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## Impacts of GHG Programs and Markets on the Power Industry

This Chapter provides an overview of the global responses to Climate Change (CC) and of the established and emerging GHG Markets and Programs arising from this. The impacts on the electrical power industry and how it is taking advantage of these programs and markets and adapting to CC is discussed. This includes the impacts on policy, strategy and decision-making in major players such as governments, manufacturers, utilities, contractors and consultants and how they are leading by example within their own operations..

### 15.1 Introduction

Global response to CC is well established and growing daily due to international initiatives such as the Kyoto Accord and the more recent Asia Pacific Partner Ship (APP) Climate Pact which the USA and Australia developed with a group of key Asian countries, notably China and India and which now includes Canada. International negotiations for the post Kyoto period got underway in Bali in December 2007 and a decision was reached to adopt the "Bali road map" for a future international agreement on CC. There are also many programs and initiatives at national, state and regional levels to monitor, record and reduce Greenhouse Gas (GHG) emissions. An effective tool or mechanism to accelerate the achievement of cost effective GHG targets is the concept of emissions trading or transfers among participants [1]. Essentially this involves treating GHG emission allowances and reduction/removal credit units like any other commodity in the marketplace. Arrangements are made for them to be traded on national and international exchanges. The marketplace sets the value of GHG emission credit units. These are bought and sold by countries and companies to facilitate meeting their GHG targets at lowest cost.

The main established markets for trading GHG credits and allowances are the European Emission Trading Scheme (ETS), the Chicago Exchange (CCX), the New South Wales Trading System in Australia and the International Emissions Trading (IET) scheme established as part of the flexibility mechanisms of the Kyoto Accord. There are many other markets and programs under development such as the Carbon Trust, the Regional GHG Initiative (RGGI) in North-east USA (discussed in section 4.); and the California Climate Action Registry CCAR).

### 15.2 International Response To Climate Change: An Overview

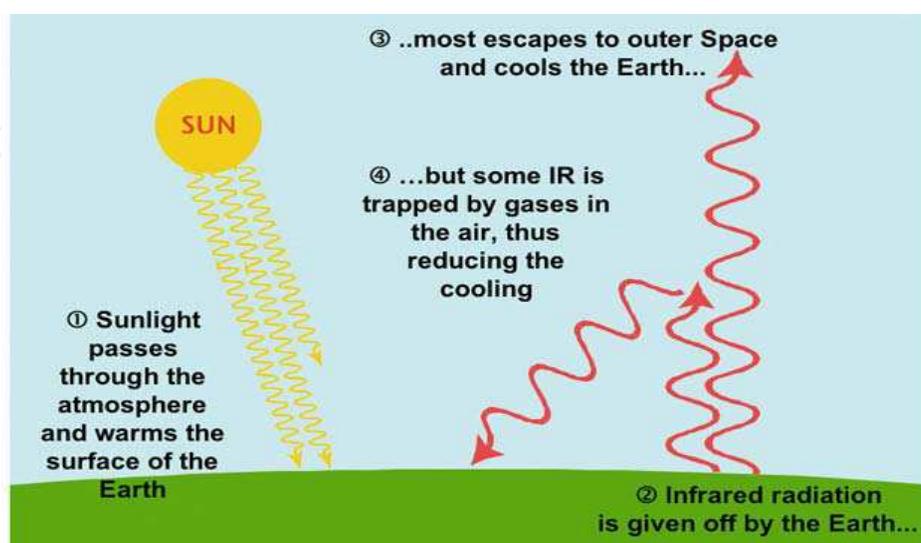
Access to modern forms of energy is fundamental to development and the eradication of poverty in the developing world, but energy is also responsible for much of the Greenhouse Gas (GHG) emissions that threaten stability of the climate system. Therefore the goal of GHG reduction efforts is not to deny people access to energy, but to reduce the carbon intensity of development and to moderate and stabilize the concentrations of GHGs in the

atmosphere through a less carbon intensive energy supply, increased efficiency of energy use, improved carbon sinks and the capture and storage of carbon emissions at source. As different approaches to achieve this goal are carefully evaluated and international negotiations continue, most countries have implemented programs that promote research, tracking and reporting on carbon emissions, voluntary mitigation and adaptation measures, energy efficiency and renewable energy technologies. However, with the exception of a handful of European countries that have implemented some form of carbon/energy tax, governments have not banned or placed restrictions on fossil fuels or CO<sub>2</sub> emissions.

Efforts to reduce carbon-intensity of energy supply generally focus on increasing the efficiency of power plants and promoting low-carbon fuels and renewable energy (wind, solar, hydro, geothermal, etc.). Efforts to reduce energy use typically promote energy efficiency and conservation in the industrial, commercial, transport and residential sectors. Efforts to encourage improved management of agricultural and forest lands and the protection of forests tend to enhance the Earth's natural capacity to assimilate carbon and mitigate the impact of CO<sub>2</sub> emissions. Efforts to capture and store carbon emissions at source are focusing on coal fired power plants – so-called clean coal technology. An overview of international efforts to reduce the impact of GHG emissions through mitigation and climate adaptation programs is now presented [15.2.1 to 15.2.8].

### 15.2.1 Greenhouse Gases and Climate Change

The gases responsible for the strong atmospheric absorption of infrared radiation are called Greenhouse Gases (GHGs). The Greenhouse effect is illustrated in Figure 15.1. Water vapor and CO<sub>2</sub> are the most important GHGs and are responsible for the bulk of greenhouse warming. Both water vapor and CO<sub>2</sub> are naturally occurring as are other GHGs including methane, nitrous oxide, and ozone. Human activities, however, add to the levels of most of these naturally occurring gases, and are the sole source of other powerful classes of GHGs, including chlorofluorocarbons (CFCs), hydro fluorocarbons (HFCs) and per fluorocarbons (PFCs), among others.

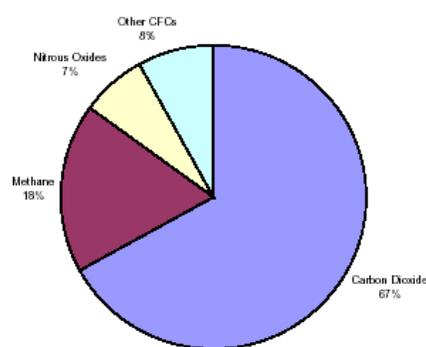


Source: Met Office Hadley Centre

Figure 15.1. The Greenhouse Effect

GHGs generally persist for long periods in the atmosphere. While many conventional air pollutants may persist in the atmosphere for only a matter of hours or days, many important GHGs persist for decades or even hundreds of years. For example, CO<sub>2</sub> has an estimated mean atmospheric persistence of 300 years and some CFCs may persist for as long as 400 years. As a result, these gases accumulate, become very well mixed in the atmosphere and have a global impact that is mostly independent of where they were emitted. GHG persistence has significant policy implications because the gases we emit today may impact the climate system for hundreds of years.

Greenhouse Gas Emissions by Relative Contribution to Global Radiative Forcing (1991)



Source: Greenhouse Gas Assessment Handbook, World Bank 1998

Figure 15.2. The contribution of selected Greenhouse Gases to Greenhouse Warming

GHGs differ in their ability to absorb infrared radiation. Among the most infrared radiation-absorbent are the CFCs, HFCs and PFCs. Other powerful GHGs include nitrous oxide and methane. For example, a molecule of CFC-12 is 15,800 times, CFC-11 is 12,400 times, nitrous oxide is 270 times and methane is 21 times as effective in absorbing infrared radiation as a molecule of CO<sub>2</sub>. However, because atmospheric concentrations of these compounds are much less than concentrations of CO<sub>2</sub>, they play a lesser role in greenhouse warming and CC. Figure 15.2 depicts the relative contribution to greenhouse warming of various GHGs when both their radiation absorbing characteristics and their relative concentration are considered. This excludes the effect of water vapour which is a major natural contributor to global warming. There is however a feedback effect of warming due to GHG emissions from human activity as warmer air can hold more water vapour. Increased water vapour also reflects more solar radiation and the net overall effect is not yet fully understood.

Carbon dioxide and other atmospheric GHGs absorb infrared radiation and create a natural greenhouse effect that warms the Earth. The natural greenhouse warming of the atmosphere keeps the Earth approximately 33°C warmer than it would be without an atmosphere. Humans have been emitting increasing quantities of these GHGs and now emit over 25 billion tons of CO<sub>2</sub> equivalent annually. Atmospheric CO<sub>2</sub> concentrations are now at their highest levels in more than 160,000 years. There is a scientific consensus that these steady additions of GHGs have begun to impact our climate and very likely may be the dominant force driving recent warming trends (see Figure 15.3). Solar cycles and oceanic currents are among the other factors that impact global climate.

