# CHAPTER II
# CONCEPTS, FRAMEWORKS, AND CONSIDERATIONS FOR LOW CARBON ELECTRICITY DEVELOPMENT

## 2.1 Why does Greenhouse gases emission matter

The presence of certain gases, such as carbon dioxide ($CO_2$), methane, ($CH_4$) and nitrous oxide ($N_2O$), enables the atmosphere to act like a greenhouse, retaining part of the solar heat. The natural greenhouse effect is desirable as it traps part of the incoming solar energy to maintain habitable temperatures on the earth's surface. However, human activity is warming the planet. Anthropogenic greenhouse gas emissions are key factors in global climate change mitigation, especially carbon dioxide emissions from energy combustion activities. Global climate change can be considered a "Tragedy of the Commons" for which no effective global coordination, regulation, or enforcement has yet been developed. Impacts are likely to include changes in precipitation patterns, increased frequency and intensity of storms surges and hurricanes, changes in vegetation, and a rise in sea level. Developing countries, especially the poor ones, are more vulnerable to these changes given their high dependence on natural resources and their limited capacity—human, financial, and institutional—to adapt to extreme events.

Human activities, like burning of fossil fuels, deforestation, agricultural practices, and manufacturing are increasing the concentration of GHGs in the atmosphere and causing an enhanced greenhouse effect resulting in higher global average temperatures. For the past millennium the Earth's average temperature varied within a range of less than 0.7°C; however, manmade greenhouse gas emissions have resulted in a dramatic increase in the planet's temperature over the past century (The Intergovernmental Panel on Climate Change, 2007). The projected future increase over the next 100 years due to growing emissions could possibly warm the planet by 5°C relative to the preindustrial period. Such warming has never been experienced by mankind and the resulting physical impacts would severely limit development. Only through immediate and ambitious actions to curb greenhouse gas emissions may dangerous warming be avoided (The World Bank, 2010).

Electricity has become such a fundamental part of our lives that we take it for granted. Despite this fact, generating power has faced all challenges as it developed and now finds itself at the center of another storm: how to prevent massive disruption to the world's climate (Lewis, Chai et al., 2010). In facing this challenge, electricity curiously finds itself with looking both ways: simultaneously under pressure as the world's biggest source of greenhouse gas emissions, yet widely touted as the solution to other, even more intractable sources of carbon dioxide from transport and even heat. There is increasing consensus in both the scientific and political communities that significant reductions in greenhouse gas emissions are necessary to limit the magnitude and extent of climate change. Importantly, because electric power generator are among the largest point sources of important air pollutants such as sulfur dioxide, nitrogen oxides and mercury (Palmer and Burtraw, 2007).

Power generation is the main source of carbon dioxide emissions and accounts for four in every ten tones of carbon dioxide dispatched to the Earth's atmosphere (The International Energy Agency, 2009a). Therefore, this sector is the most prominent target for climate policy because it is the largest single source of carbon dioxide emissions and high potential for emission reduction. Reducing electric sector carbon dioxide emissions by significant levels will require major changes in how we use and produce electricity (Board on energy and environmental systems, 2010). Reducing electric sector carbon dioxide emissions by significant levels will require major changes in how we use and produce electricity (Board on energy and environmental systems, 2010). Whether electricity can really both decarbonizes and expands hinges on one main question: whether a carbon-constrained world can effectively foster low-carbon electricity generation at scale. Clearly, our consumption of fossil fuels must decrease, partly due to a limited and uncertain future supply and partly because of undesirable effects on the environment (The International Energy Agency, 2009c).

Essentially, a sustainable supply of energy for societal needs must be secured in long term for our future generations. With well-founded scientific supports and international agreement, renewable energy sources must be urgently developed and widely adopted to meet environmental and climate related targets and to reduce our dependence on oil and secure future energy supplies. As developing country that heavily depending on imported fossil fuels for power generation, Thailand already experienced adverse impacts of energy crisis that could become major barriers for the country's future development. The country improves its power development plan for the next decades to enhance higher proportion of renewable energy generation. The critical questions are how realistic of the plan' s targets compared to existing physical supplies and technical potentials, which technology should be more pronounced, and how fast the plan's impacts can be acknowledged (United Nations Development Programme, 2007).

Thailand should contribute to mitigate the impact of climate change as a member country of the world community, in a drive towards a decrease in GHG emissions resulting from activities in various sectors. It is one thing to have the potential to make deep cuts in GHG emissions; it is another for policy makers to agree on and implement effective emission reduction policies, and for companies, consumers and the public sector to take action to make this reduction a reality. Capturing all the opportunities would entail change on a huge scale.

This chapter reviewed abatement opportunities, options challenges for promoting low carbon electricity development and commenced with importance of demand reduction; encouragement usage of renewable or low emission energy, and follow with emission reduction technology in electricity generation.

## 2.2 Abatement opportunities in electricity generation sector

In 2007, Nicholas Stern demonstrated that the cost of inaction could be as much as 10 per cent of global GDP (Stern, 2007). This got the attention of finance ministers and heads of governments, not just environment ministers. The abatement opportunities fall into three categories to promote low carbon electricity development. The first option is to use less energy by energy-savings, energy conservation, improvement of energy efficiency can help reducing the carbon problem, but they cannot by themselves solve the problem considering the huge growth in demand. The second option is to eliminate current fossil sources and replace them with non-fossil sources of energy that can fill the gap. This option is, in principle, feasible, but it would eliminate the foundation of the current energy infrastructure. The third option is to prevent the carbon dioxide that is associated with the consumption of fossil fuels from accumulating in the atmosphere. It is exceeding unlikely that any one of these three options will completely dominate the transition. For that, the constraints, even in the absence of climate change, would just be too large.

