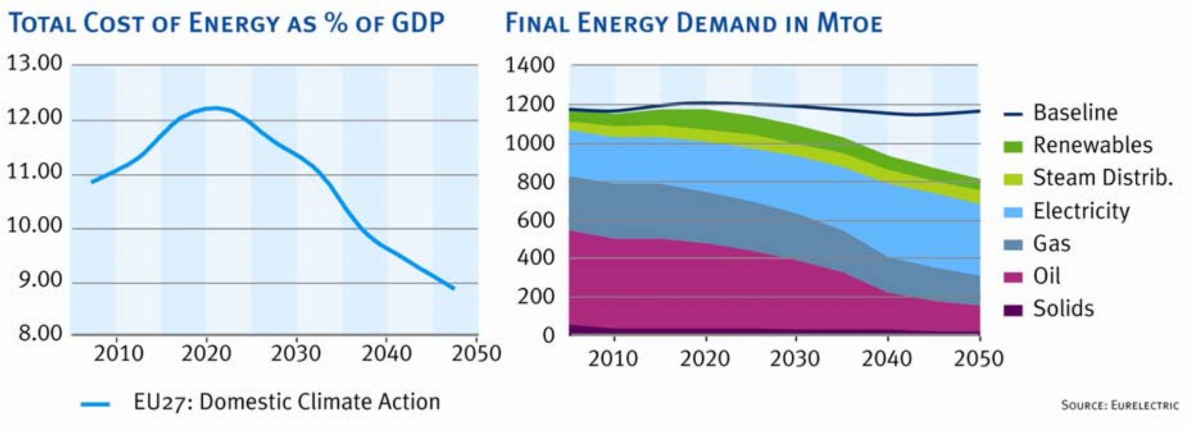
9. Cross-Sector Benefits

Electricity is an energy vector that has no greenhouse gas emissions during its transmission, distribution and at the point of use. Furthermore, there are no emissions of other gaseous pollutants. It is only at the point of generation that significant emissions occur.

Because of its high efficiency at the point of use there are a number of uses of electricity where substitution of electricity for other fossil fuels can result in a reduction in the overall emissions of CO_2 even with the present generation fuel mix. This reduction increases significantly as the carbon intensity of electricity generation is reduced.

There are numerous examples in the transport, industrial and domestic sectors such as electric and plug-in hybrid vehicles, electro-technologies (such as inductive heating), heat pumps, etc. These technologies, though continuing to be developed, are available and commercial today and, in some countries, are making a significant impact.

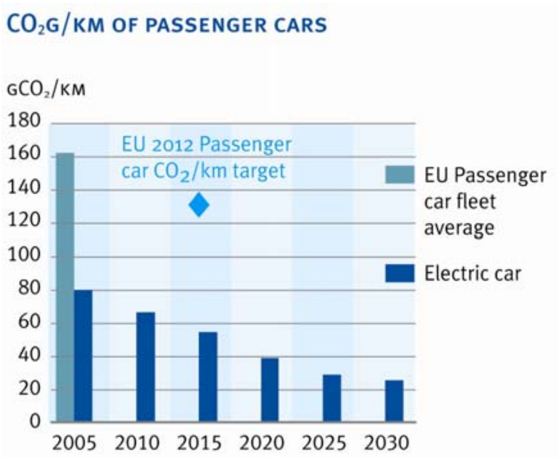
A number of studies have shown that the simultaneous reduction of carbon intensity in electricity generation and the substitution of fossil fuels at the point of use can bring substantial benefits. These benefits include an overall reduction of carbon emissions, increased energy efficiency and security of supply and reduced overall energy costs and imports. However, a paradigm shift is needed to ensure the intelligent use of electricity as a substitute for the use of fossil fuels.

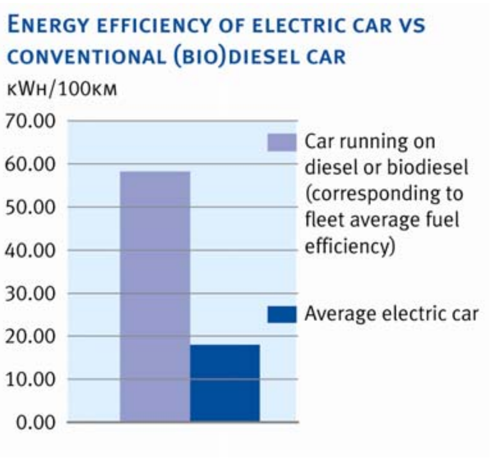


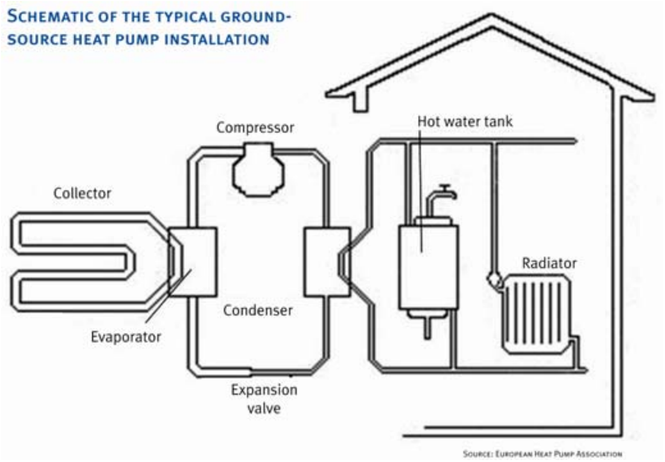
SOURCE: EURELECTRIC

These advantages will only be realised within a political framework which delivers policies that ensure that:

- substantial investment is made in low-carbon power generation and modern, intelligent transmission and distribution networks
- barriers to deployment are removed and efficient permitting procedures for the necessary construction projects are put into operation
- electric vehicles and the supporting infrastructure are rapidly developed and deployed
- efficient electric technologies, such as heat pumps in buildings, are brought into widespread use
- all sectors face the full cost of carbon through appropriate policies
- a strong international agreement on climate change is reached

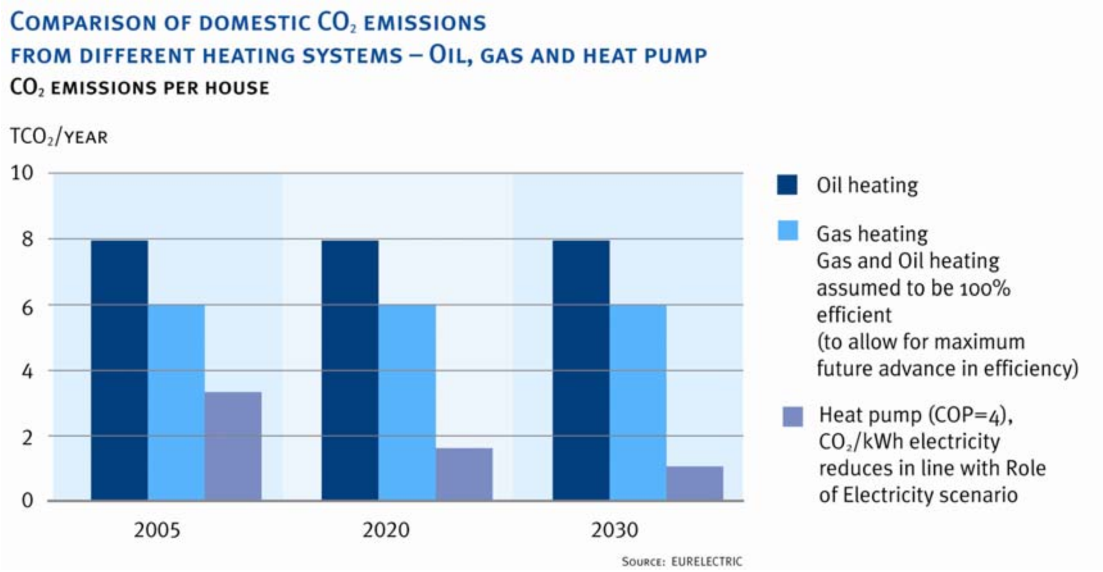

CO₂G/KM OF PASSENGER CARS


ENERGY EFFICIENCY OF ELECTRIC CAR VS CONVENTIONAL (BIO)DIESEL CAR


SCHEMATIC OF THE TYPICAL GROUND-SOURCE HEAT PUMP INSTALLATION

SOURCE: EUROPEAN HEAT PUMP ASSOCIATION

Ground Source Heat Pumps are well established in the Swiss market, 61% of new single family homes in 2004 being built with heat pumps, rising from 14% in 1991 Source: Swiss Heat Pump Association


COMPARISON OF DOMESTIC CO₂ EMISSIONS FROM DIFFERENT HEATING SYSTEMS – OIL, GAS AND HEAT PUMP
CO₂ EMISSIONS PER HOUSE

SOURCE: EURELECTRIC

10. Renewable Energy

Today, renewable resources are both essential energy producers and important drivers of progress at the national and global levels. Projections for the future vary considerably, but most observers anticipate that commercial renewable energy technologies will make growing contributions to the world's energy supply and use mix in coming decades due to continuing innovations, improving cost-competitiveness, expanding policy mandates, and enduring challenges relating to energy security, fuel price volatility, climate change, and sustainability. However, there remains a massive gap between available resources and ones that currently can be harnessed in economically, environmentally, and socially acceptable ways. Technical progress is critical to fill this gap.