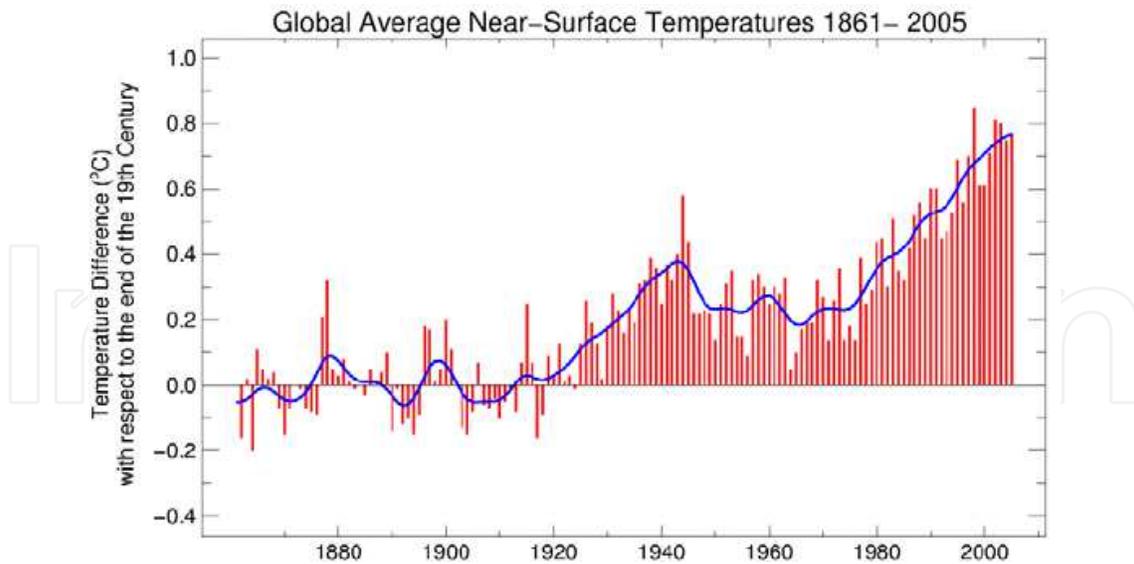
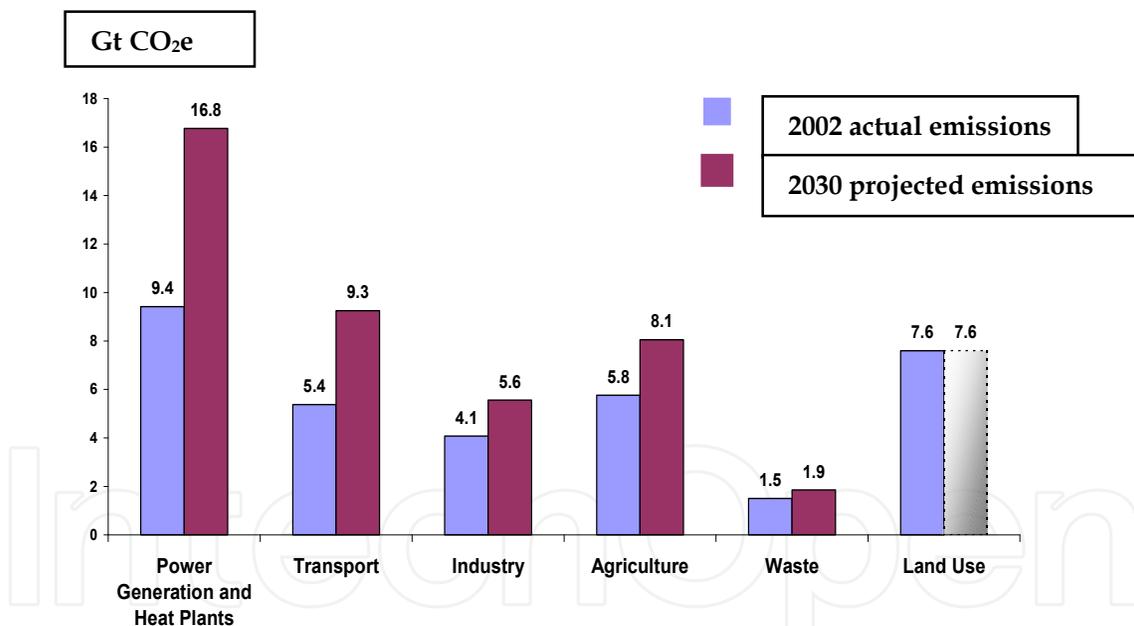


Figure 15.3. Global Average Near Surface Temperatures

As shown in Figure 15.4, global emissions are forecast to grow from all sources – transport and power generation growing fastest.

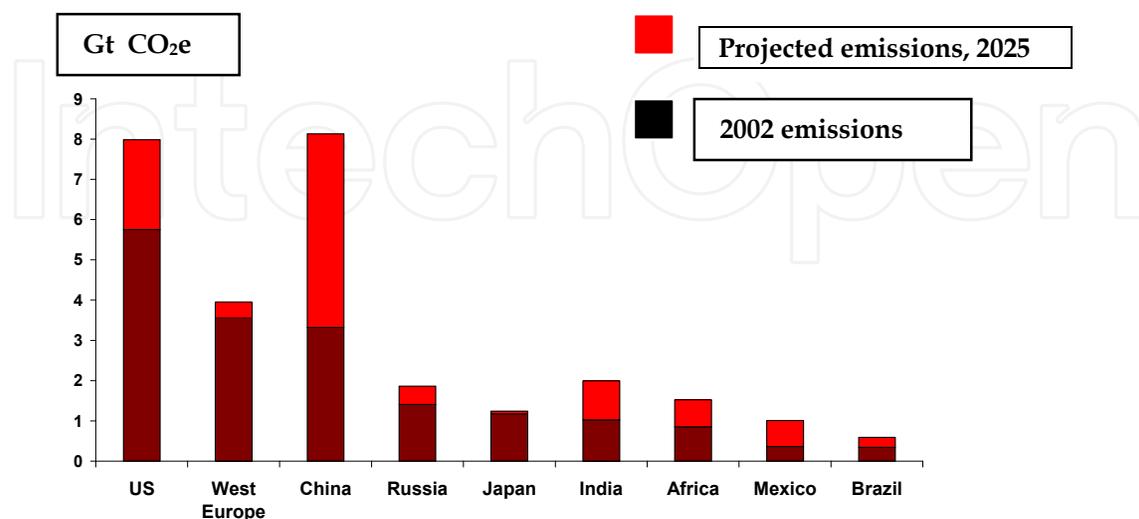


Source: Hadley Centre for Climate Prediction and Research Based on Folland et al (2000) and Jones and Moberg

Figure 15.4. Forecast growth in GHG emissions by Sector

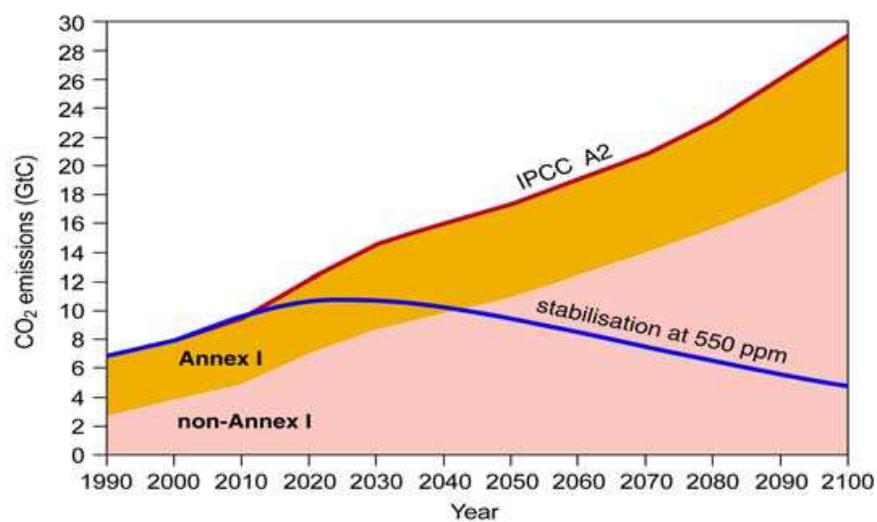
Current emissions per capita are highest in the developed nations, the USA being highest at 20 tonnes of CO<sub>2</sub> per capita per year. However the larger fast-growing developing countries such as China and India account for much of the forecast growth in CO<sub>2</sub>e emissions (see Figure 15.5). By 2025 China will be emitting GHGs at the same level as the USA. Thus the developed and developing nations must both be part of the solution and action must be

taken urgently if we are to stabilize CO<sub>2</sub> emissions at 550 ppm or lower (see Figure 15.6). Stabilization at 550 ppm is projected to limit global temperature rise to 2°C during the 21<sup>st</sup> Century. The Stern Review Report has estimated that this will require a 60% reduction in emissions from the energy sector by 2050 (see [www.sternreview.org.uk](http://www.sternreview.org.uk)).



Source: World Resources Institute, CAIT Energy Information Administration Reference Scenario, Energy emissions only.

Figure 15.5. Forecast GHG emissions by major developing nations compared to US & Europe



Source IPCC

Figure 15.6. Depiction of CO<sub>2</sub> emission reductions required to stabilize at 550ppm

### 15.2.2 Major Impacts on Power Systems

Some of the major impacts that CC will have on the power industry and systems include:

Rising average and peak air, ground and water temperatures and variable river water flows

- Impact on equipment/plant ratings and power system security
- Changes to seasonal demand patterns and peaks
- Impact on reserve margins and reliability of supply.