From study of McKinsey and Company (2009) reported the abatement opportunities in the period between now and 2030 fall into four categories: energy efficiency, low-carbon energy supply, terrestrial carbon (forestry and agriculture), and behavioral change. The first three, technical abatement opportunities, which are the focus of our study, add up to a total abatement opportunity of 38 $GtCO_2$ per year in 2030 relative to reference (BAU) emissions of 70 $GtCO_2$. There is potential by 2030 to reduce GHG emissions by 35 percent compared with 1990 levels, or by 70 percent compared with the levels we would see in 2030 if the world collectively made little attempt to curb current and future emissions.

Capturing enough of this potential to stay below the 2 degrees Celsius threshold will be highly challenging. They also stated that their research finds not only that all regions and sectors would have to capture close to the full potential for abatement that is available to them; even deep emission cuts in some sectors will not be sufficient. Action also needs to be timely. However, if this full potential was captured, emissions would peak at 480 ppm This would be sufficient to have a good chance of holding global warming below the 2 degrees Celsius threshold, according to the Copenhagen Accord that commits to limiting temperature increases to two degrees Celsius.

### 2.2.1 Reduced energy consumption with demand reduction

The question of how much tackling climate change is going to cost is a recurrent issue in today's global discussion e.g. how to transform in to a low-carbon economy, how large will capital investments need to be, which sectors offer the highest returns on those capital outlays? Ideally, energy use would be optimized by supply and demand interactions in the market. For electricity use in particular, the price paid on the market is often regulated or fixed, and in many cases does not reflect the full cost of production. Electricity use can vary dramatically on short and medium time frames, and the pricing system may not reflect the instantaneous cost as additional higher-cost ("peaking") sources are brought on-line. In addition, the capacity or willingness of electricity consumers to adjust to prices by altering demand (elasticity of demand) may be low, particularly over short time frames. In many markets, consumers (particularly retail customers) do not face real-time pricing at all, but pay rates based on average annual costs or other constructed prices.

The Demand Side Management[3] (DSM) is the process of managing the consumption of energy, generally to optimize available and planned generation resources. Without DSM programs, these energy and peak demand savings would not occur or would materialize only after significant delay, and in any case could not be relied upon, forcing utilities to construct expensive back-up capacity and causing higher rates. At that time, annual demand-side management expenditures measured in billions of dollars, energy savings measured in billions of kilowatts hours, and peak load reductions stated in thousands of megawatts.

Papagiannis et al. (2008) investigate the economic and environmental impacts that result from the implementation of an intelligent demand side management system, called Energy Consumption Management System (ECMS), at the European level. Implementation of DSM program can reduced 1–4 percent of primary energy, 1.5–5 percent in carbon dioxide emissions and a 2–8 percent saving in investment costs for power generation expansion.

Gellings and Parmenter (2008) discussed on benefits of implementation of DSM campaign in electricity sector reduces customer energy bills, the need for power plant, transmission, and distribution construction, stimulates economic development, creates long-term jobs that benefit the economy, increases the competitiveness of local enterprises, reduces maintenance and equipment replacement

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[3] Energy demand management, also known as demand side management (DSM), entails actions that influence the quantity or patterns of use of energy consumed by end users, such as actions targeting reduction of peak demand during periods when energy-supply systems are constrained. Peak demand management does not necessarily decrease total energy consumption but could be expected to reduce the need for investments in networks and/or power plants.

costs and reduces local air pollution. From study of WEC (2008) presented the implementation of energy efficiency policy is important as driving force for greenhouse gas emission reduction. Improving the efficiency with which electricity is produced is therefore one of the most important ways of reducing the world's dependence on fossil fuels, thus helping both to combat climate change and improve energy security. Additional fuel efficiency gains can be made by linking electricity generation to heating and cooling demands through high efficiency combined heat and power (CHP) systems (e.g. in industry and for district heating).

Thailand became the first country in Asia to formally adopt a nationwide DSM master plan. To support energy conservation activities, the Government of Thailand passed the Energy Conservation Promotion Act, or ENCON Act, in 1992, to provide a regulatory framework for energy conservation and efficiency programs and investments. This Act included the creation of an Energy Conservation Promotion Fund (ECF) to provide working capital, grants and subsidies to promote and facilitate energy conservation measures and renewable energy initiatives. Under the ENCON Act, the Department of Alternative Energy Development and Efficiency (DEDE) was appointed as the executing agency for the Compulsory (energy audits and public/private building efficiency investments) and Complementary (public relations and training) Programs.

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

2.2.2 Reduced energy consumption by improvement of energy efficiency

End-use energy efficiency can be defined as the efficiency with which energy is consumed by end-users within the commercial, industrial and residential sectors. Through end-use energy efficiency improvements, the same economic benefits are achieved with less energy, meaning that fewer resources are consumed per unit of economic activity, and emissions are avoided. The efficiency of the existing electrical generating system which is not nearly as good as it could be, go on to what the charge for carbon emissions might be if the costs to society that come from emissions were to be included in the price of electricity generated from fossil fuels, and end with catching and storing the greenhouse gases. The reason for the inefficiency in generation and the larger than needed emissions that go with it is a combination of low fuel costs for fossil-fueled generation plants, and ignorance of the consequences of greenhouse gas emissions until relatively recently. Energy efficiency measures have not only been proven the most cost effective in terms of $CO_2$ mitigation, but also possess significant potential. High transaction costs, market and behavioral barriers have proven challenging to overcome. The emissions in electrical generation depend on the fuel used in the power plant. Energy and environmental policies cannot be implemented at an abstract level (Reddy, Assenza et al., 2009).