The primary commercial bioenergy technology for electricity generation is combustion of solid biomass either alone or in combination with fossil energy, while gasification and pyrolysis systems are emerging. Fuels include residues from woods and forests, and from the wood, paper, agricultural, and wastewater industries, and, in the future, trees and grasses grown as dedicated feedstocks. Landfill gas and digester gas systems are also commercially mature but resource constrained. Resources are huge globally but may conflict with food production. At present there is about 50GW globally.

Increasing geothermal power generation will require further progress in locating and extracting energy from hydrothermal reservoirs, as well as advances in hot dry rock/enhanced geothermal systems. Conventional dry- and flash-steam hydrothermal technologies are mature, while much of the recently installed or planned geothermal capacity relies on advanced energy conversion cycles to generate electricity from lower-temperature resources. Resources for near-term development are substantial but geographically limited and may be in remote areas while resources deep underground are large but challenging to access. At present there is about 10GW globally.

Kakkonda geothermal power plants Tohoku Electric Power Company Co., Inc., Japan

Deployment of solar photovoltaics, concentrating solar thermal electric, and solar thermal heating and cooling will accelerate at a rate paced by technological advances and other factors leading to increasingly attractive economics. Resources for photovoltaics are large and globally abundant and at present there is about 10GW of photovoltaics globally. For concentrating solar thermal resources are substantial but geographically limited, and sometimes located in areas remote from the grid. At present there is about 500MW globally.

Solar PV

Concentrating Solar Power

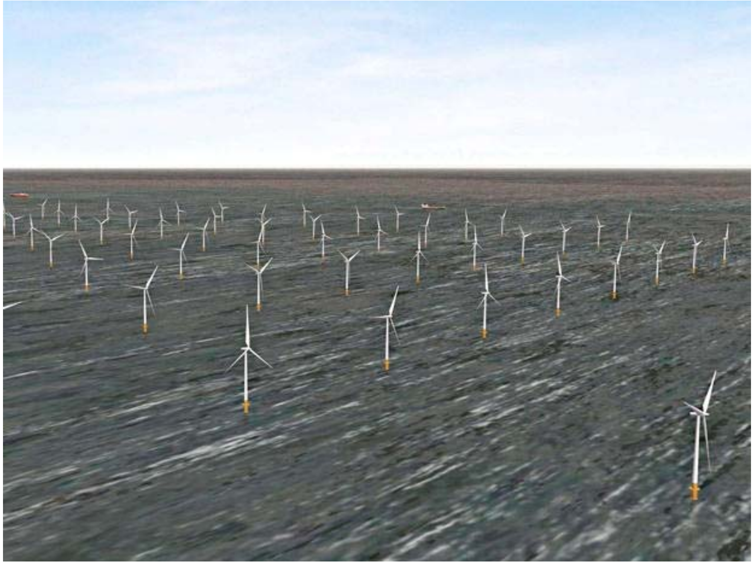
Application of waste-to-energy technologies will increase as global population growth creates the need to extract more of the useful energy embodied in what would otherwise be unused or discarded resources. Resources are substantial and many plants are operating globally.

Water power may continue to represent the world's leading source of renewable electricity if conventional hydro technologies advance and emerging hydrokinetic devices are commercialized. Novel in-stream hydro, tidal, ocean current, and wave energy technologies will provide access to currently untapped resources in natural environments and water conveyance systems. Conventional hydro untapped resources are substantial but geographically limited and sometimes located in areas remote from the grid. There is over 700GW installed globally.

Conventional Hydropower – Hoover Dam

Run of River Hydropower

Sustaining the rapid expansion in wind energy deployment will depend on continued advances in technology and on public acceptance. Progress is needed both in turbine components and in deployment, integration, and O&M technologies for land-based and offshore wind farms. Offshore windfarms will need substantial investments in offshore grids. Land-based and offshore wind resources are huge, geographically dispersed, and sometimes located in areas remote from the grid. There is over 100GW installed globally.

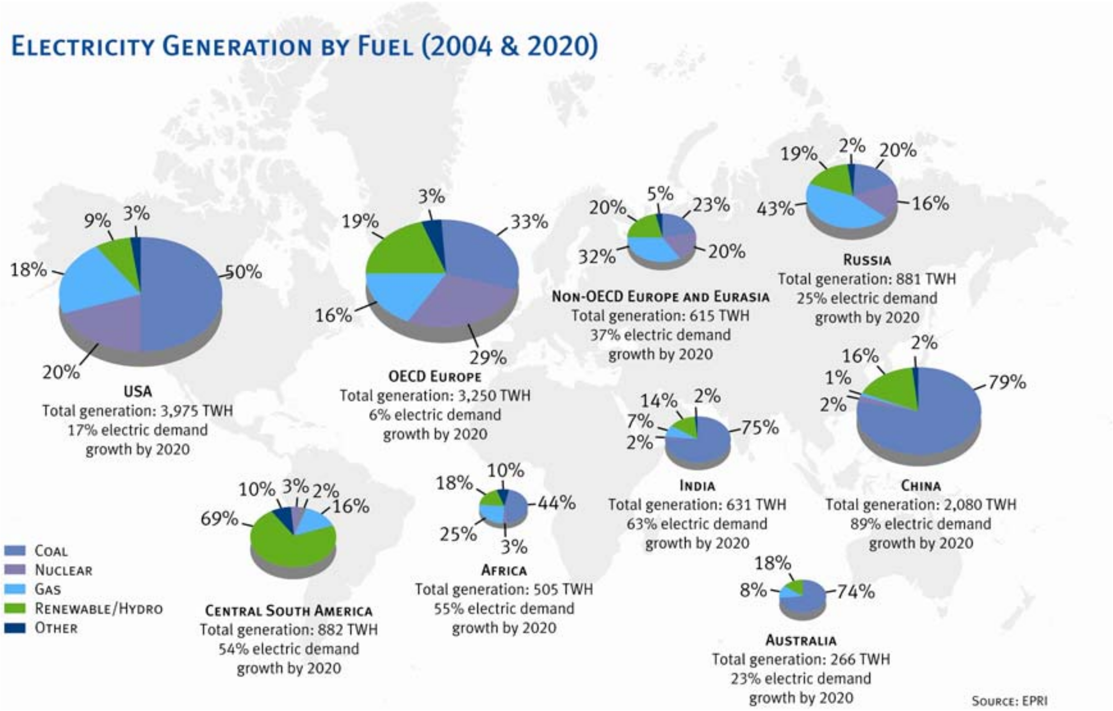


Offshore Wind farm – Thames Array

Renewable resources will continue to be harnessed and advanced technologies deployed within both technical and societal contexts. The rate of adoption and scale of penetration will be determined by the extent to which renewables can be seamlessly integrated within existing and evolving energy infrastructures - including the transmission and distribution networks - and social, political, economic, and environmental systems.

11. Advanced Clean Coal Technologies

Around the world, electricity is largely produced from fossil fuels, and coal is the predominant fuel choice. In North America, Australia, and parts of Europe, Asia, and Africa, coal-fired power plants supply more than half of the electricity consumed. Coal has become the primary fuel for affordable and reliable electric power production because it is relatively easy to transport and use, and because many countries have indigenous coal resources.



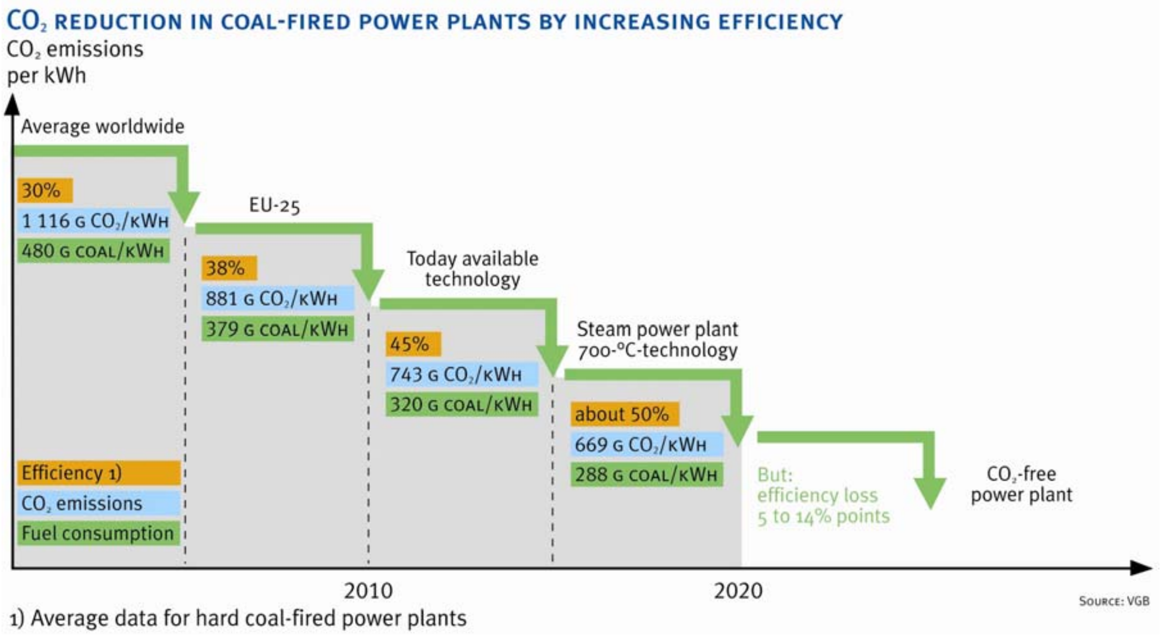
SOURCE: EPRI

In exploiting the benefits of electricity generated from coal and other fossil fuels, societies face many environmental quality challenges. During the last few decades, producers of coal-based electricity have successfully responded to ever-more stringent regulations to control emissions from coal plants. Research indicates that even with aggressive development and deployment of alternative energy sources, coal-based electricity generation will remain an important part of the power portfolio, especially in rapidly expanding economies like those of China and India.