#### Extreme weather events (eg hurricanes)

- Increased risk to generation, delivery systems (Transmission and Distribution (T&D), telecommunications, and System Control Center reliability)
- Emergency response and restoration needs and costs increased
- Need for improved extreme weather advance warning systems.

#### Forest Fires & Floods

- Increased risk to generation and delivery (T&D) infrastructure with impacts on reliability and costs.

#### Rising sea levels

- Risk to coastal generation and delivery systems (T&D) infrastructure and populations

There is a need to monitor and record these climate changes and impacts in order to establish sound databases on which to base the design and implementation of appropriate response and adaptation measures.

### **15.2.3 Major Global Programs**

We will now take a look at some of the major programs and initiatives by the international community to mitigate and adapt to CC.

#### **15.2.3.1 Kyoto protocol**

The Kyoto Protocol developed by the UN Framework Convention on Climate Change (UNFCCC) was signed in December 1997 after two years of debate and negotiation about the inadequacies of the UNFCCC and its voluntary mechanisms and the need for more meaningful requirements. Much of the impetus for the Protocol came from the Intergovernmental Panel on Climate Change's (IPCC) Second Assessment Report which concluded that "the balance of evidence suggests a discernible human influence on global CC." The Kyoto Protocol commits developed countries which have signed the protocol to legally-binding emission reduction targets for six greenhouse gases - carbon dioxide, methane, nitrous oxide, hydro fluorocarbons, per fluorocarbons, and sulfur hexafluoride -- to be reached by the period 2008-2012. (CFCs are controlled under the Montreal Protocol.) These targets, which range by country from -8% to +10%, provide for a 5% emissions reduction from 1990 levels in aggregate.

With ratification of the protocol by Russia in the fall of 2004, the required level of "55% of developed country emissions" was reached and the protocol officially came into force on February 16, 2005. The Issue of the IPCC Fourth Assessment Report in 2007 strengthened the case for reducing GHG emissions.

#### **15.2.3.2 Intergovernmental panel on climate change (IPCC)**

IPCC was established by the World Meteorological Organization (WMO) and United Nations Environmental Programme (UNEP) in 1988. It is open to all members of the UN and WMO. Its objective is:- "to assess scientific, technical and socio- economic information relevant for the understanding of CC, its potential impacts and options for adaptation and mitigation."

The IPCC produces Assessment Reports, Technical Papers; and Supporting Material. The Fourth assessment reports for Working Group I and Working Group II were issued in early 2007. They concluded that GHG forcing has *very likely* caused most of the observed global warming over the last 50 years. This strengthened the scientific evidence for anthropogenic global warming and the case for increasing adaptive capability to cope with the CC already occurring. The latter is particularly important for the poorest developing countries which will be hardest hit by CC and have the least capability to adapt.

### 15.2.3.3 Asia Pacific partnership on clean development and climate (APP)

The Asia-Pacific Partnership (APP) on Clean Development and Climate is an innovative new effort to accelerate the development and deployment of clean energy technologies. APP Partner Countries Australia, Canada, China, India, Japan, Republic of Korea, and the United States have agreed to work together and with private sector partners to meet goals for energy security, national air pollution reduction, and CC in ways that promote sustainable economic growth and poverty reduction.

APP was announced by President Bush on July 27, 2005. The initial six countries were Australia, China, India, Japan, Republic of Korea & USA which together are responsible for about 50% of world GDP and CO<sub>2</sub> Emissions. Canada joined in 2007. The objective of APP is:- "To focus on practical measures to create new investment, build local capacity and remove barriers to the introduction of clean, more efficient technologies to improve national energy security, reduce pollution and address long term CC." The major power industry priorities are clean energy & high efficiency.

APP held their first meeting in January 2006 in Sydney, Australia. At this meeting a Work Plan was developed and eight Task Forces were setup with a focus on the power sector and energy intensive industries. This included:-

- Cleaner fossil energy
- Renewable energy technology and distributed generation
- Power generation and transmission efficiency (supply-side efficiency)
- Steel; Aluminum; Cement; and Coal mining
- Buildings and appliances (demand side efficiency).

The Task Forces will build on existing initiatives.

India hosted the second APP meeting in October 2007. Examples of APP successes include:

New Energy Efficiency labels used in China, similar to those in the U.S. ENERGY STAR program, are expected to encourage Chinese consumers to use more energy efficient appliances. This APP coordinated activity is projected to bring about an annual carbon emission reduction of 17.7 million tons of CO<sub>2</sub>, the equivalent of removing three million cars from the road for just one appliance, television set-top boxes.

- Solar Turbines, an APP private sector partner, has worked with Chinese partners to identify and setup units that provide 35 megawatts of clean energy technology to the

coking industry in China. Initial projections indicate an annual savings of approximately 410,000 metric tons of CO<sub>2</sub> equivalent when all units are operational.

#### 15.2.4 Other Programs and Initiatives

There are many other programs and initiatives at the regional, national, state/province and individual company/entity level. We consider the North American scene in the following and the UK Stern Review is noteworthy as it looks at the economics of CC both UK and global. Clinton's Large Cities Climate Leadership is also noteworthy - grass roots action in 22 cities.

##### 15.2.4.1 Other programs and initiatives

Federal policies are driven by economy concerns, but the GHG lobby is pushing hard.

States are showing leadership in developing regulations and setting GHG reduction targets:

- NJ; MA; NY; NH; ME; CA have set reduction targets
- North-east US Initiative (RGGI and RGGR) (see Section 15.4. of this Chapter)
- Western Governors Alliance developing GHG policies
- The California Assembly passed the Global Warming Solutions Act (Assembly Bill 32) on August 30, 2006 and a companion bill for the electricity sector (Senate Bill 1368) which sets power plant emission performance standards
- Many states adopting Renewable Portfolio Standards (RPS) (see Section 15.4.2, and Energy Efficiency (EE) Programs).

There are several independent voluntary programs by Business, Individuals, and NGOs

##### 15.2.4.2 Canada

The Conservative Government in Canada is developing a "Made in Canada" Plan. Canada has ratified the Kyoto Protocol but economic analysis shows that meeting Kyoto targets cannot be done without major impact on the economy (recession). Large industry emission reduction targets are expected with provision for "offsets". The focus is on technology solutions. For example The Early Actions Measures (TEAM) program has invested in leading edge projects. Also energy efficiency, renewable energy technologies, clean coal with carbon capture and storage, nuclear and hydrogen are priorities. Through Kyoto, Canadian entities have access to the Kyoto mechanisms of CDM & JI (see Section 15.2.6 for details).

##### 15.2.4.3 Stern review report main conclusions

Doing nothing is not an option; action must be global, prompt and strong and we must mitigate and adapt. As already mentioned, the target **for the energy sector** is a 60% reduction in CO<sub>2</sub> emissions by 2050 to stabilize at 550 ppm (see [www.sternreview.org.uk](http://www.sternreview.org.uk)). The global economic impact is manageable "we can grow and be green". An important priority is to increase the adaptive capability of the poorest developing countries that will be hit earliest and hardest by CC and are least able to cope.

### 15.2.5 Renewable Energy

Renewable energy projects, particularly wind, small hydro and solar, offer compelling environmental advantages when compared to conventional fossil fuel-based power generation, including little or no conventional pollutant and GHG emissions. Renewable energy projects face serious challenges competing with conventional fossil fuel-fired power projects. They have achieved only limited success in the marketplace.

One of the most significant challenges facing renewable energy projects is the subsidy given by many governments to conventional forms of energy. Another challenge facing renewable energy development is the remote, decentralized nature of many renewable energy projects.

The wind industry now has a global installed capacity of over 50,000 MW and is growing at 35 to 40% per year. In 2006, for the first time, more new wind capacity was brought on line than nuclear power. The solar photovoltaics industry, which is now a \$1 billion industry, is growing at 30% per year. The potential of renewables has not escaped the big conventional energy companies, including BP Amoco, ABB, GE, Enron and others, all of which have made considerable investments in the renewable sector. For example BP's alternative energy investments are valued at up to \$7 billion. GE is investing heavily in its Ecomagination program launched in 2004. This is GE's commitment to imagine and build innovative solutions that solve today's environmental challenges such as climate change and benefit customers and society at large. The target investment in renewable energy is \$6 billion by 2010. (See: <http://ge.ecomagination.com/site/index.html>)

### 15.2.6 Emissions Trading

An effective tool or mechanism to achieve cost effective GHG reduction targets is the concept of emissions trading or transfers among participants. Essentially this involves treating GHG emission allowances and reduction/removal credit units like any other commodity in the marketplace. Arrangements are made for them to be traded on national and international exchanges. The marketplace sets the value of GHG emission credit units. These are bought and sold by countries and companies to facilitate meeting their GHG targets at lowest cost. For this to work, just like any other commodity, there must be internationally accepted standards or a "common currency" for the measurement, monitoring, reporting, verification and certification of emission credit units [1]. The effectiveness of emissions trading schemes has been proven by the success of trading in acid rain gases (SO<sub>x</sub> and NO<sub>x</sub>) in curbing acid rain in North America. GHG trading schemes in the UK and Europe are already showing successful results for reducing CO<sub>2</sub> emissions ( see: <http://www.defra.gov.uk/environment/climatechange/trading/eu/operators/compliance.htm>. and: <http://ec.europa.eu/environment/climat/emission.htm>

#### 15.2.6.1 Emerging GHG markets

GHG markets can currently be split into two categories:

- The Kyoto compliant market
- The non-Kyoto compliant market.