Investment in energy efficiency and investment in renewable are two different ways of balancing demand and supply in energy markets. Policies to promote energy efficiency may conversely make it harder for renewable to compete in electricity markets. If efficiency programs are cost-effective, electricity prices would be lower than they would be without the program, though not necessarily lower than before the program. There would be less demand for investment in renewable, and investment would be less profitable, all else being equal (Board on energy and environmental systems, 2010; Chandler, 2008). Peak-time electricity is expensive. Electricity demand peaks daily in any power system, and is also subject to sudden spikes, which may or may not be forecast. These relatively short periods, which may only amount to a few hours in the course of a year, are catered for by accessing reserves in the form of stored energy or flexible, "peaking" generators, which may only be operated at such times. Most of the Thailand's electrical generating plants are old, when they were built, fuel was cheap and global warming was a thing few scientists worried about, much less citizens or governments.

Energy efficiency is a low-cost, rapidly deployable, and saving energy resource. Reducing growth in energy demand is essential to any clean energy strategy: without efficiency advances, clean energy supplies might not keep up with demand and carbon emissions could continue to grow (Reddy, Assenza et al., 2009). Despite efficiency's benefits, many of the policy mechanisms intended to reduce greenhouse gas emissions will not fully value energy efficiency in proportion to its economic potential unless policy and market barriers are reduced. Using electricity generated by conventional steam turbine power plants that burn brown and hard coal, the level of efficiency is between 35 and 45 percent. Modern gas and steam turbine power plants that use natural gas achieve up to 60 percent. However, this means that at least 40 percent of the primary energy fizzles out unused through the cooling tower of the power plant. When it comes to increasing efficiency, combined heat and power (CHP) or cogeneration[4] is often promoted as a promising candidate. CHP plants use the heat from electricity generation effectively and are able to exploit up to 90 percent of the fuel.

As a result, in an optimal case less carbon dioxide is produced than when electricity and heat are generated separately. Many comparisons of cogeneration power plants that generate heat and electricity separately using fossil fuels show possible carbon dioxide savings of up to 50 percent. However, these comparisons usually pit CHP plants against antiquated electricity plants. If the comparison is made on the basis of optimal functioning plants on both sides, the carbon dioxide savings are reduced to a meager 15 to 20 percent (See also in Figure 5). Furthermore, these savings are only possible with optimal plant operation. For example, in summer when a cogeneration plant is only supposed to generate electricity but not heat, it will have

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[4] Cogeneration is the co-production of electricity and useful heat. All electricity generation produces heat as a byproduct, of course, but in many cases the heat is not used because it is not of sufficiently high quality (i.e. not of high enough temperature) to be useful. Cogeneration is widely used in industries that need both heat and electricity (such as the pulp and paper and petrochemical industries) and in district heating systems.

great difficulty in even coming close to the dream efficiency level of 90 percent. The cogeneration plant can sometimes end up producing even more carbon dioxide than a straightforward electricity power plant.

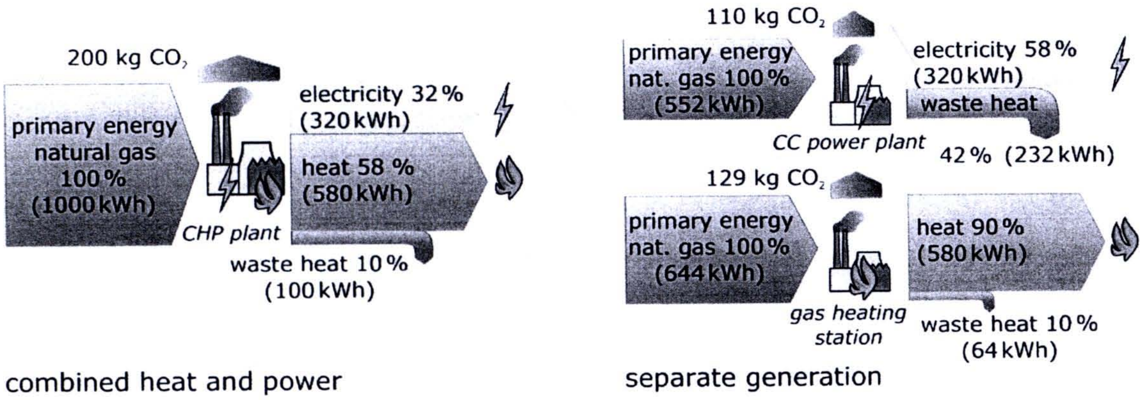


Figure 5 Comparison of Primary Energy Requirements and Carbon dioxide Emissions between Power Heat Coupling and Separately Generated Heat and Electricity in Modern Power Plants

Source: Quaschning (2010)

If, on the other hand, a sufficient requirement for heat exists over the entire year, cogeneration plants can help to reduce carbon dioxide. With cogeneration plants that use fossil fuels the savings for effective climate protection are too low. Those that use renewable energy sources, such as biomass and geothermal energy, are totally carbon-free and can continue to accelerate the switch to carbon-free energy supply. Prindle et al. (2010) describe efficiency's potential contribution to reducing carbon emissions, identify policy and market barriers to efficiency investments in a climate policy context, and outline policy and program solutions.

### 2.2.3 Decarbonisation of energy supply in electricity generation

Fossil fuels such as coal, oil and natural gas (primary energy) are converted into electricity (a form of secondary energy) with substantial losses during the conversion process. Reducing these losses, thereby increasing the overall efficiency of electricity generation, is the first opportunity in the chain of energy use for reducing the primary energy intensity of the global economy (Harvey, 2010). When a fossil fuel is burned, the chemical energy of the bonds in the fuel is converted to thermal energy. Some of this thermal energy is converted to electricity in the power plant, and the rest is lost as heat that is dissipated to the environment (the surroundings). The reported energy content of a fossil fuel is the thermal energy that is produced when the fuel is burned.