Many countries view their indigenous coal resources as an essential element of their plans for national economic development and security. Coal is also relatively easy to mine, ship, and store. These qualities make coal-fired power plants important electricity price stabilizers and reliable producers, especially in electric systems using more price-volatile or intermittently available resources.

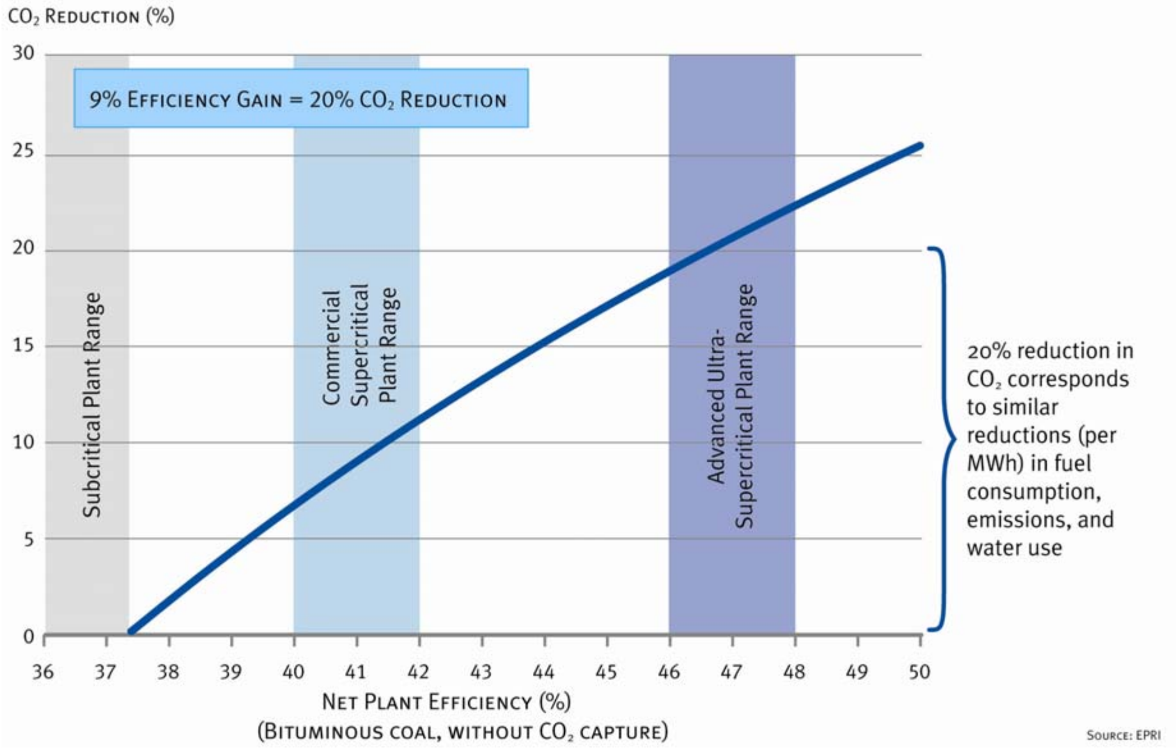
Given the large investment in coal-based power plants around the world, analysts believe that many nations want to continue using coal for electricity generation for decades to come. Development and deployment of advanced coal technologies are crucial to fulfill the need for affordable energy while addressing environmental concerns.

One of the most cost effective ways of reducing CO_2 emissions is to replace older plant with the most efficient modern technology – thus moving from a modern subcritical coal plant to an advanced ultra-supercritical plant will improve plant efficiency by some 9% and reduce CO_2 emissions by 20%. The reductions are even more significant when older, less efficient plants are replaced. These reductions will also significantly lower the cost of carbon capture and storage (CCS) as well as reducing the energy penalty that CCS imposes. As with all plant it is essential to maintain the efficiency of the plant by proper maintenance and operation.



1) Average data for hard coal-fired power plants

SOURCE: VGB



SOURCE: EPRI

To realize the benefits of competition, and to accommodate the cost and performance risks of any one technology, the power industry will require multiple, competing technologies. In addition, because fuel properties are a major driver in designing coal-based power plants, different technologies often are needed when different coals are used (in contrast to natural gas and nuclear plants, where fuel homogeneity allows for greater standardization). No single advanced coal technology holds clear-cut advantages across the full range of coal types and operating environments. These technologies are described below.

Pulverized Coal (PC): Traditional coal plants in which coal is ground to the consistency of flour and blown into a boiler for rapid combustion to create superheated steam, which a steam turbine uses to generate power. PC plants can be categorized into two types (subcritical and supercritical), based on the thermodynamic state of the steam entering the first turbine.

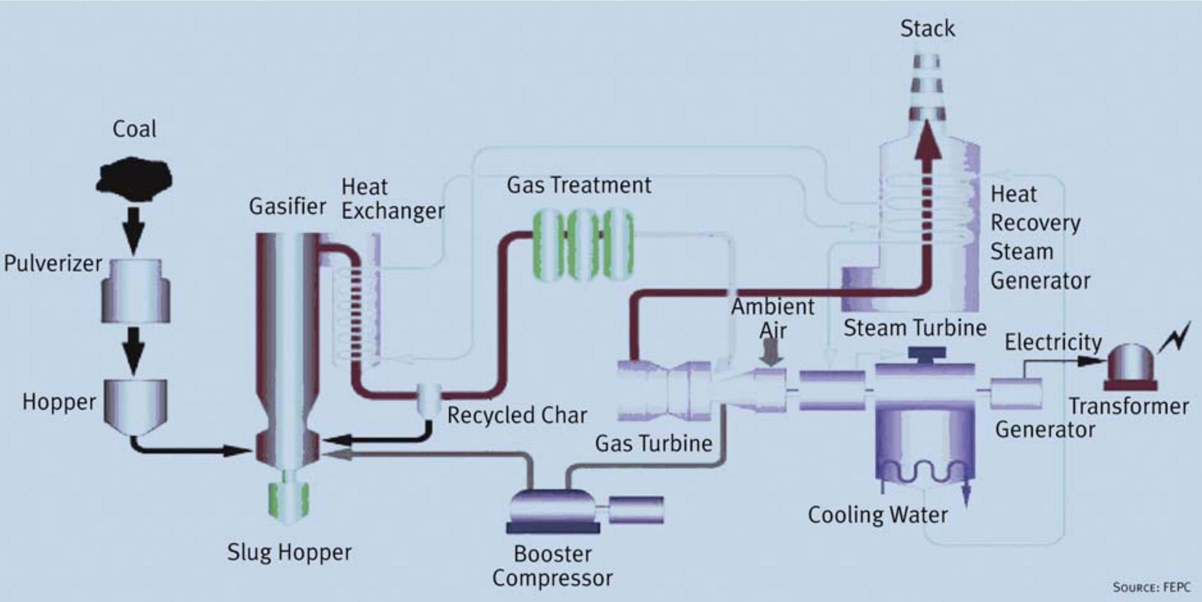
> ***Supercritical Pulverized Coal (SCPC):*** SCPC is a fully commerical technology. Plants typically employ a "main steam" (i.e., high-pressure turbine inlet) with a temperature of 1050-1100°F (565-595°C). The "reheat steam" (i.e., intermediate-pressure turbine inlet) temperature usually is the same as, or slightly higher than, the main steam temperature.
>
> ***Ultra-Supercritical Pulverized Coal (USCPC):*** Defined to mean plants with a main steam temperature greater than 1100°F (595°C), these highly efficient plants have been built commercially in Europe and Asia, but not in North America. A major gain in efficiency will come from "advanced" USC (AUSC) conditions (main steam up to 1400°F or 760°C), which will require development of new nickel-based alloys with improved high-temperature strength and creep and corrosion resistance.

Circulating Fluidized Bed Combustion (CFBC): This type of plant combusts coal and other solid fuels in a bed of hot sorbent particles suspended in motion (fluidized) by combustion air. The chief benefit of CFBC technology is its fuel flexibility; almost any combustible material, including biomass and municipal waste, can be readily burned. At present, only the subcritical design is commercially available, although a supercritical unit is under construction.