The bulk of the current global activity in GHG trading is centered on the Kyoto compliant market. Developed countries, which have ratified the Kyoto Protocol and accepted their GHG emission reduction target, termed Annex 1 countries, may meet their commitments through domestic CC policy activity and the use of the Kyoto mechanisms. These "flexibility" mechanisms are Joint Implementation (JI); Clean Development Mechanism (CDM) and International Emissions Trading (IET).

Both JI and CDM are "project based mechanisms" and involve carrying out CC mitigation projects for the reduction or removal of GHG emissions. JI projects allow Annex I Parties to implement projects that reduce GHG emissions by sources, or enhance removals by "sinks", in the territories of other Annex I Parties, and to credit the resulting emission reduction units (ERU) against their own emission targets. CDM projects allow Annex I Parties to implement projects that reduce or remove GHG emissions in developing countries. Annex I Parties may use certified emission reductions (CER) generated by CDM projects in developing countries to contribute to compliance with their GHG emission commitments. The rules governing the CDM are available at: <http://cdm.unfccc.int/> and those for JI projects are expected to be similar - see <http://ji.unfccc.int/index.html>. IET permits an Annex I Party to transfer (sell) part of its assigned GHG emission allowance (the amount of emissions the Party may emit during the commitment period) to another Annex I Party. It also permits trading of CERs and ERUs - see following web-site for background and rules: [http://unfccc.int/kyoto\\_protocol/mechanisms/emissions\\_trading/items/2731.php](http://unfccc.int/kyoto_protocol/mechanisms/emissions_trading/items/2731.php).

Canada's Clean Development Mechanism and Joint Implementation (CDM & JI) Office was established within the Climate Change and Energy Division of the Department of Foreign Affairs and International Trade (DFAIT) in 1998. The Office is the federal government's focal point for CDM and JI activities. It was created to enhance Canada's capacity to take advantage of the opportunities offered by the CDM and JI. Opportunities for Canadian industry can include: (i) generation of emission reduction credits; (ii) access to new markets and investment opportunities; (iii) an opportunity to demonstrate the viability of a voluntary approach; (iv) a showcase for environmental leadership. The services provided are aimed at reducing transaction costs for Canadian companies given the elaborate steps and procedures for these mechanisms.

The main non-Kyoto compliant markets are the UK Emission Trading Scheme (UK-ETS), the European Union-Emission Trading Scheme (EU-ETS), the Chicago Climate Exchange, and the New South Wales Trading System. The UK-ETS was launched in 2002 and was the world's first national economy wide GHG trading scheme. It is essentially a cap and trade scheme open to all entities in the UK, including 6,000 companies that already had CC Agreements. Full details of the scheme and results to date can be found on the web-site of the UK Department of Environment, Food and Rural Affairs (DEFRA) at:

<http://www.defra.gov.uk/>. See the following web-site for a full report on 2006 results:-

<http://www.defra.gov.uk/environment/climatechange/trading/eu/operators/compliance.htm>

In 2003, the New South Wales (NSW) Government in Australia introduced an emissions trading scheme building on an existing emissions benchmarking program in connection with electricity retailer licensing conditions. The benchmark system requires electricity

retailers to reduce annual emissions from 8.65 to 7.27 tonnes CO<sub>2</sub>e per capita. All six GHGs expressed as units of one tonne of CO<sub>2</sub> are covered. They can achieve their targets by offsetting their liability with credits created from renewable energy and low emission generation, tree planting and energy efficiency. The system operates with a financial penalty of up to, but not higher than, AUS\$15 (about US\$8.5) per tonne of excess tonne CO<sub>2</sub>e emitted.

The EU-ETS was launched in January 2005 and trades in EU Allowances (EUA) are already taking place. In this scheme each regulated entity in the scheme is assigned an “allowance” or amount of GHG it is permitted to emit. Entities may buy surplus allowances from other entities to meet their CO<sub>2</sub> commitments. The EU scheme may also be linked with the Kyoto CDM and JI project mechanisms. Details of the EU-ETS may be found at: <http://ec.europa.eu/environment/climat/emission.htm>. This includes reports on results to date and plans for the future of the scheme.

Although the former Presidential Administration in the U.S. did not seek ratification of the Kyoto Protocol, American companies are pursuing voluntary programs to reduce greenhouse gas emissions. Many are turning to emissions trading as a means of making reductions in their overall greenhouse gas emissions profile. Tradable units are Verified Emission Reductions (VERs) and have been trading since 1999. California and other West Coast states as well as Northeastern states are now entering the carbon constrained world through government mandates. Nine Midwestern states are also moving in this direction. In two years, it is highly likely the US Federal Government will mandate economy wide greenhouse gas emissions reductions that will focus on reducing the US carbon footprint of over 6 billion tons

Typical prices in voluntary GHG markets range from \$1 to \$10 per tCO<sub>2</sub>e and the EU market has ranged as high as \$30 per tCO<sub>2</sub>e. Latest information on GHG market prices can be obtained by registering at the web-site of the Evolution Markets LLC: <http://www.evomarkets.com>

### **15.2.7 Mitigate and/or Adapt**

While programs to reduce/remove GHGs will help mitigate the extent of change in global climate, there is still a need to adapt to the changes that have already occurred and may occur in the future. Thus adaptation programs are equally important to mitigation programs and there are many national and international initiatives for the assessment of CC variability and impacts and associated adaptation measures. An internet search for the term “adapting to CC” gives over 20,000 hits which is a measure of the global, extensive interest in this topic.

The Government of Canada Conference on Adapting to CC held in Montreal in May 2005 covered the following key topics which is indicative of the global scope of CC impacts: Coastal Zones; Forestry and Forest Ecosystems; Infrastructure; Communities; Industry; Engineering; The Arctic; Health and Vulnerable Populations; Tourism; Regional Water Impacts: Physical and Social Health Impacts; Agriculture; Water Resources Management; Fish and Aquatic Resources. There were also general sessions on Risk Management; Hazards and Extremes; Research Programs and Tools; Adaptive Capacity; Economics; Education and Awareness; and Taking Action on Adaptation.

The financial and insurance industries are particularly interested in the risks and impacts associated with CC. Reference [6] provides an overview of risks to the financial sector and stresses the need for international collaboration and research. Reference [7] provides the perspective of the insurance industry.

The IPCC Fourth Assessment Report Working Group II Report "Impacts, Adaptation and Vulnerability" has Chapter 18 discussing the inter-relationships between mitigation and adaptation measures and the trade-offs between the two. See: <http://www.ipcc.ch/ipccreports/ar4-wg2.htm>

Striking the balance between mitigation and adaptation investments is an exercise in risk management. Focusing on technology measures for adapting to CC that has and may continue to occur is strategically important in managing those risks. Because of the complexities and considerable uncertainties in CC science and predictions, investment in adaptation measures to manage climate risks may prove to be of better value and have more certain, tangible benefits than CC mitigation (GHG reduction) measures. This is particularly important for the poorest developing countries which are least able to adapt and would be hardest hit. The risks of not developing the economies of these countries (that requires energy development as a critical driver) is far greater than the risks of CC. The human race has shown a great ability and propensity to adapt to climate circumstances beyond its control.

Figure 15.7 illustrates a classic cost/risk minimization approach to mitigation and adaptation. The mitigation curve is characterized by rapidly increasing costs and risks to the global economy the lower the target for CO<sub>2</sub>e concentrations in the atmosphere. The adaptation curve is characterized by rapidly increasing costs and risks to the climate and the global economy the higher CO<sub>2</sub>e concentrations are permitted to go. The sum of the two curves gives a range of CO<sub>2</sub>e concentrations for minimizing cost and risk. This is estimated by some researchers to be in the range of 450 to 550 ppm of CO<sub>2</sub>e.

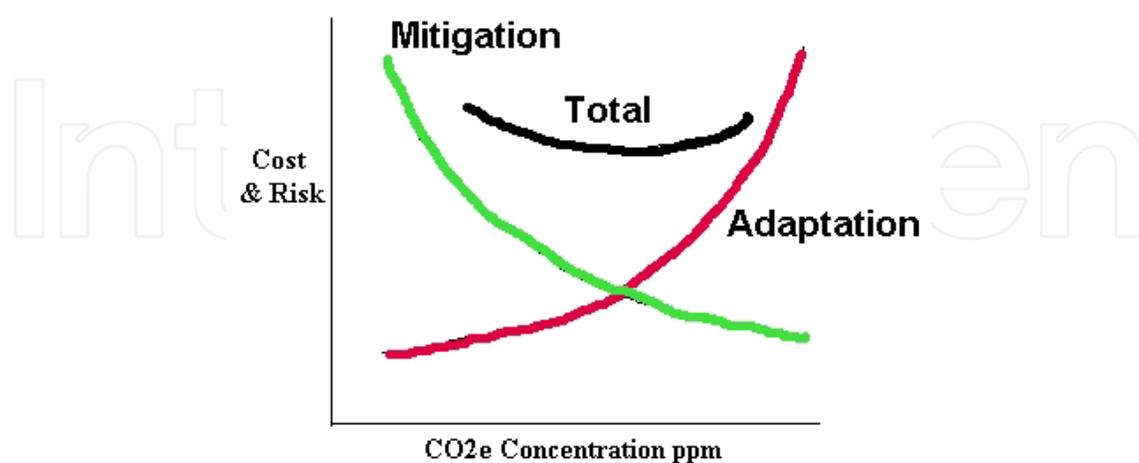


Figure 15.7. Cost/Risk Minimization Curves

### 15.2.7.1 Mitigation priorities for power industry

- No silver bullet: - Silver buckshot!!