Carbon-free technologies, chiefly nuclear and renewable energy for electricity, will also play an important role in a carbon-constrained world, but absent a technological breakthrough that we do not foresee, coal, in significant quantities, will remain indispensable (Ansolabehere, Beer et al., 2007). Immense challenges are presented by the need to reduce the vulnerabilities associated with climate change, energy supply interruptions, and volatile fossil-fuel markets. Reducing electric sector carbon dioxide emissions by significant levels will require major changes in how we use and produce electricity. Cutting energy imports and substantially reducing our dependence on fossil fuels also will involve major changes (Board on energy and environmental systems, 2010). Decarbonisation of energy supply is among the key issues facing policymakers in the years ahead.

This section presented status of technology for prevents carbon dioxide that is associated with the consumption of fossil fuels from accumulating in the atmosphere.

2.2.3.1 Fuel switching to renewable energy supply

Generation of electricity from most renewable resources also reduces vulnerability to increases in the cost of fuels and mitigates many environmental impacts, such as those associated with atmospheric emissions of greenhouse gases and emissions of regulated air pollutants. REN21 (2009) reported annual renewable energy investment has increased fourfold to reach $120 billion in 2008. In the four years from 2004 to 2008, solar photovoltaic (PV) capacity increased six-fold to more than 16 Gigawatts (GW), wind power capacity increased 250 percent to 121 GW, and total power capacity from new renewable increased 75 percent to 280 GW, including significant gains in small hydro, geothermal, and biomass power generation.

There are many opportunities to shift energy supply from fossil fuels to low-carbon alternatives[5]. There are three categories of renewable energy, the first is solar energy that strikes the earth in vast amounts, providing heat for the oceans and land surfaces, drives the winds and waves, produces biomass and fuels through photosynthesis, and provides the energy for the hydrological cycle. The second source is the heat of the earth, which results primarily from natural radioactive decay. Finally, there is gravitational energy from tides and falling water. One can compare current societal energy use with natural energy fluxes to get some sense of the enormity of the renewable energy supply. While these renewable energy "fuels" are free, the challenge and the cost lie in the development and deployment of the multiple technologies to harvest the available energy and to integrate them into an efficient integrated system (Moomaw, 2008).

Renewable energy technologies such as wind power and solar photovoltaic (PV) devices have achieved major cost reductions over the last decades, which are expected to continue in the medium term as large global companies entering new energy markets for wind, solar and biomass technologies (Freris and Infield, 2008). By early 2009, at least 64 countries had some type of policy to promote renewable power generation (Board on energy and environmental systems, 2010). Multilateral agencies and private investors alike are "mainstreaming" renewable energy in their portfolios. Further, distributed renewable electricity generation located at or near the point of energy use, such as solar photovoltaic systems installed at residential, commercial, or industrial sites, can offer operational and economic benefits while increasing the robustness of the electricity system as a whole.

Renewable energy systems already reduce GHG emissions from the energy sector, although on a modest scale. The use of renewable electricity provides some significant advantages over the use of fossil-based electricity. Many types of

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[5] If these low-carbon alternatives were to be fully implemented, from study of McKinsey and Company (2009: 192) estimate that they have the potential to provide about 70 percent of global electricity supply by 2030 compared with just 30 percent in 2005.

renewable electricity generating technologies can be developed and deployed in smaller increments, and constructed more rapidly, than large-scale fossil or nuclear-based generation systems, thus allowing faster returns on capital investments. Many renewable technologies and industries have been growing at rates of 20 to 60 percent, year after year, capturing the interest of the largest global companies (REN21, 2008). So much has happened in the renewable energy sector during the past five years that our perceptions lag far behind the reality of where the industry is today. Several of these low-carbon energy technologies are too expensive today to deploy on a large scale without financial incentives, emphasizing the need to provide sufficient support to make them travel down the learning curve allowing them to contribute to their full potential. Key examples include electricity production from wind, nuclear, or hydro power, as well as equipping fossil fuel plants with carbon capture and storage (CCS), and replacing conventional transportation fuel with biofuels.

Thailand has demonstrated its regional leadership in the South East Asia region during the last 20 years in energy and environment. Though having relatively low levels of GHG emissions in the last decades, now Thailand has increasingly experienced higher levels of GHG emissions and expects an even stronger increase in the future due to its continued economic development and population increase, among others.[6] As a result, Thailand should, therefore, contribute to mitigate the impact of climate change as a member country of the world community, in a drive towards a decrease in GHG emissions resulting from activities in various sectors (Ministry of Energy, 2009). It is likely that the main threat that will face fossil energy in the future is the development of catastrophic evidences on the climate change. It will put strong pressure to reduce drastically the carbon emissions. Even emerging countries will not escape penalization of the goods they produce on the export market if they are not carbon free.

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[6] Thailand GHG emissions from the consumption and flaring of fossil fuels accounted for 1% of World's GHG emissions; ranking 22nd in the World's top GHG emitters. Thailand is the second largest contributor to fossil fuel GHG emissions in ASEAN after Indonesia.