Integrated Gasification Combined Cycle (IGCC): Although not widely deployed - only 5 power generating IGCCs plants are operational in the world - the experience base for IGCC technology is sufficient to qualify these plants for nascent commercial status. An IGCC plant consists of a gasifier to convert coal to a fuel gas, which is cleaned up in a series of chemical processing stages. A gas turbine burns the cleaned gas followed by a steam turbine heat recovery unit to raise steam.

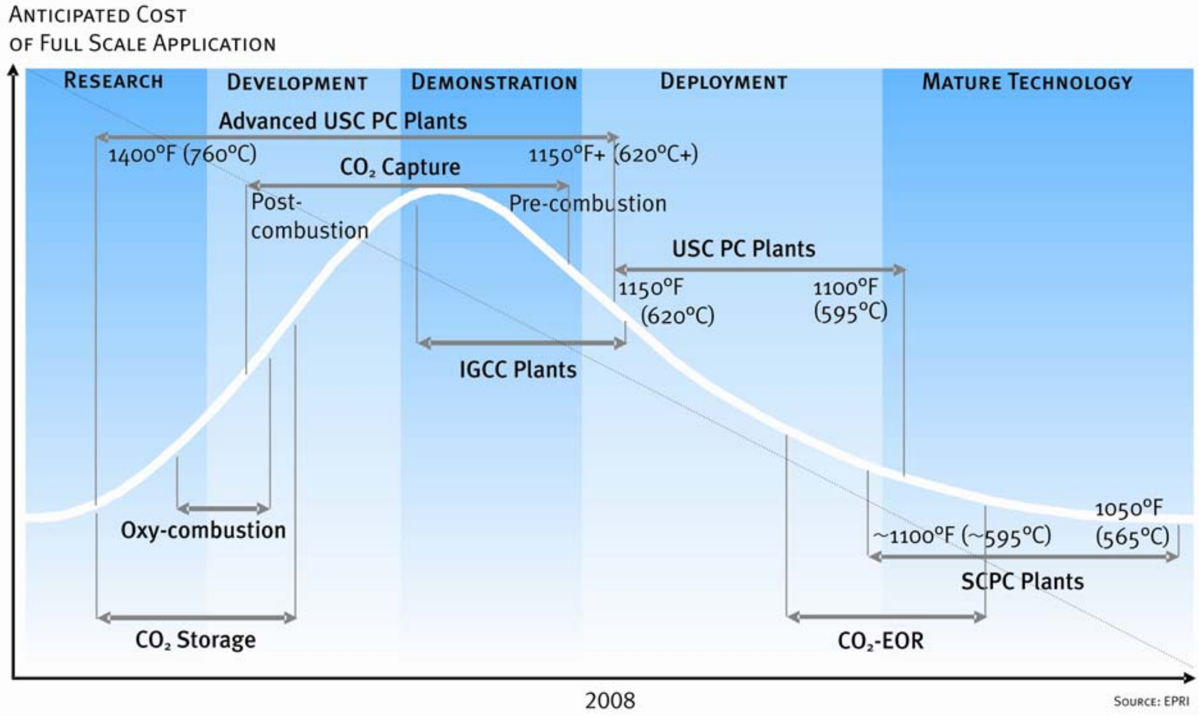
The typical path for commercializing a technology moves from the conceptual stage to laboratory testing, then to pilot-scale tests, larger-scale tests, full-scale demonstration, and finally to deployment of multiple systems in full-scale commercial operation. For capital-intensive technologies such as advanced coal power systems, each stage can take several years or more to complete and entails increasing levels of investment.

Integrated Gasification Combined Cycle (IGCC)



Source: FEPC

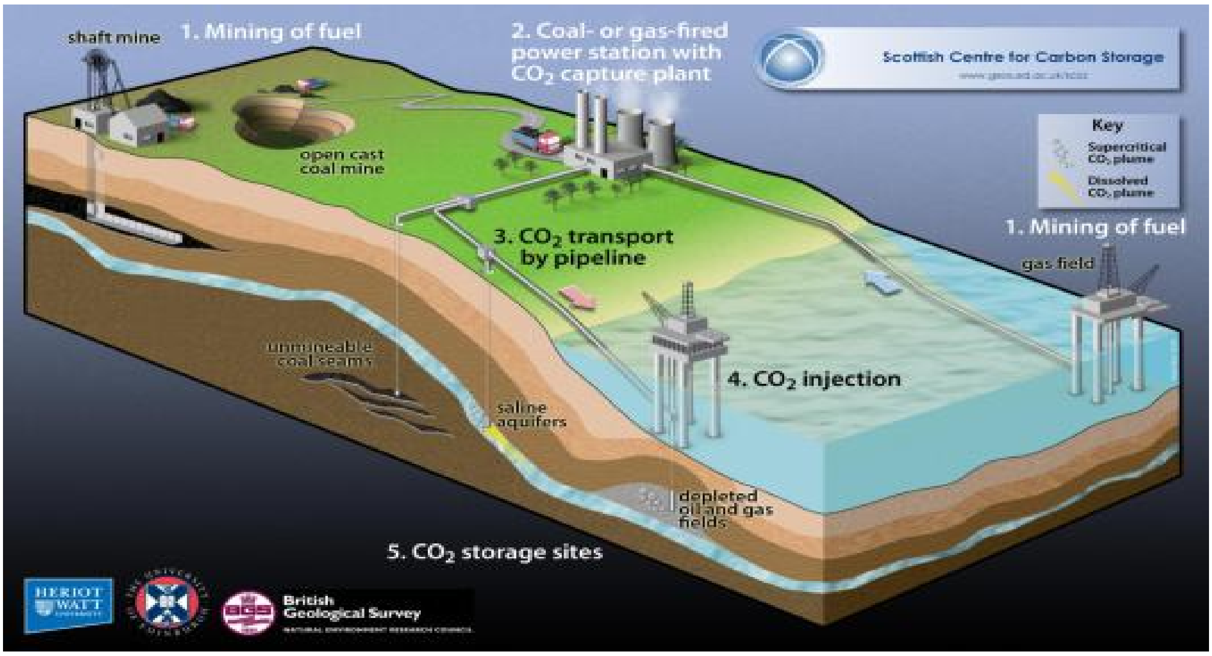
Status of Major Advanced Coal and CO_2 Capture and Storage Technologies



Source: EPRI

12. Carbon Capture and Storage

Carbon capture and storage (CCS) involves the separation and capture of CO_2 (either before or after combustion) and its permanent storage to ensure that it is not released to the atmosphere.



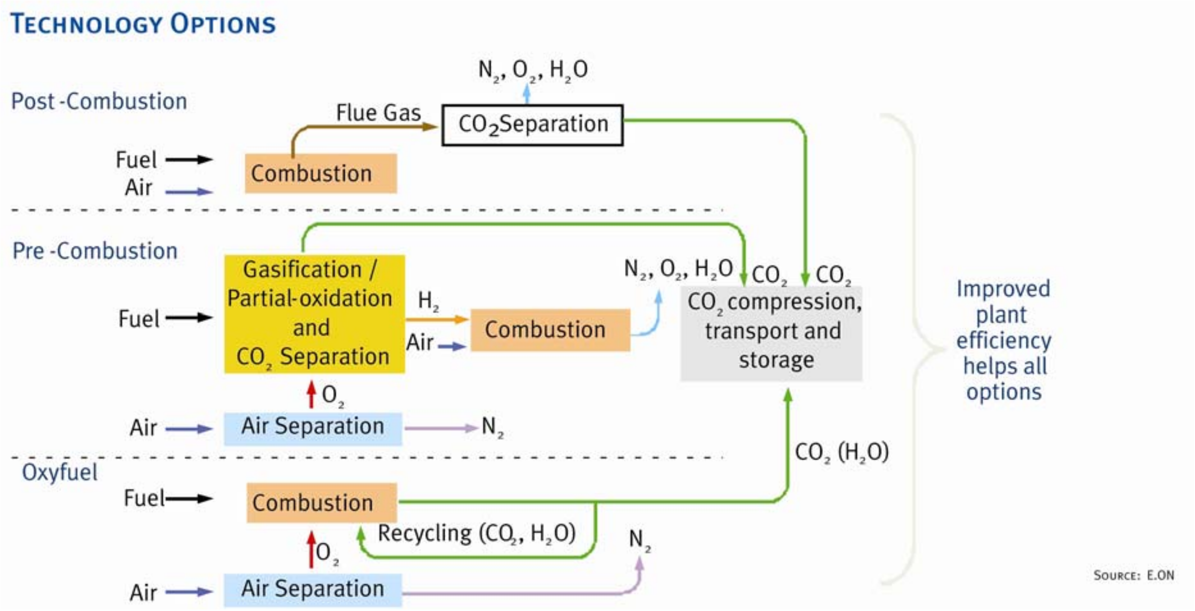
CCS is generally considered a potential technology solution for CO_2 emissions from stationary combustion activities. These include the burning of coal and gas to generate electricity and in other industrial processes that emit large amounts of CO_2 such as from steel, cement and ammonia manufacture. There are three main stages to CCS – capturing the CO_2, transporting it and sequestering it – each with its own set of technologies.