The scale of the problem is so large that there is no single solution to reducing global GHG emissions. We will need all the options to achieve success, including:

- Energy Efficiency and Conservation (End Use and Supply Side)
- Low emission energy technologies (Renewable energy such as wind, solar, hydro, geothermal etc)
- Clean Coal (Includes Carbon Capture & Storage -CCS)
- Reducing dependence on fossil fuels
- Development of LNG & Biofuels
- Advanced Nuclear new build
- Development of the Hydrogen economy.

### 15.2.7.2 Adaptation priorities for power industry

- Adaptation is essential to deal with CC that has already occurred
- Adaptive capacities need to be increased to deal with CC impacts, particularly in poor countries that will be hardest hit and least able to cope
- Power Sector Adaptation Measures: Examples
  - "Hardening" grid systems against extreme events
  - Coping with changed load patterns & plant ratings
  - Strengthening advance warning, emergency response & restoration plans
  - Improving back-up telecommunications and grid control
  - Extending climate monitoring and recording.

### 15.2.8 Section Conclusions

The global response to CC is diverse and major and covers both mitigation and adaptation technologies. Much more needs to be done and business and governments must work together on cost effective solutions to minimize risk. Major thrusts must be on clean, hi-efficiency technology for mitigation, and increasing adaptive capacity, particularly in the poorest countries that will be hit earliest and hardest by CC and are least able to cope. There may be funding challenges as will ensuring the skilled resources are available to implement the needed measures.

Climate science is hugely complex and still fraught with uncertainties and it is prudent to adopt a "no regrets" strategy at this time that makes good sense and minimizes costs and risks whatever the outcome on actual global climate change. We need a risk management approach that balances the costs and economic risks of overly severe CO<sub>2</sub> emission reduction targets against the costs and benefits of increasing our adaptive capability to cope with climate change. This is particularly so in the developing countries which would be hardest hit by overly restrictive targets affecting their economic development and currently have the least adaptive capability.

### 15.3 Value of Non-Carbon Power and Emissions Avoidance

Estimates for the range of values to be ascribed to the avoidance and reduction of emissions using non-carbon or low emitting sources is now evaluated. This analysis utilizes published data

to establish the values of the business and investor return, emissions avoidance, energy reduction, efficiency improvement, conservation and alternate technology deployment. It shows that there is no one unique, globally traded and valid value. The range of values ascribed to avoidance is coupled to the economic value of energy use. The range of costs of emissions reduction is highly dependent on the socio-politico-economic assumptions. Numerical results for both present and future energy scenarios are provided, explicitly including hydrogen and other non-carbon power sources in defining the economic value of a sustainable non-carbon future.

That carbon and emissions avoidance has value has been already understood and analyzed by the oil and gas industry, and carbon pricing has been assumed and undertaken in business planning [8]. In the UK, there is an ongoing formal review [9] that states: *"The economic challenges are complex. At its most basic level, CC is an externality: the emission of greenhouse gases damages others. But these costs will be felt over a long period and over the entire globe; their exact nature is uncertain; they interact with other market failures and imperfections; and those most affected – future generations – are not able to speak up for their interests. This points to a long-term international collaborative response. Effective collaboration will require a shared understanding of the incentives and institutions needed, and careful attention to the complex ethical issues involved."*

In the UK there are future generational and moral issues to consider, with their own special emotive power and value. CC has already impacted commercial and industrial strategy. One leading oil and gas company has taken a position summarized as: *"We have worked for most of the last decade on the basis that one day carbon will be priced and that the application of technology which can reduce carbon will have a commercial value."*[8].

To proceed with a transparent economic analysis, the existence and definition of two contributory values may be postulated and considered: an objective monetary value based on a market or trading of rights to emit GHGs and the associated emission avoidance costs; and a subjective social value based on the estimates of the probabilities of mitigation, of planet-wide changes to human lifestyle, and of species change, and their relevant costs. The true comparative *"value"* is therefore a composite estimate, including both tangible and intangible costs and risks, and depends on evaluation of the components contributing to these two types of values.

### 15.3.1 Nuclear Energy Example

To look at any alternate energy sources, it is necessary to define ones own costs and emissions, based on prevailing market and economic conditions. The potential impacts of GHG reduction and avoidance, and the opportunities and benefits from fuel switching that would be needed to stabilize the atmospheric GHGs to preserve economic growth and social progress, should be defined.

Illustrative estimates of the *"value"* to be assigned to avoidance and reduction using nuclear energy from the present zero value assigned to nuclear energy to the actual economic and social values derived from emissions avoidance that would still supply a sustainable energy future should be determined. These can then be directly compared to values derived from carbon credit trading, energy portfolio standards, and carbon sequestration, including the direct and indirect costs, risks and uncertainties.

### 15.3.2 Valuing Emissions Reduction

To value reduction and energy source substitution, it is necessary to value usage and emissions increase, which in present society are an acquired historical right. Then, the several different approaches to establishing a benchmark value for emissions avoidance by comparing it to the value of the original emissions themselves can be evaluated.

#### 15.3.2.1 Economic value to a nation and the world

The value of carbon energy to the world is in providing economic growth. The purely *economic value* of the carbon emissions and power source is reflected in producing financial wealth for the country (such as the national GDP) using carbon energy. Energy is greatest in developed (rich) nations and a correlation between the growth in GDP to the growth in carbon energy use can be observed. This relationship also holds true at the global level. Hence, the global growth in GHG concentration in the atmosphere over the last 30 years (measured as ppmCO<sub>2</sub> at Mauna Loa, Hawaii where 1 ppmCO<sub>2</sub> ~ 9.10<sup>12</sup> tCO<sub>2</sub>) is directly and linearly correlated to the Gross World Product (GWP) (measured in teradollars, \$10<sup>12</sup> US). GWP data (source:[http://www.earth-policy.org/Indicators/Econ/Econ\\_data.htm](http://www.earth-policy.org/Indicators/Econ/Econ_data.htm)) is compared with CO<sub>2</sub> concentrations from Mauna Loa in Figure 15.8. To reduce the effect of the year-to-year noise in the CO<sub>2</sub> concentrations, five-year averages for GWP are plotted against the change in CO<sub>2</sub> measured over those five years. Rather than plot ppm values of CO<sub>2</sub>, the change is converted to Gt of CO<sub>2</sub> released based on 7.9 Gt of CO<sub>2</sub> required to cause a 1 ppm increase in the atmosphere accompanied by an equal release being absorbed in the oceans. 1 ppm was taken to be equivalent to a total of 15.8 Gt of CO<sub>2</sub> released. A linear fit of the data was calculated as:

$$\text{CO}_2 \text{ (Gt)} = 0.433 \text{ GWP(t\$)} + 8.70$$

The data can be interpreted as flattening over time, indicating diminishing energy intensity in the creation of value, but the average global economic value between 1950 and 2004 is 430 \$(US 2004)/t CO<sub>2</sub> (it is reasonable to use 1950 as the base year since the CO<sub>2</sub> build-up prior to about 1950 was relatively small).

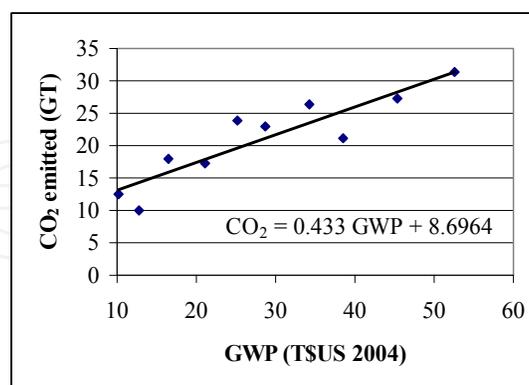


Figure 15.8. The global correlation.

#### 15.3.2.2 Economic value to investors

In addition, the economics also involve the value to shareholders and investors in oil and gas companies: they have implicitly assigned a value by owning the company and taking a dividend on the profits.

To set the market value, it is noted that oil and gas already has an assigned market value, and hence so has the carbon content used for energy production, since 1 bbl oil contains  $\sim 115\text{kgC}$  ( $= 495\text{kgCO}_2$ ).

To set the order of magnitude, the value to stockholders and owners as profit from corporate sales is taken. At the 2006 BP Annual General Meeting ([www.bp.com](http://www.bp.com)), and in the Financial and Operating Information for 2001-2005, it was reported that \$19B was distributed to investors in 2005-2006 with a replacement cost /bbl in 2005 of  $\sim \$48/\text{bbloe}$ . The profit per  $\$/\text{kgC} = 41.8\text{¢}/\text{kgC} = 418\text{\$/tC}$  translates to a present carbon emissions value to investors of  $114\text{\$/tCO}_2$ , assuming no carbon is sequestered and all is used in combustion, oxidation and/or transportation.