To deal with the above issues, the Ministry of Energy has launched an ambitious program to increase investments in renewable energy such as wind, solar, biomass and other clean renewable energy sources. The Ministry has also set in motion the plans to speed up the preparation of the 15-Year Alternative Energy Development plan (AEDP) 2008- 2022 as well as the implementation pursuant to the Energy Conservation Program, Phase 3 (2005-2011), under which the target of energy saving has been adjusted from 10.8 percent to 20 percent by focusing mainly on energy saving promotion in the industrial and transportation sectors. These policies will promote energy security of the kingdom by reducing energy imports and increasing energy resources, building competitive energy market for sustainable economic growth, and help reducing the emission of greenhouse gases in the long run (Ministry of Energy, 2008).

The cabinet approved the 15-Year of Alternative Energy Development plan (AEDP) on January 28, 2009. The announced goal is to speed up the utilization of renewable energy to constitute up to 20 percents of total energy consumption by 2022. Policies that came out from the plan will promote energy security of the kingdom by reducing energy imports and increasing domestic energy resources, building competitive energy market for sustainable economic growth, and help reducing the emission of greenhouse gases in the long-run. For increase sharing of renewable energy mixed to 20 percent of the final energy demand in 2022 (Ministry of Energy, 2009). Regions in Thailand present different potentials for renewable supply on biomass, municipal wastes, hydropower, and wind. To maximize renewable energy development in each area, location is matter. Currently, energy-derived biomass is widely utilized within the country, however if droughts happen more often and severe, it will not only affect food security but also energy security.

This section reviewed the latest situation on renewable powers and developmental strategies toward low carbon electricity generation in Thailand. Government recently has spent tremendous financial and legislative supports to promote the uses of indigenous renewable energy resources and fuel diversification while contributing in global greenhouse gas emission reduction. Major policy challenge is on which types of renewable energy should be more pronounced to ensure sustainable future of the country.

2.2.3.2 Generate electricity from nuclear power sources

The topic of electricity generation from nuclear power elicits strong emotions from supporters and critics. Although nuclear power supplies only the equivalent of 5.7 percent of the world primary energy at the time of writing this thesis, some believe this should be expanded massively. IEA (2009b) estimated the expansion of electricity generation from nuclear power plants rises from 2,719 TWh in 2007 to 3,670 TWh in 2030. Nuclear power generation capacity reached 371 GW in 2007 and is projected to rise to 410 GW by 2015 and to 475 GW by 2030. They also argue that it is an attractive source of electricity, having very low carbon emissions. Nuclear power plants produced 446 TWh or 4.9 percent of total gross electricity production reported for Non-OECD countries for 2007. Nuclear generation rose by 2.5 percent compared to 2006. Nuclear generation growth in Non-OECD countries expanded very rapidly from 1973 to 1985 with an annual average rate of 26 percent. Since, growth was noticeably lower with an annual average rate of 3 percent from 1985 to 2007.

After the Three Mile Island and the Chernobyl accidents there was a period of nearly ten years during which almost no new nuclear capacity was constructed. However, the recent concerns regarding fossil fuel security have prompted a number of countries to consider new building programmes (Rothwell and Graber, 2010). China and India are planning to build several tens of reactors each and the USA is posed to do the same. In contrast with Europe, only Finland has embarked on the construction of a new nuclear plant while, Sweden, Switzerland and Germany all have moratoriums in place leading to a phasing out of nuclear power. France on the other hand, remains committed to nuclear power which contributes about 80 percent of its present electricity needs.

Thailand will inevitably face energy crisis with the dramatic energy demand growth while oil and natural gas resources will be depleted sharply in the near future. Thai Government is considering for other promising alternative energy source that is nuclear power. Growing electricity demand, fluctuation of fossil fuel prices and climate change pressure bring all in a favor of nuclear power. From study of EGAT estimated every one kilowatt-hour of electricity produced in Thailand emits $CO_2$ by 0.5 kilogram (Electricity Generating Authority of Thailand, 2010b).

Therefore, the use of nuclear power will assist in achieving emission reduction goal for climate change in the future. To power future energy supply, Thailand issued the 20 years Power Development Plan covered a period 2010 to 2030 (PDP-2010), to enhance reliability of power supply, fuel diversification, power purchase from neighboring countries, power demand forecast and others. The PDP-2010 was approved by the National Energy Policy Council (NEPC) and endorsed by the cabinet in April 2010. Under PDP-2010, five thousand megawatt of nuclear power plant (5,000 MW) are expected to start operations during 2020-2030 and the first nuclear power plant will operate in 2010 (Electricity Generating Authority of Thailand, 2010b).

However environmentalists, public policy makers, and financiers like to see a risk assessment of the nuclear option compared to other possible solutions (Eerkens, 2010). Such stakeholders want to be convinced that an expansion of nuclear power plants can be done safely and economically before they will give it their supports. They are apprehensive because a multitude of fear-instilling misrepresentations has been circulated in the media about nuclear power. Many of these stakeholders favor development of more diverse renewable energy e.g. solar, wind, and biomass energy at the exclusion of nuclear power without considering the scale, cost, and feasibility to replace the vast quantities of portable fuels presently extracted from oil fields. Government believes that modern nuclear plants are safe and have high quality-control standards.

Human factor is often weak point in the use of advanced technologies; education is very important, training also a key issue to develop specific behavior that can make the different between industrial culture and safety culture, which is critically required by nuclear operation. Now, the systematic process of nuclear development program will require both a strong political will and people's acceptance to be open and transparent in order to create public trust by providing essential and precise information to public along with the benefits to the country. Within 2012, the cabinet will make the final approval on the construction of the first nuclear power plant based on the results of the feasibility study on infrastructure information, utility and public acceptance.