Capturing the CO_2 is the first stage. This can be done in several ways. Broadly, three different types of technologies exist: post-combustion, pre-combustion, and oxyfuel combustion.

- In *post combustion capture*, the CO_2 is removed after combustion of the fossil fuel. The technology is well understood and is currently used in other industrial applications, although not at the same scale as would be required in a power station.

- The technology for *pre-combustion* is widely applied in a variety of industries including fertilizer manufacturing. The fossil fuel is partially oxidized in a gasifier, creating a synthetic gas (CO and H_2) and this gas is converted into CO_2 and more H_2. The resulting CO_2 can be captured from a relatively pure exhaust stream. The hydrogen is used as the fuel for combustion with water as its main emission.

- In *oxy-fuel combustion* the fuel is burned in oxygen instead of air. The flue gas consists of mainly CO_2 and water vapour, the latter of which is condensed through cooling. The almost pure CO_2 stream can be transported to a sequestration site.

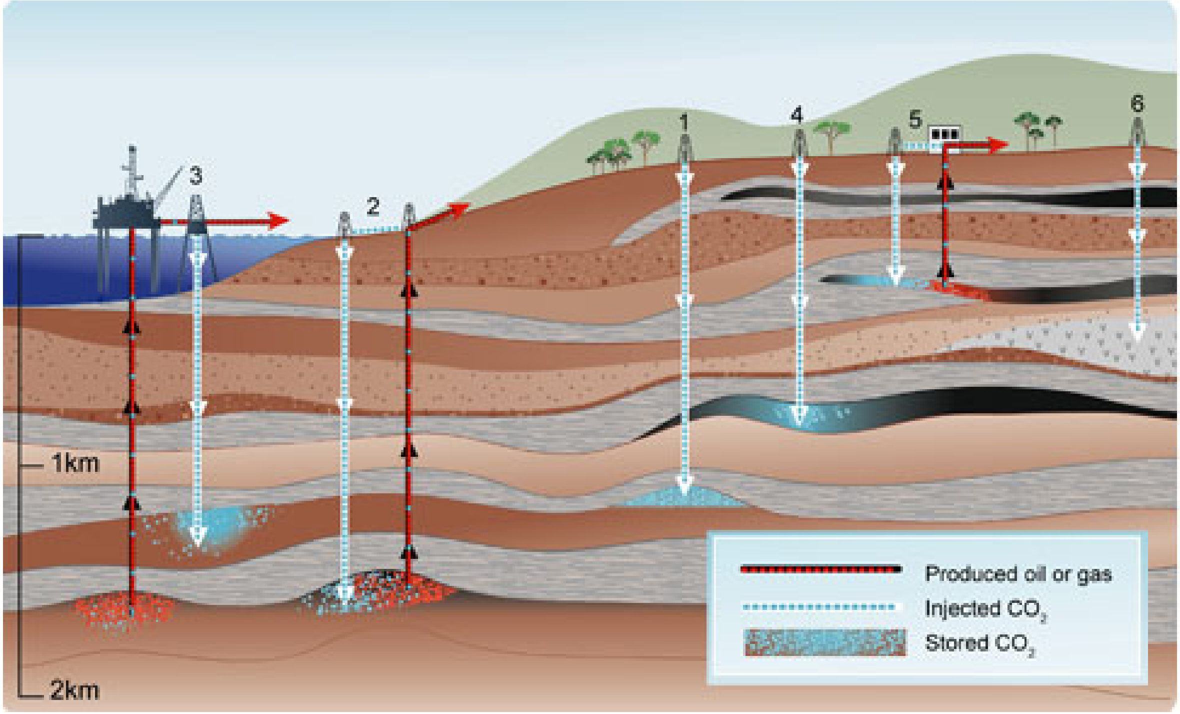


SOURCE: E.ON

The suitability of CCS is heavily dependent on the availability of appropriate conditions such as stable geological formations and transport measures.

In many cases, suitable geological sites for the storage of CO_2 will be some distance – perhaps thousands of kilometres – from the facilities where the CO_2 is produced and captured. Consequently transportation facilities will be required to move the CO_2 to its storage location. The CO_2 will normally be compressed to a supercritical state before transport by pipeline or ship. There are many pipelines transporting CO_2 for a variety of commercial purposes though the volumes of CO_2 from power plant CCS to be transported will be vastly greater than has been experienced to date.

The permanent storage of CO_2 on a large scale requires techniques and facilities that are capable of reliably and securely storing large volumes of CO_2 indefinitely. Geo-sequestration (where CO_2 is injected and stored in suitable subterranean geological structures) is currently the most favoured approach. Depleted oil and natural gas fields, which generally have proven geological traps, reservoirs and seals, are potentially excellent sites for storing injected CO_2.



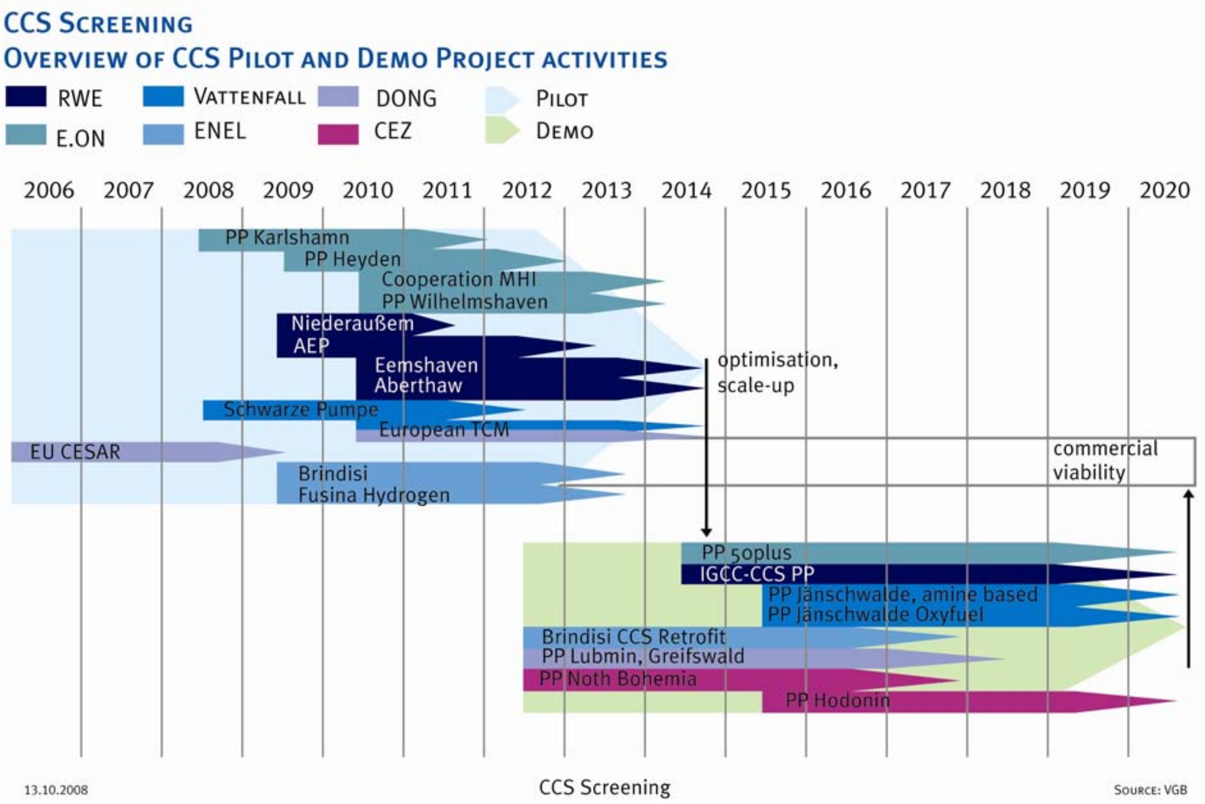
Source CES

To monitor the safe injection and storage of CO_2, a comprehensive monitoring and verification program, which includes a large range of subsurface, surface and atmospheric technologies is deployed. Technologies including geochemical and geophysical sensors that were developed by the oil, gas and waste storage industries are now being used to track the migration and trapping of CO_2. The ultimate fate of the stored CO_2 is dependent on the characteristics of the reservoir.

CCS technology development has been recognised by the electricity industry and governments in many parts of the world as holding the key to delivering a low emission future while still being able to utilise low cost and abundant fossil fuels for power generation.

The significance of carbon capture and storage technology has been acknowledged publicly by the G8 in the Leaders Declaration issued at the conclusion of the Hokkaido meeting in 2008 in which the Leaders noted that they - '…strongly support the launching of 20 large-scale CCS demonstration projects globally by 2010, taking into account various national circumstances, with a view to beginning broad deployment of CCS by 2020.'

While the individual technology elements of CCS systems are already available and demonstrated, this has occurred in other industries and for different applications. There has not yet been industrial scale demonstration or operation of CCS technologies for commercial power generation. Consequently there are significant research and development efforts being pursued in a number of countries. However it is unlikely that CCS will be commercially available for large-scale deployment before 2020.