The future potential or prospective distribution to shareholders is given as  $\sim \$65\text{B}$  over the three years 2006-2008. With a refining margin  $\sim \$850/\text{bbl}$ , the 2005 production was  $\sim 2.5\text{Mbbbl/d}$  at a cost of  $\sim \$50/\text{bbl}$   $\sim \$45\text{B/a}$ .

Returning about  $\$65\text{B}$  over 3 years  $\sim \$22\text{B/a}$ , so the projected future profit/bbloe  $\sim \$22\text{B}/0.91\text{Bbbbl} = \$24/\text{bbloe}$ . Hence the investors' future Carbon value  $\sim \$48/\text{tCO}_2$ .

To attract investment or to be economically competitive without subsidy, any non-carbon alternate or carbon reduction scheme must have at least this substitute market investment value.

### 15.3.2.3 Assumed value of the right to emit

In a carbon-constrained system, the right to emit is governed by voluntary and/or regulated limits on total emissions. Thus emitting carbon can have a price or cost. The Kyoto Treaty targets are approximately a 5% global percentage reduction from prior years (1990 was taken as the baseline). To meet or encourage meeting this modest target, some nations invoked an "*emissions trading schemes*" either individually or collectively.

Many economic studies have attempted to determine or set limits on the assumed value, and establish the impact on the national, regional or local economy (e.g., Regional Greenhouse Gas Initiative (RGGI) report). Funds that are spent on carbon costs that raise energy prices cannot be spent on consumer goods. If promoting such a scheme a low value is assumed (typically  $\$5\text{-}10/\text{tCO}_2$ ), but the results are clearly sensitive to the assumed cost. In Canada, the impact on future national "scenarios" were examined under certain key assumptions.

These included the assumptions of a  $+2\%/a$  base GDP growth, but also assumed a  $\$10/\text{tCO}_2$  cap guarantee with international permits from other countries who were below their agreed targets (e.g., Russia). The negative impact was about 3.5% over some 30 years, or  $\sim 0.1\%/a$  lost economic growth. This has an estimated value of the fraction of the GDP,  $\sim 0.01 \times \$1\text{T/a}$   $\sim \$10\text{B/a}$  in GDP reduction.

Assuming a needed  $200\text{MtCO}_2$  reduction to meet the target, this implies an allowed economic value  $\sim \$10\text{B}/200\text{Mt} = \$50/\text{t}$ .

#### 15.3.2.4 Actual trading value

A value can therefore be assigned from what emitters will actually pay to preserve or obtain the rights or credit of releasing GHGs. This value can be determined from a defined and hopefully market-driven “emissions trading” scheme, where the right to emit is established via some limit placed on the total allowed amount (a so-called cap-and-trade system). Within the pre-determined GHG emissions amount, which is distributed between emitters and energy market sectors, credits can be traded and exchanged for a price determined by credit supply and emissions demand.

Currently, it is estimated [10] that about 100 million tons of carbon credits are transacted in various markets worldwide. The World Bank report [11] stated: “There are four active markets for GHG allowances as of May 2005; the EU-ETS, the UK Emissions Trading System, the New South Wales trading system and the Chicago Climate Exchange”. Volumes exchanged on these allowance markets have increased dramatically compared with 2005, and is now comparable to the volumes exchanged through project-based transactions. Cumulative volume exchanged on these four markets from January 2004 to March 2005 is about 56MtCO<sub>2e</sub>.

Of the four allowance markets, the EU-ETS is the largest, with an estimated 39MtCO<sub>2e</sub> exchanged since January 2004, the bulk transacted since January 2005.

Unlike project-based assets, allowances are homogeneous assets, and purchase contracts for allowances are fairly homogenous. As a result, the spread of prices for one tonne of CO<sub>2</sub> of emissions (an EUA) at any given point in time is small.

The dominant trading is clearly in the EU, where an emissions trading scheme has been deployed which allowed trading of emissions credits (i.e., emissions rights) on the open market, within some overall limit or cap on the EU total. Presently, some 25 countries with some 6,000 participating companies constitute a trading volume of 2.1 billion allocated tons CO<sub>2</sub> per year.

In this European Trading Scheme (ETS) predictions have also been made of the effect of demand on the trading price [12].

The estimates ranged from \$20 to \$100/tCO<sub>2</sub> depending on actual US demand, which is presently zero. A useful conversion factor to bear in mind, since economic studies use different currencies, is that for 2006 currency conversion rates, \$100/tC = 20€/tCO<sub>2</sub>. For 2005-2006 the ETS trading value range was between 10 and 30€/tCO<sub>2</sub> [13], and fluctuated widely.

This estimate is as close to an actual market value that is available. It is artificial as it refers solely in the EU, is not a global value, and is dependent on meeting arbitrary EU Kyoto targets.

#### 15.3.2.5 Negative value of negawatts: conservation and efficiency relative socio-economic values

The *conservation cost* is obtained by adopting or encouraging restrictions in the energy demand (so-called demand-side management) and use, plus impact of efficiency and conservation measures versus adding energy sources.

There are more subtle social values also that can be determined from the so-called external impacts or from reduced use of carbon energy. The most popular are called conservation and efficiency improvements, and are presumed to value energy-use reduction, and hence emissions avoidance. Reduced energy usage is good if energy efficiency is also improved and there is also a net relative benefit. Reductions in energy use have been given the term “Negawatts” [14] to reflect the reduction attained.

There are two ways to improve economic efficiency: (i) in the production of energy, and (ii) in its use. By using a standard discounted cash flow model, as used for actual power plants and systems, the costs of saving electricity to their assumed new power plant generating costs, using consistent discount rates can be compared.

A test case (scientific data) for the claims of efficiency gains leading to energy and emissions reduction is taken from actual USA data. After extensive effort, the results of improvements in energy technology and efficiency are clear. The US Department of Energy (DOE) has had a large and important program of work on efficiency for many years. This shows the perverse market effect that as (carbon) energy is made cheaper, more is used, leading to actual increases in energy use and in emissions.

Consider the actual and projected energy intensities, energy use and emissions in the USA for 1990-2020. The data and projections are shown in “*Energy Outlook 2001*” [10].

The numbers and figures clearly show that energy use and emissions rise as energy technology improves and the price falls (similar trends appear in prior years), both in the past and into the future.

Improved efficiency (technology) was responsible for about 60% of the observed decline in energy intensity, is now declining and is more expensive to introduce. As a result of the continued improvements in the efficiency of end-use and electricity generation technologies, total energy intensity in the reference case is projected to decline at an average annual rate of 1.6 percent between 1999 and 2020.

The projected decline in energy intensity (1.6%) is considerably less than that experienced during the 1970s and early 1980s, when energy intensity declined, on average, by 2.3% per year. Approximately 40 percent of that decline can be attributed to structural shifts in the economy – shifts to service industries and other less energy-intensive industries; however, the rest resulted from the use of more energy-efficient equipment.

Although more advanced technologies may reduce energy consumption, in general they are more expensive when initially introduced. In order to penetrate into the market, advanced technologies must be purchased by the consumers; however, many potential purchasers may not be willing to buy more expensive equipment that has a long period for recovering the additional cost through energy savings, and many may value other attributes over energy efficiency. In order to encourage more rapid penetration of advanced technologies, to reduce energy consumption or carbon dioxide emissions, it is likely that either market policies, such as higher energy prices, or non-market policies, such as new standards, may be required.

Basically, the needed proven and projected efficiency improvements are more expensive, and cannot keep pace with increased carbon-based energy demand, so need policy incentives (tax and cost breaks) to be adopted. Therefore, only by adopting non-carbon energy sources can the trend of increased CO<sub>2</sub> emissions be changed, and therefore, a mix of non-carbon sources is needed, including nuclear, as is also assumed by the United Nations Intergovernmental Panel on Climate Change (IPCC).

In fact globally the situation is perversely made worse: the decreasing demand in one country attained by precious conservation measures causes some reduction in what would otherwise have been the cost of global energy production favoring increased demand by others, as these other economies grow. Thus, the developing economies of, say, India and China will use all the energy that others make available to the market place by conservation and efficiency measures. The most that can be claimed in world markets is a decrease in the rate of carbon energy growth, but not an actual decrease in the amount of carbon energy used. This is confirmed by the data and all authoritative projections.

#### 15.3.2.6 The alternative or substitution value

This value can be estimated based on alternate energy technology options that reduce emissions but with added development, deployment and market costs that vary from technology to technology, and from sector to sector. In principle, it is possible to consider the value of emissions reduction versus emissions avoidance approaches (e.g., switching to hydrogen as an energy carrier).

It is not so simple to apply a value which is a composite based on relative health, emissions, land use, fuel supply, social and political aspects to arrive at relative rankings for differing substitute energy sources, emissions reduction technologies and GHG sinks in portfolio of options.

Consider the simplest case of power generation. Different sources and means produce differing amounts of emissions over their full "life cycle", meaning from mining the raw materials, the construction and the operation, and finally the disposal and decommissioning. For any given source of power, there is a GHG emissions amount per kWh.