2.2.3.3 Introduced clean coal technology

Coal is undoubtedly part of the greenhouse problem. The main greenhouse gas emissions from coal combustion are carbon dioxide, sulfur dioxide, nitrogen oxides, particulates, and mercury (Zhang, Zhuo et al., 2008). The three major uses of coal are: electricity generation, steel and cement manufacture, and industrial process heating. Coal-fired technologies are very common and widespread worldwide, both in developing countries and in industrialized countries. In 2006, total coal production increased by 7.6 percent, well above the 10-year average growth trend of 3.0 percent. Hard coal production increased by 8.8 percent (or 435.8 Mt) to 5,369.8 Mt. Brown coal production increased by 0.9 percent (or 7.8 Mt) to 913.8 Mt, a little above its 1997 level (The International Energy Agency, 2007).

Globally, the largest source of anthropogenic GHG emissions is $CO_2$ from the combustion of fossil fuels – around 75 percent of total GHG emissions covered under the Kyoto Protocol. Coal is the second source of $CO_2$ emissions within the OECD: between 1971 and 1985, coal was used as the main substitute to oil and its share increased, especially between 1978 and 1985, from its lowest point (31%) to its highest point (39%). Indeed, the challenge for governments and industry is to find a path that mitigates carbon emissions yet continues to utilize coal to meet urgent energy needs, especially in developing economies. Currently and for the near future, coal provides the major portion of global electric power supply. GHG emissions from coal-fired power generation arise mainly from the combustion of the fuel, but significant amounts are also emitted at other points in the fuel supply chain (Jaccard, 2005).

From study of MIT on future development of electricity generation from coal examines the role of coal as an energy source in a world where constraints on carbon emissions are adopted to mitigate global warming (Ansolabehere, Beer et al., 2007). The study suggested government should and will take more action to restrict the emission of carbon dioxide and other greenhouse gases. It should be noted that uses of clean coal technologies (CCTs) can reduce the environmental impact of burning coal. During the last two decades, significant advances have been made in the reduction of emissions from coal-fired power plants. In short, greenhouse gas reduction policies have, and will have, a major impact on the future use of coal. The coal industry's technical response to the environmental challenge is ongoing, with three core elements. First, to eliminating emissions of pollutants such as particulates, oxides of sulfur and nitrogen from electricity generation processes. Second, improving combustion technologies to increase efficiency and development of carbon capture and storage (Ansolabehere, Beer et al., 2007).

#### 2.2.3.4 Introduce carbon capture and storage system

Growing concerns over the consequences of climate change may severely limit future access to fossil fuels. A forced choice between energy and environment could precipitate a major economic crisis, an environmental crisis, or both. Averting such a crisis will be difficult, because fossil energy resources are an essential part of the world's energy supply and climate change is mainly driven by the build-up of carbon dioxide in the atmosphere. Applications to fossil fuel power plants are especially important, since such plants account for the major portion of $CO_2$ emissions from large stationary sources. Recently, the concept of carbon capture and storage (CCS) as a means for reducing $CO_2$ emissions from power plants has emerged with several projects planned worldwide (Pocklington and Leese, 2010). The option of capturing $CO_2$ and storing it offers a means of allowing the large reserves of fossil fuels to be utilized while at the same time controlling GHG emissions. Methods of capturing and then storing $CO_2$ from major sources, such as fossil fuel burning power plants, are being developed in order to reduce the levels emitted to the atmosphere by human activities (Lackner, 2010).

Carbon dioxide is the unavoidable product of fossil fuel consumption. Therefore, the use of fossil fuels collides directly with global environmental concerns. Unfortunately, fossil fuels are difficult to replace, but stabilizing the atmospheric concentration of carbon dioxide requires a nearly complete transition to a carbon-neutral economy. This implies either the abandonment of fossil fuels or the introduction of carbon capture and storage, whereby for every ton of carbon extracted from the ground, another ton of carbon is put back. The capture of carbon dioxide from flue gases of industrial combustion processes and its storage in deep geological formations is now being seriously considered as one of the options for mitigating climate change. Given the growing worldwide interest in CCS as a potential option for climate change mitigation, the expected future cost of CCS technologies is of significant interest (Tondeur and Teng, 2008).

Schumacher et al. (2009) describe roles of CCS to provide low-emissions coal power station. CCS is an incremental innovation, representing a change within the existing system that does not endanger its overall structure. CCS allows for the continued use of fossil fuels, can be combined with the existing infrastructure (that is, mostly large-scale centralized power plants) and implemented by existing actors. Opponents therefore fear that CCS may further delay the urgent transition to a carbon-free electricity system. However, CCS may also be considered as an innovation that "buys time" for radical restructuring and may serve as a bridging technology towards a sustainable energy future. CCS could then be an innovation that paves the way out of the current carbon focus of electricity generation.

CCS has issues of concerns, i.e. CCS is an energy-intensive process, which lowers the overall efficiency of the power plant. In order to compensate for this efficiency loss, more fossil fuel per unit of electrical output must be used thus leading to further emissions. Furthermore, while capturing $CO_2$ from the power plant can reduce direct emissions from the power plant itself, upstream emissions resulting from fuel and material procurement and downstream emissions resulting from waste disposal cannot be captured. These upstream and downstream emissions are small when compared with emissions from combustion. However, when CCS is included, these emissions become dominant and so they must be included in the assessment (Odeh and Cockerill, 2008). CCS has an important and inevitable energy cost, implying that when it is applied, more primary energy is needed and, ultimately, more carbon dioxide is generated to produce a given amount of final energy. Clearly, this has to be accounted for carefully in accounting the benefits. The analysis of energy consumption is strongly related to the technology, in particular to the mode of combustion employed in the power plants.