CCS SCREENING
OVERVIEW OF CCS PILOT AND DEMO PROJECT ACTIVITIES
RWE
E.ON
VATTENFALL
ENEL
DONG
CEZ
PILOT
DEMO
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020
PP Karlshamn
PP Heyden
Cooperation MHI
PP Wilhelmshaven
Niederaußem
AEP
Eemshaven
Aberthaw
optimisation,
scale-up
Schwarze Pumpe
European TCM
EU CESAR
commercial
viability
Brindisi
Fusina Hydrogen
PP 50plus
IGCC-CCS PP
PP Jänschwalde, amine based
PP Jänschwalde Oxyfuel
Brindisi CCS Retrofit
PP Lubmin, Greifswald
PP Noth Bohemia
PP Hodonin
13.10.2008
CCS Screening
SOURCE: VGB

13. Nuclear Power Technologies

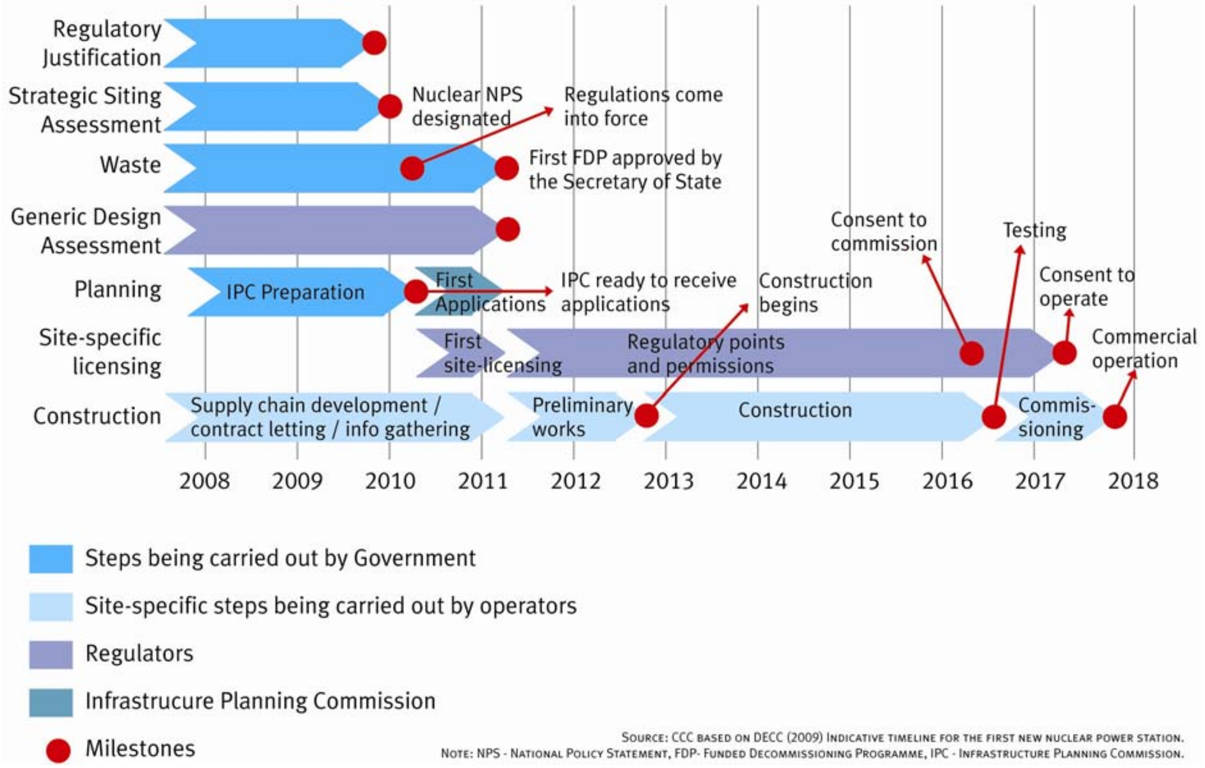
Around 16% of the world's electricity comes from 436 nuclear power stations in 30 countries with 372 GW of total capacity. This figure is projected to rise to 433 GW by 2030 mainly because of the increase in Asia, China, India, Japan and South Korea.

Sizewell A & B Power Station – Source British Energy

Nuclear power generation is an essential part of the portfolio of carbon-free power generation. Nuclear power has high capital costs but low running costs and high availability and is particularly suited for stable base-load generation.

The global distribution of uranium production enhances energy security with some fifteen countries producing concentrated uranium oxides. There are about 150-200 years supply of uranium available. Fast breeder reactors will extend this significantly.

Current plants typically have capacities of the order of 1,000-1,600 MW, and a lifetime of 40-60 years. Nuclear plants are capital intensive (overnight costs are generally about US$1,000-2,000/kW) and project lead times are relatively long (>5 years). There are large risks and uncertainties in both licensing and subsequent construction, operation, waste management and de-commissioning. Controlling costs is thus a key objective.



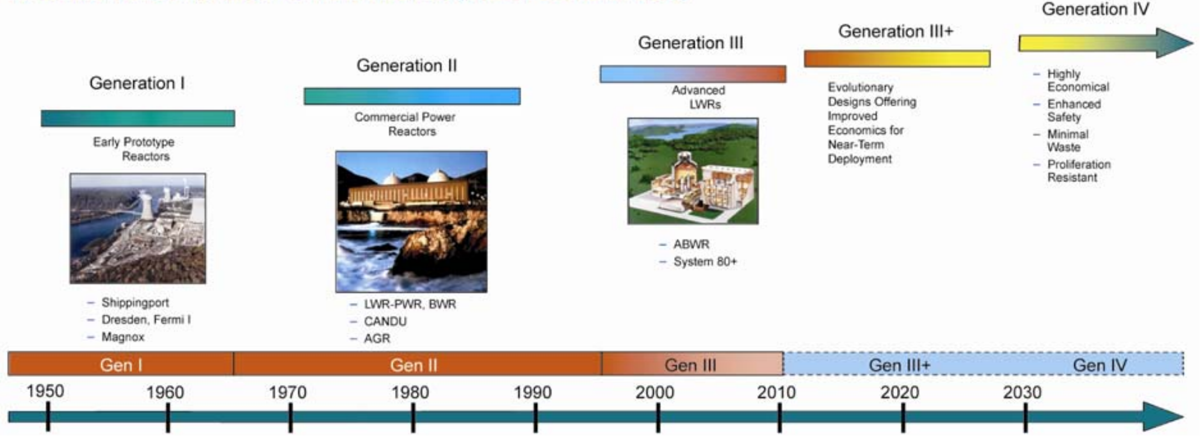
Source: CCC based on DECC (2009) Indicative timeline for the first new nuclear power station.

Note: NPS - National Policy Statement, FDP- Funded Decommissioning Programme, IPC - Infrastructure Planning Commission.

The wide range of nuclear technologies can generally be categorized into 4 generations:

- Prototypes and first reactors, developed in the 1950s and 1960s.
- 85% of today’s reactors are water-cooled Generation II reactors. Developed from the 1970s, they include light water, boiling water and heavy water reactors.
- Generation III reactors were designed after the Chernobyl accident in 1986, principally to improve safety and operability, and also to improve economic performance. A small number have been built or are under construction in East Asia, Europe, India and China. Pebble bed and prismatic high-temperature gas-cooled reactors are also being developed. Lying somewhere between Generation III and Generation IV, these would range from 150-200 MW while being much smaller and more modular.
- Generation IV is currently at the R&D stage.

NUCLEAR TECHNOLOGY GENERATIONS (VGB POWERTECH)



In the short term the intensive use and life extension of existing reactors is one of the quickest and most economical measures to optimise the contribution that nuclear power can make to emission reduction and energy security.

Intensive R&D is being undertaken into all aspects of the nuclear cycle, from mining uranium to the final decommissioning of plant with the objective of improving safety and waste management, decreasing costs and reducing proliferation risks.

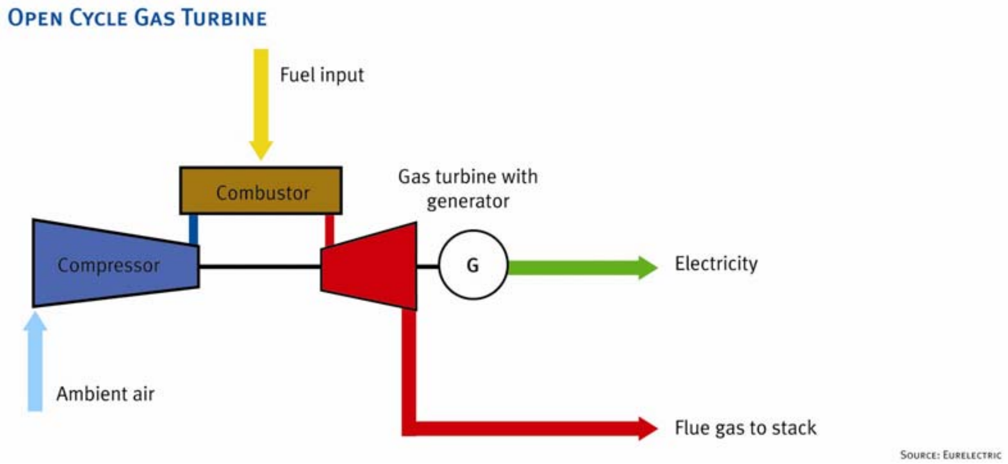
Perhaps more than any other electricity generation technology, nuclear power depends on public acceptability as well as economic competitiveness. The industry and independent regulatory authorities have been effective in improving performance and maintaining public confidence in the safe operation of nuclear plants. Nuclear power evokes a wide range of opinions from stakeholders and it is only through safe and economic performance over a period of time, coupled with transparency, public understanding and debate, that the nuclear industry can thrive.