To evaluate the relative emissions value of any two options, a calculation can be made as follows:

Differential Value of Avoidance, \$ =  $[\Delta\text{gCO}_2/\text{kWh}] \times [\Delta\text{kWh}] \times [\Delta\$/\text{gCO}_2]$

where,

$\Delta\text{gCO}_2/\text{kWh}$  is the difference between the emissions for any two sources

$\Delta\text{kWh}$  is the difference in the amount of power generated

$\Delta\$/\text{gCO}_2$  is the difference in the generating cost for any two sources.

Typical relative values are shown in Figure 15.9 for a variety of modern electric power units and a variety of studies, to illustrate the order of magnitudes.

For any given carbon value, for any given generation source, it is even more straightforward. For generation of 5TWh each year (by 600MW.a) avoiding approximately 3Mt/a @20\$/t, then the avoided emissions value may be assumed to be roughly \$60M/a.

These emissions differences may be translated into generating costs impacts, that is the price actually paid by a consumer (cf. gasoline). Avoiding 5Mt/yCO<sub>2</sub> @\$30/t = 150M\$/y. With a 1000MW(e) plant, approximately 7.8TWh/y will be generated, so the added cost of emissions, or conversely the benefit of avoidance is 1.9c/kWh, which is about a 30% increase in generating cost.

### 15.3.2.7 Avoidance, capture and sequestration value

The alternative is to eliminate, avoid or capture the emissions. Recently focus has been on establishing so-called Carbon Capture and Storage (CCS) as a viable option, which is essentially the immobilization of CO<sub>2</sub> in either: (a) a gas in natural or man-made geologic structures such as existing mines, deep saline aquifers, oil and gas wells, and salt domes; or (b) other stable chemical or physical forms. Also, pressurized re-injection into oil wells to recover additional oil (called Enhanced Oil Recovery (EOR)) is feasible at such sites, and CO<sub>2</sub> can also be collected elsewhere and piped to the injection location.

Electric Energy Technology	Switzerland PSI GaBe 2000 www.psi.ch	Canada Andseta & Gagnon HQ, 2000	IAEA Spadero et al. 2000 www.iaea.org	France (production only) Gouvernement de France, 2000
Natural Gas	605		696	500
Coal	1071	974	978	
Solar Panels	114 - 189		97	
Nuclear	16	3 - 15	21	0
Oil	855	778	811	701
Wind	36		36	
Hydro	4	15	16 - 23	

Figure 15.9. The relative life cycle emissions from differing sources.

Capture	Cost (£/teCO <sub>2</sub> )**
Coal PF Retrofit	19
GTCC Retrofit	14
New IGCC	13-34***
New GTCC	21
Pipeline transport for EOR	7-8
Pipeline transport for storage in depleted gas fields	4-6
Injection for EOR	7
Injection for gas field storage	1

Figure 15.10. The comparative value of CCS. (Source: DTI, 2003.)

Since the amounts (volume and mass) of carbon are potentially very large, it is preferable to site CCS facilities near larger sources. The recent UK report [16] has costed many concepts, and derives a CCS cost range of some 10-30\$/tCO<sub>2</sub>. Perhaps unsurprisingly, this cost range is consistent with the trading value, implying that these are perhaps the two main competing options (i.e., CCS or buy emissions credits). The comparative value of CCS taken from the Department of Trade and Industry (DTI) report is indicated in Figure 15.10.

This range does perhaps underestimate the real cost since the figures do not usually include collateral CO<sub>2</sub> emission associated with the CCS operation. The use of combined EOR, CCS and gas recovery is presently being examined at full scale, combined with hydrogen production and power generation (see [www.bp.com](http://www.bp.com)).

### 15.3.2.8 Value of alternate technologies

With continually rising emissions, there is a so-called “technology gap” to the desired goal of some reduced level. It would be of value if alternate technologies were some “magic bullet” that removed emissions, but a diversified portfolio of options is often recommended [17]. The costs to develop and deploy can be subsidized in the short term. But in a competitive marketplace, like the energy sector, the chance of success or market share for a new technology or product is heavily dependent on relative or comparative cost.

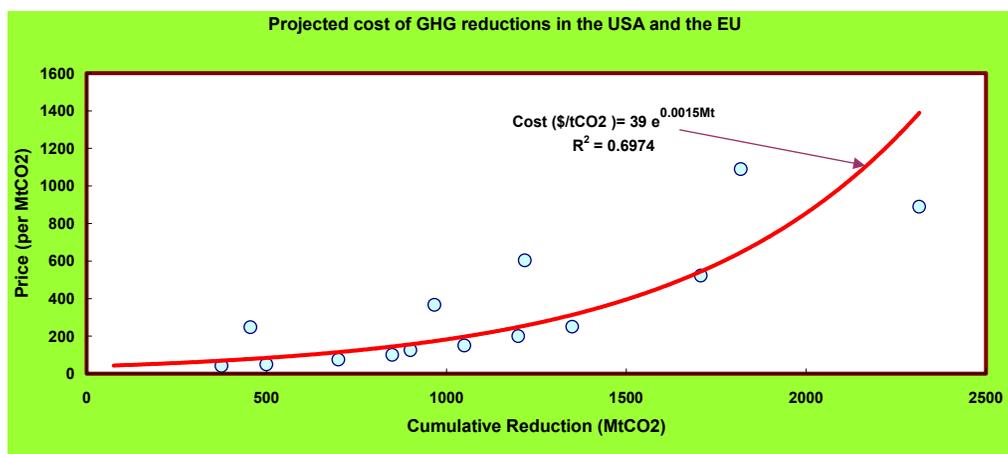


Figure 15.11. The Value of Technology

Recently, analyses of the emissions reduction potential of alternate technology pathways and scenarios have been published by the OECD’s International Energy Agency at the specific request of the G8 countries [18]. This was to address the socio-political issues of environment, energy security, air pollution and poverty to determine a “clean, clever and competitive energy future”. The study concluded that deployment of technologies that have an additional cost of less than a cost of \$25/t CO<sub>2</sub> could halve oil and electricity demand and stabilize emissions by 2050. Unfortunately sensitivity to the value was not studied, but it is clear that this value would exclude many of the technology options in Figure 15.11 and will not really impact transport emissions as it represents only some 1-2% of current fuelling costs.

### 15.3.2.9 Policy value: energy insecurity and carbon taxes

Government and national policy makers like to retain control over their own destiny and country. Since many of the major sources of carbon energy are focused in regions of relative geo-political instability, there is a value to be placed on having energy security and diversity of supply. The use of “policy measures” (a euphemism for taxes) is usual for governments, to raise revenue and/or provide fiscal incentives.

Thus, the recent Province of Quebec’s “Plan d’Action” [19] is based on monetary incentives for GHG emissions avoidance.

For a cost of some \$200M in taxes plus \$328M in other measures, with a program total \$1.2b, the goal of the Plan is to avoid  $\sim 10\text{Mt/aCO}_2$  in six years. The specific value assigned to carbon emissions avoidance is not stated, but can be estimated from the proposed program costs given above as within a range:

$$\text{High } \sim \$1.2\text{B}/(10\text{Mt/a} \times 6) = \$20/\text{tCO}_2$$

$$\text{Low } \sim \$200\text{M}/(4.8\text{Mt/a} \times 6) = \$7/\text{tCO}_2$$

If the cost or value is too high, the democratic election process usually solves this issue.

#### 15.3.2.10 Global value of sustainable avoidance

As a final estimate of the value of emissions avoidance, some global limit or “target” for allowable emissions should be assumed. This is taken as a doubling of pre-industrial  $\text{CO}_2$  concentrations to about 550 ppm in the atmosphere. The reduction achieved by any avoidance or technology means can be translated into an atmospheric concentration reduction. As a working example, the impact for a range of emissions reduction assumptions based on the UN’s IPCC scenarios [20] for future energy use [21] has been evaluated. This was done using the MAGICC/SCENGEN [22] global model as an emissions scenario sensitivity tool. Any emissions avoidance could be assumed, but specifically we adopted the range covering high- and low-energy use by (the IPCC, the A1F1 and B2 base scenarios) [21]. These scenarios were modified by inclusion of significant added penetration of sources with low carbon dioxide emissions (including nuclear energy) for new power generation by 2030; and the adoption of a significant fraction of hydrogen in global transportation by 2040.

The results [21] show an emissions avoidance/reduction potential of 200 to 300 ppm  $\text{CO}_2$  by 2100, using such a penetration of non-carbon power. This scale of emissions avoidance essentially allows for unconstrained economic growth, which is good for the developing nations pursuing this course of action.

#### 15.3.3 Results

Using existing data, estimates for the range of values to be ascribed to carbon emissions were evaluated and provided. This analysis utilizes published data to establish the values of the business return, emissions avoidance, energy reduction, efficiency improvement, conservation and alternate technology deployment. As a result, it is shown that there is no one unique, globally traded and valid value. The value ascribed to avoidance is coupled to the economic value of energy use; and hence the range of costs of emissions reduction is highly dependent on socio-politico-economic assumptions.

The use of alternate non-carbon energy is relatively of high value in typical schemes, including impact of conservation and efficiency measures. The results show a definite trend that confirms the considerable advantage of adding new-build advanced nuclear energy plants as potentially the lowest cost emissions reduction option with the highest value.