Table 1 Summary of Availability of New Technologies Affecting the Electricity Industry

| Generation Technologies | | | |
|---|---|---|---|
| Technology | Impact | Limitation | Availability |
| Integrated gas combined cycle turbines (IGCC) | Reduce $CO_2$ emissions; higher conversion efficiency; well suited to meet intermediate and peak demands | Gas price and supply uncertainty; still emits some $CO_2$ | Now |
| Nuclear Power | No direct $CO_2$ emissions | High cost, public perception, spent fuel, security | Now |
| Biomass | Large $CO_2$ reduction | Cost of collection; aesthetics; technical limits to % that can | 10 years |
| Wind Power | Most competitive renewable energy option; recent growth driven by incentives (taxes, credits) and renewable portfolio standards | Land availability; aesthetics; high cost of storage | 10 years |
| Solar Photovoltaic (PV) power | High % of $CO_2$ reduction | Intermittent; conversion is both expensive and inefficient | 25 years |
| Hydrogen (used in fuel cells) | Potentially large $CO_2$ reduction from electric power | Hydrolysis of water is costly; natural gas ($CH_4$), coal gasification the most likely sources | 40 years |
| Internal combustion engines (ICE) | Use of natural gas reduces $CO_2$ emissions; use of CHP; increases end-use efficiency | Many current regulations limit distributed generation and micro-grids | Now |
| Micro-turbines | Use of natural gas reduces $CO_2$ emissions; use of CHP increases end-use efficiency | Many current regulations limit distributed generation and micro-grids | 15 years |
| Advanced flow control systems | Improved system efficiency and reliability | Market learning needed to bring costs down | 5 years |
| Superconducting material | Reduced line losses Greater control over power flow | | |
| Energy Efficient End-Use Devices and Advanced Load Control<br>Energy-efficient end-use devices and advanced load control | Reduce energy consumption<br>More efficient end-use appliances | Mainly behavioral and institutional | Now |

Source: Modified from Labatt and White (2007)

### 2.2.4 Capacity building in clean energy industry

In order to address the global climate change challenge, the electricity sector recognizes the need for more efficient electricity consumption and less carbon-intensive electricity supply. This shift will require the use of all technology and energy use management options available today, as well as future solutions currently face technological or commercial barriers to deployment. The decarbonisation of electricity is the key enabling factor for reducing emissions from power consumption sectors. It has a smaller role in enabling reductions in emissions from industry. Varieties of options exist for the utility sector; including the expansion of renewable energy like wind and solar, improving the thermal efficiency of electric generation as well as co-firing fossil fuel with biomass.

Collaborative Economics (2010) described the clean energy economy comprises five categories: (1) Clean Energy; (2) Energy Efficiency; (3) Environmentally Friendly Production; (4) Conservation and Pollution Mitigation; and (5) Training and Support. However, the clean energy economy also generates jobs, businesses and investments while expanding clean energy production, increasing energy efficiency, reducing greenhouse gas emissions, waste and pollution, and conserving water and other natural resources. Although specific jobs and businesses will change over time, the categories will not providing a clear, practical and consistent framework for policy makers and the private sector to track investments, job and business creation, and growth over time. Investing in clean energy already provides tens of thousands of workers with good jobs during hard times. The renewable energy industry in the United States opened 450,000 jobs in 2006 (Board on energy and environmental systems, 2010).

Table 3 and Table 4 show breakdown of renewable energy specific positions in US. Examples of jobs: Financial analysts and consultants specialize in clean technology investments, lawyers and paralegals provide legal services, researchers and engineers develop new energy generation technologies, and vocational teachers train new workers for the clean energy economy.

Table 2 Direct Jobs in US Renewable Energy Sector in 2006

| Industry Segment | Revenues/Budget (billion USD) | Direct jobs |
|---|---|---|
| Wind | 3.0 | 16,000 |
| Photovoltaics | 1.0 | 6,800 |
| Solar thermal | 0.1 | 800 |
| Hydroelectric power | 4.0 | 8,000 |
| Geothermal | 2.0 | 9,000 |
| Bio-power | 17.0 | 66,000 |
| Federal government (including direct-support contractors) | 0.5 | 800 |
| DOE laboratory (including direct-support contractors) | 1.8 | 3,600 |
| State and local governments | 0.9 | 2,500 |

Source: Board on energy and environmental systems (2010)

Table 3 Green Job Industry Segment in US

| Green Job Industry Segments | Included within Industry Segment |
|---|---|
| 1. Low Carbon Power & Renewable Power | Renewable/conventional equipment & power sales, project design & development |
| 2. Carbon Capture & Storage (CCS) | Systems, equipment |
| 3. Energy Storage: Equipment & Systems | Equipment & systems (batteries, hydrogen, etc.) |
| 4. Energy Efficiency and Demand Response | Systems, equipment & appliances, audit & studies |
| 5. Green Buildings | Design & development, building materials |
| 6. Transportation | Vehicles, fuels & systems |
| 7. Carbon Markets: Trading & Projects | Carbon trading, project development & operation |
| 8. Climate change Adaptation | Risk assessment, planning, engineering & construction |
| 9. Public-sector/ Government | Conservation & pollution prevention, rules & enforcement |
| 10. Consulting & Research | Consulting & engineering, climate science |
| 11. Waste Reduction & Management | Recycling & waste treatment |
| 12. Non-Profit Sector | Policy analysis & advocacy |

Source: Environmental Defense Fund (2009)

Table 4 Example of Breakdown of Renewable Energy Specific Positions

| Wind | Solar | Biomass | Geothermal |
|---|---|---|---|
| Electrical, mechanical, engineers and technicians | Electrical, mechanical, chemical | Chemist and biochemist | Geologist, geochemist and geophysicists |
| Aeronautical engineers | Material scientists | Agricultural specialist | Hydrologists |
| Construction workers | Physicists | Microbiologist | Hydraulic engineers |
| Meteorologists | Construction worker, architects and builders | Electrical, mechanical, chemical engineers and technicians | HVAC contractors |