14. Natural Gas Power Generation Technologies

Gas turbine technology has recently seen a tremendous rise in popularity for power generation, across the globe. This has resulted from a combination of factors, the most important being the rapid technological development, resulting in lower cost per kW of capacity installed, plus the deregulation of the power markets, which have favoured the technologies that are less capital-intensive and faster to build.

Gas turbines can be built to operate in open cycle or combined cycle modes. In the combined cycle mode the exhaust gas from the gas turbine is fed to a heat recovery boiler to raise steam to drive a steam turbine, electricity being generated from both turbines.

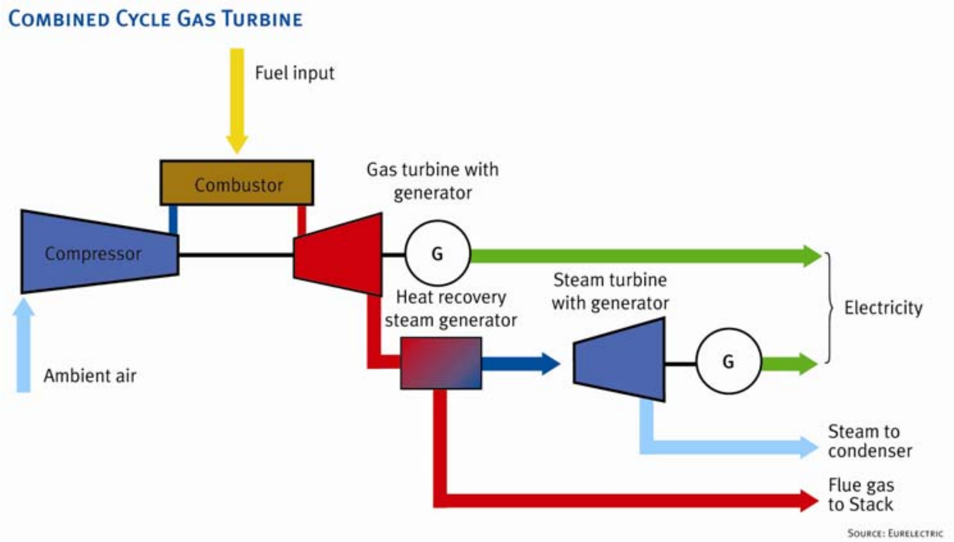
Gas turbines have long been used in open cycle mode for peak service in the power generation industry, where natural gas or distillate liquid fuels have been used, and where their ability to start and shut down on demand is essential. The present baseload efficiency for the basic open cycle gas-fired turbines can reach 39%. Development is underway to improve efficiency.



SOURCE: EURELECTRIC

In a Combined Cycle Gas Turbine (CCGT) the combination of two cycles makes it possible to obtain much higher efficiencies than with single cycle plants (gas turbine or water/ steam cycles).

More recently, as simple cycle efficiencies have improved and as gas prices have fallen, gas turbines have been more widely adopted for base load power generation, especially in combined cycle mode. CCGT power plant capacities are economically feasible from 100 MW, and can reach a size of 1000+ MW. Specific investment costs per kW installed reduce as the size increases.



This type of power plant is being installed in increasing numbers around the world where there is access to substantial quantities of gas (including liquefied natural gas - LNG). Efficiencies up to about 60% are possible for large new gas-fired stations. It is also possible to use steam from the boiler for heating purposes therefore such power plants can operate to deliver electricity alone or in combined heat and power (CHP) mode. During the past decade, gas-fired power generation has even replaced coal fired plants as the technology of choice for new and replacement power plant in many parts of the world. For example in Europe, CCGTs are forecast to rise to some 25% of Europe's installed capacity by 2020.

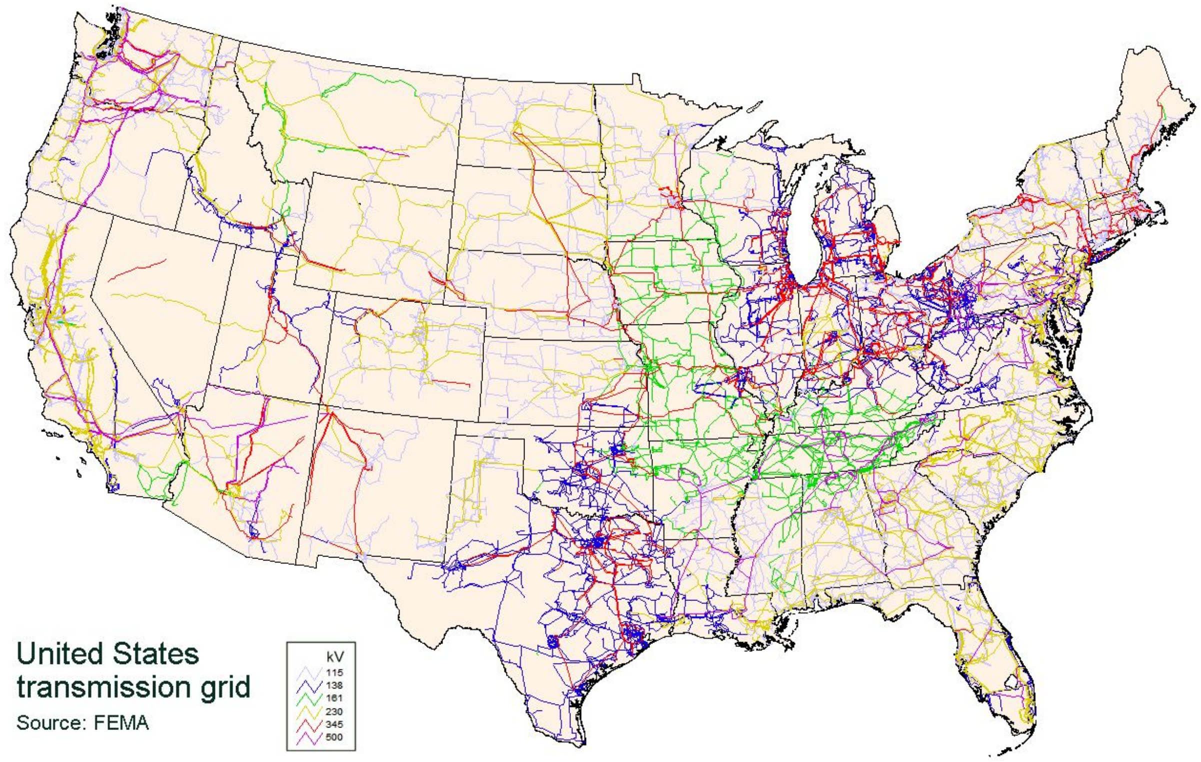
The investment cost of gas-fired power capacity is still regarded as being very competitive, as other technologies have also increased in cost. Uncertainty is linked to the level of future gas prices.

The use of new materials and multilayer ceramic coatings for gas turbines and improved blade cooling techniques allow higher gas turbine inlet temperatures and increase the efficiency of the combined cycle gas turbine process to figures above 60%.

In the future it is also feasible to fit CCGT plant with CO_2 capture and storage, which requires additional equipment. This will however only become economically competitive with significantly higher power prices than today, due to the reduction of plant efficiency. Therefore it is likely that CCGTs will continue to operate without CCS in the foreseeable future.

15. Networks Issues

Efficient electricity transmission and distribution systems are a fundamental requirement for providing an essential energy source and meeting the demands of the 21st century. The present grid networks were constructed and optimised to take advantage of the cost savings from large scale centralised power stations. The transmission grid plays an active role for grid management and balancing, while the distribution network has a passive role for bringing electricity to the end customer.