## 15.4 Impact of Regional Greenhouse Gas Initiative and Renewable Portfolio Standards on Power System Planning

Two developments in the Northeastern United States are having an impact on power system planning in that region. One is a cap on CO<sub>2</sub> emissions recently adopted by seven states. This is the result of a voluntary Regional Greenhouse Gas Initiative (RGGI) developed by nine states over the last two years. The second development is Renewable Portfolio Standards (RPS) that have been implemented in most states in the Northeastern US.

### 15.4.1 RGGI

The initial RGGI agreement<sup>#</sup> involved seven states (Maine, New Hampshire, Vermont, Connecticut, New York, New Jersey and Delaware) that signed a Memorandum of Understanding (MOU) in December 2005 to implement a cap and trading program for CO<sub>2</sub> emissions from power plants greater than 25 MW in those states. Massachusetts and Rhode Island joined in February 2007 and Maryland joined in April 2007. Pennsylvania, the Eastern Canadian Provinces, and New Brunswick are observers in the process. While participation in RGGI was voluntary, the MOU makes the cap mandatory.

The MOU establishes a CO<sub>2</sub> cap of 126.1 million tons for the initial seven states that would be implemented starting in 2009 and remaining at this level until 2014. In 2015, a gradual reduction in the cap would start and reach a 10% lower level by 2019. The cap would be implemented with a Model Rule as a framework for states to implement state regulations governing the details of the state cap and trading rules, compliance etc. The overall program would be administered through a Regional Organization, but would not have regulatory authority.

The CO<sub>2</sub> cap would be apportioned among the seven states and the states would apportion their caps to the individual generators in their state granting one CO<sub>2</sub> allowance for each ton of emissions. The trading of CO<sub>2</sub> allowances would be allowed across the seven states. To provide consumer benefits from this program the states would withhold 25% of the allowances from the generators. These could be sold and the funds used to support energy efficiency, renewable resources, carbon capture, or customer rebates.

A compliance flexibility feature of the RGGI program will be the ability of an affected generator to use offsets for up to 3.3% of its compliance obligation. Offsets are reductions in CO<sub>2</sub> or other greenhouse gases made outside of the electric sector that have been approved and certified by a regulatory process as to their legitimacy. These offsets can be created from a number of possible designated greenhouse gas reductions in the RGGI states on a one for one basis, or created in the U.S. outside of RGGI on a two for one basis. An additional flexibility aspect of the RGGI program is that it has two price triggers when CO<sub>2</sub> allowances reach price thresholds of \$7/ton and \$10/ton. With allowances at these price levels, more compliance flexibility is allowed in the use of offsets with an increase in the percentage use for compliance and a broader geographical area from which the offsets can be created and bought.

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<sup>#</sup> [www.rggi.org/agreement.htm](http://www.rggi.org/agreement.htm)

Massachusetts (MA) and Rhode Island (RI) also participated in the development of the RGGI program but did not sign the initial MOU. MA implemented its own CO<sub>2</sub> cap in 2006 affecting six fossil generating plants in that state. The MA cap is based on historical emissions (tons), and on a maximum emissions rate of 1800lb/MWH. It also established price caps so it has similarities to the RGGI program.

#### **15.4.2 Renewable Portfolio Standards**

RPS have been implemented by state legislation and regulation to encourage development of renewable resources. The RPS are percentage targets of the energy supplied that the load serving companies are required to meet on an annual basis. The percentage target generally increases each year and can be met with a range of renewable technologies. These typically include solar photovoltaic, wind, biomass, energy from wastes, and in some states fuel cells. The Northeast states with RPS include Maine, Vermont, Massachusetts, Rhode Island, Connecticut, New York, New Jersey, Pennsylvania and Maryland.

Compliance by the load serving entities generally is made from the energy from renewable projects across the region and is accomplished with the purchase of Renewable Energy Certificates (RECs<sup>1</sup>) associated with these projects. The value of a REC adds to the worth of the energy from a project, and provides greater incentives for investing in the development of renewable resources

#### **15.4.3 Impacts on Power System Planning**

Both RGGI and RPS have impacts on electric system planning in the region. The RGGI program would function similar to the SO<sub>2</sub> and NO<sub>x</sub> cap and trade systems that have been functioning in the US and Canada. These systems provide regulatory certainty as to emission requirements for the generating plants affected. RGGI would be adding a third mandatory emissions cap for power plants in the seven participating states.

The RGGI Cap would function in the same manner like the SO<sub>2</sub> and NO<sub>x</sub> caps, and cause dispatch or bidding adders that would increase the operating cost of fossil plants, especially coal and oil since these fuels have the highest CO<sub>2</sub> emission rates. These costs could change relative dispatch of the units and hence the system transmission flows.

In the modeling conducted during the development of the RGGI program, a wide range of natural gas price assumptions was examined for the electric system expansion to show feasibility of the cap. The results showed a very diverse set of generation additions to serve the energy and peak load growth out through 2024. For assumptions of more historical levels of natural gas prices the additions included a large amount of natural gas fueled combined cycle (NGCC) and onshore wind generation. For assumptions of higher natural gas prices, such as were experienced in 2005, clean coal plants were the major capacity addition with a lesser amount of NGCC and a similar amount of wind was selected in the model (to meet RPS) as with lower natural gas prices. The large amount of wind may not be feasible if the siting difficulties of current wind projects continue. These RGGI scenarios

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<sup>1</sup> A REC equals one MWH of renewable energy.

also assumed that the natural gas infrastructure would be expanded as needed. In the ISO/RTOs' regional planning processes, generation expansion scenarios will need to be examined with more detailed modeling to confirm that system reliability can be maintained and to determine the magnitude of the market costs of implementing the RGGI CO<sub>2</sub> cap.

RPS is providing some incentives for new renewable projects, especially wind and biomass. Based on the ISO/RTO system interconnection queues, wind and biomass appear to be the more attractive renewable projects being built. These renewable projects have to be sited where the energy source is located, which is usually not close to a major load centers, i.e. on remote ridgelines for onshore wind or where there are forested areas to provide wood harvesting with minimum transportation costs.

### 15.5 Conclusions

There is growing evidence of impacts of CC due to GHGs. Action is needed to reduce GHG emissions to mitigate risks of CC and to increase global capability to adapt. The power industry is a major part of the problem and must be part of the solution and show leadership. Much has been done through global and other programs, but there is urgency to do much more to reduce risks.

It is prudent to adopt a "no regrets" strategy at this time that makes good sense and minimizes costs and risks whatever the outcome on actual global climate change. The preferred risk management approach must balance the costs and economic risks of overly severe CO<sub>2</sub> emission reduction targets against the costs and benefits of increasing our adaptive capability to cope with climate change. This is particularly so in the developing countries which would be hardest hit by overly restrictive targets affecting their economic development and currently have the least adaptive capability.

Major thrusts must be on clean, hi-efficiency technology for mitigation of emissions, and increasing adaptive capability, particularly of poorer developing countries. There are many opportunities for the power industry to show leadership in technology, processes and markets. There will be funding and skilled resources challenges, but there are many good investment opportunities.

Business and governments must work together on climate change mitigation and adaptation. GHG reductions can be realized through use of (i) market-based programs in which customers or manufacturers are provided technical support and/or incentives; (ii) mandatory energy-efficiency standards, applied at the point of manufacture or at the time of construction; (iii) voluntary energy-efficiency standards; and (iv) increased emphasis of private or public R&D programs to develop low emission energy technologies and more efficient products.

There is no one unique, globally traded and valid value for carbon. The value ascribed to avoidance is coupled to the economic value of energy use; and hence the range of costs of emissions reduction is highly dependent on socio-politico-economic assumptions. The use of alternate non-carbon energy is of relatively high value in typical schemes, including impact of conservation and efficiency measures. The results show a definite trend that

confirms the considerable advantage of adding new-build advanced nuclear plants as potentially the lowest cost emissions reduction option with the highest value.

Adapting to climate changes will present challenges for all involved in infrastructure design and construction, health and medicine, water resources management, coastal zone management, agriculture, land use and forestry, and other areas. Increasing adaptive capability is a priority for the short term, particularly for the poorest developing countries which will be hit earliest and hardest by climate change and are least able to cope.

The RGGI CO<sub>2</sub> cap and the RPS requirements in Northeastern USA are adding new impacts and considerations for power system planning in that region. RGGI will most likely increase energy costs from fossil generators in the states where it will apply and possibly affect reliability. RPS will encourage smaller renewable resource projects, mostly onshore wind and biomass fuels that will interconnect at lower transmission or distribution voltage levels, and will not likely help serve large load centers. As larger amounts of wind projects are added, they could affect the need for increased operating reserve.

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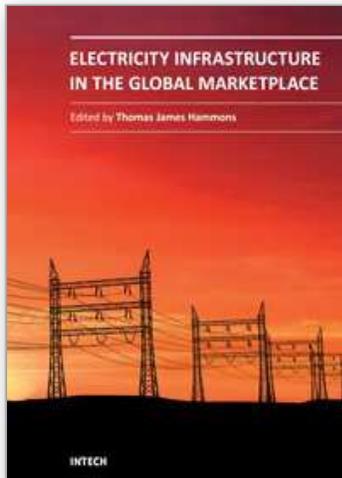
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