United States transmission grid

Source: FEMA

Climate change will have a significant impact on the operation and developments of the transmission and distribution networks of the electricity supply system. These changes will come from:

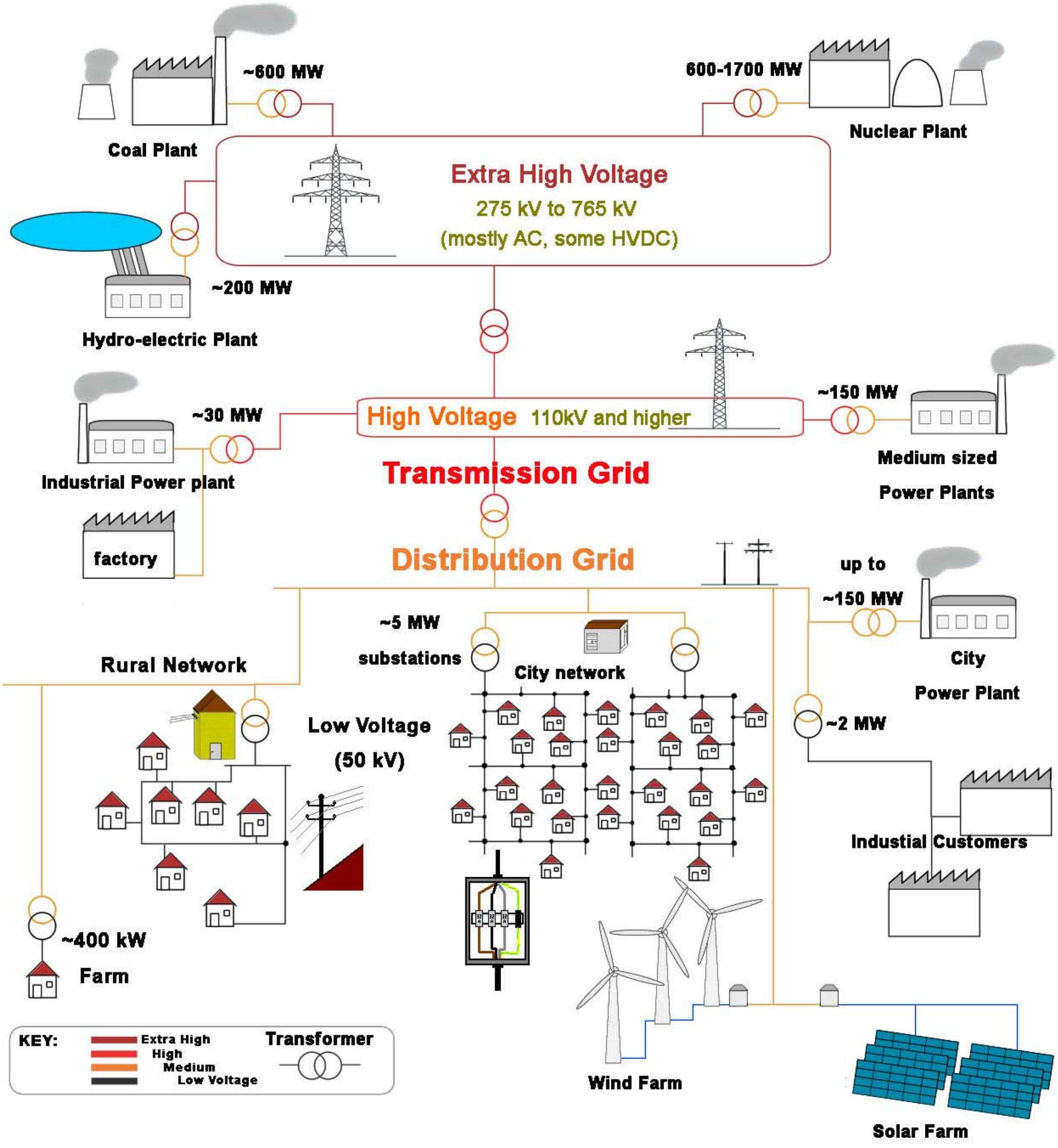
- the direct physical impact that climate change will have on infrastructure
- the impact that new and distributed generation technologies will bring
- changes in demand patterns
- smart grids and their contribution

Climate change will bring a number of negative impacts, including: sagging of conductors; de-rating of line capacity; increased risk of flooding and storm damage; extra cooling requirements for transformers and underground cables.

Increasing use of renewables, distributed generation, electric vehicles, etc will have significant implications for network operation.

With the increased interest in distributed generation and the availability of new technologies (e.g. smart meters), operation of the distribution system is becoming more important. Some analysts consider that the paradigm of centralised power supply will soon be overtaken by the rapid development of small and decentralised generation units.

Much of the energy generated today is produced by large-scale, centralised power plants using fossil fuels (coal, oil and gas), hydropower or nuclear power, with energy being transmitted and distributed over long distances to consumers. In this paradigm, power flows only in one direction: from the central power station to the network and to the consumers.

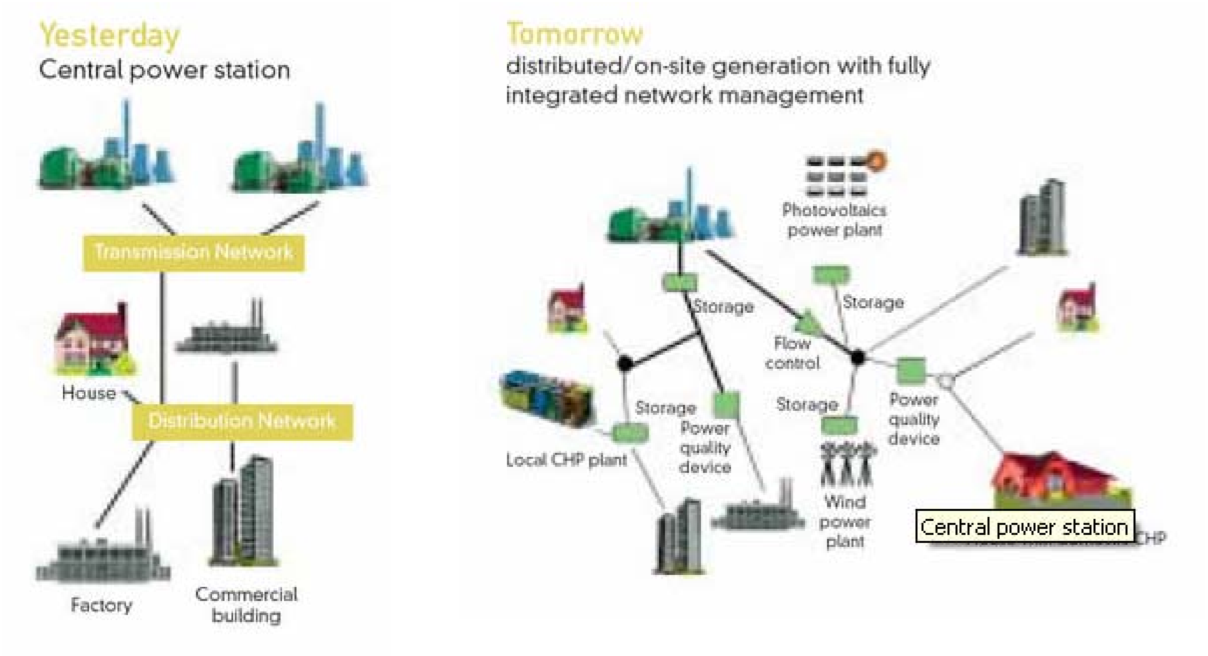


Source: EPRI

There are a number of drawbacks to such a system, such as the high level of dependence on imported fuels, the environmental impact of greenhouse gases and other pollutants, transmission losses and the necessity for continuous upgrading and replacement of transmission and distribution facilities.

In contrast, in a power system composed of distributed energy resources, smaller amounts of energy are produced by numerous small, modular energy conversion units, which are often located close to the point of end use. These units can be stand-alone or integrated into the electricity grid.

The models for the future architecture of electricity systems recognise the fundamental fact that with increased levels of distributed generation the distribution network can no longer be considered as a passive appendage to the transmission network - the entire system has to be designed and operated as an integrated unit. A number of conceptual models have been envisaged, all of which could have application depending on geographical constraints and market evolution.



Source Eurelectric

Both the transmission and distribution segments will need tremendous investments in the next decades. Transmission grids must be reinforced and extended, inter alia to transport increasing volumes of off-shore windpower. The distribution network will need to integrate decentralised generation and electric vehicles into the system. Both distribution and transmission grids will have to facilitate balancing of intermittent renewable power sources. The appearance on the market of new electricity applications, such as electric vehicles and efficient electric heat pumps for spatial heating and cooling, will offer new opportunities for balancing intermittent power sources.

Using a combination of software and hardware to enable more efficient power routing and allow consumers to better manage their demand is a part of the essence of ‘smart’ grids. Such grids will benefit customers, suppliers, grid operators and society as a whole. An advanced smart metering infrastructure offers the possibility for additional energy related services such as demand side management and realisation of virtual power plants.

16. Conclusions

The Fourth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC) indicated that, in order to stabilise atmospheric CO_2 emissions within the crucial threshold of a 2^0C rise, global emissions would have to fall by 50% on current levels and that the OECD countries would have to reduce their emissions by 60-80%. This implies that the OECD power sector would have to be the major contributor to a low- carbon society by 2050.

The analysis has shown that it is possible to deliver low-carbon power by 2050:

- through intelligent and efficient electricity generation, transmission, distribution and use
- with intelligent electricity use as the driver for a secure, low-carbon energy future
- at a lower long-term total energy cost than under a business as usual scenario
- provided that policy action, according to national circumstances, is taken to incentivise very substantial investment in:
  - large-scale uptake of renewable energies, deployment of carbon capture & storage technologies and nuclear power
  - ‘smart’ grids and networks
  - roll-out of electric road vehicles, heat pumps and other efficient electro-technologies
  - widespread energy efficiency in our economy and society

However there will be limited emission reductions before 2020, with the major reductions occurring in the 2025–2040 period, which means that the current political timeframe lacks recognition of the critical timing for commercial deployment of the required low-carbon technologies.

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