Source: Board on energy and environmental systems (2010)

## 2.3 International Response for Greenhouse Gas Mitigation

The problem's political dimension is further complicated by the different time horizons affecting climate change (decades to centuries); the time horizon of assets in the electricity generation business (decades); and the time horizon of consumers, voters, and politicians (typically months to years). Decision making in these various segments necessarily follows different patterns with different priorities. To address these significant disparities, yet again, an integrated approach is need. This could be the most difficult challenge we are facing to address the carbon problem. This call for international cooperation to address environmental challenges was reiterated during the 1992 United Nations Conference on Environment and Development (commonly referred to as the "Earth Summit"). Among other things, the Rio Declaration[7] identified a clear link between sustainable development, economic growths, environmental protection, and called on countries to "cooperate to promote a supportive and open international economic system that would lead to economic

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[7] The Rio Declaration on Environment and Development defines the rights of the people to be involved in the development of their economies, and the responsibilities of human beings to safeguard the common environment. The declaration builds upon the basic ideas concerning the attitudes of individuals and nations towards the environment and development

growth and sustainable development in all countries, to better address the problems of environmental degradation."

The Earth Summit was also crucial from a climate change perspective, as it led to the adoption of the United Nations Framework Convention on Climate Change (UNFCCC); the first global effort to address climate change. The Intergovernmental Panel on Climate Change (IPCC) established by the World Meteorological Organization (WMO) and the United Nations Environment Programme (UNEP), is widely recognized as the principal authority for objective information on climate change, its potential impacts, and possible responses to these. The "ultimate objective" of the UNFCCC is the "stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference (i.e. resulting from human activity) with the climate system." The Convention elaborates a number of principles to guide parties in reaching this objective: for instance, the Convention calls on parties to employ a "precautionary approach" to climate change. The UNFCCC also manifest the principle of "common but differentiated responsibilities," which recognizes that even though all countries have a responsibility to address climate change, they have not all contributed to the same extent to cause the problem, nor are they all equally equipped to address it (Tamiotti, Teh et al., 2009). In the current period of concern regarding climate change, activity has taken place at both scientific and political levels (Table 5). The following section summarizes the progress made in these two areas.

Table 5 Major Milestones in the International Climate Change Regimes

| Date | Activities |
|---|---|
| 1954 | The World Conservation Union Meeting in Copenhagen |
| 1972 | The First Earth Summit at Stockholm |
| 1979 | The first World Climate Conference |
| 1987 | The UN General Assembly declares climate change as "common humanity concern" |
| 1988 | UNEP and the World Meteorology Organization (WMO) establish the Intergovernmental Panel on Climate Change (IPCC) |
| | Toronto Scientific Conference on the Changing Atmospheric |
| | Calls for a 20 percent cut to 1988 GHG emission by 2005 |
| 1990 | The IPCC first Assessment Report concludes that the planet seems to be warming and human activities seems to be responsible for it. |

| Date | Activities |
|---|---|
| 1992 | The UN Framework Convention on Climate Change (UNFCCC) is agreed to at the Rio Earth Summit |
| | The Rio Convention calls for a stabilization of GHG emissions by 2000 |
| 1994 | The UNFCCC enters into force |
| 1995 | The UNFCCC COP-1 Meeting at Berlin |
| | The IPCC Second Assessment Report concludes that there is evidence suggesting a discernible human influence on the global climate |
| 1997 | The COP-3 meeting at Kyoto |
| | Adoption of the Kyoto Protocol to the UN Climate Convention |
| 1998 | The COP-4 meeting at Buenos Aires and call for action plan on how to reach the targets |
| 2001 | The IPCC Third Assessment Report on scientific evidence of global warming |
| | The IPCC finds stronger connection between human activities and global climate system |
| | The UNFCCC COP-10 meeting at Marrakesh |
| 2002 | The Third Earth Summit at Johannesburg |
| 2004 | Russia ratifies the Kyoto Protocol |
| 2005 | Kyoto Protocol enters into effect on February 16th |
| | First Meeting of the Parties (MOP) of the Kyoto Protocol takes place in Montreal, Canada |
| | The UNFCCC COP-11 meeting at Montreal and release Montreal Action Plan |
| 2006 | The Fourth Assessment Report on "warming of climate system is unequivocal" |
| 2007 | The UNFCCC COP-12 meeting at Bali and adoption on the Bali Road Map |
| 2008 | The UNFCCC COP-13 at Poznan |
| 2009 | The Bangkok Climate Change Talk |
| 2009 | The UNFCCC COP-14 meeting at Copenhagen |
| 2010 | Expected to draft the post Kyoto Protocol |

Source: Summarized from Baumert et al. (2005), Staley and Freeman (2009) and UNEP GRID-Arendal (2009)

### 2.3.1 The Kyoto Protocol

The Kyoto Protocol to the United Nations Framework Convention on Climate Change (UNFCCC) entered into force on February 16, 2005, following ratification by the Russian Federation. As of May 11, 2007, 172 countries and the regional economic integration organization (European Economic Community) have ratified, accepted, approved, or acceded to the Kyoto Protocol (The World Bank, 2008). The UNFCCC includes the principle of "common but differentiated responsibilities[8]" to reduce GHG concentration in the global atmosphere (The United Nations, 1998; UNFCCC, 2010c).

The objective of the Kyoto climate change conference was to establish a legally binding international agreement, whereby all the participating nations commit themselves to tackling the issue of global warming and greenhouse gas emissions. At the same time, an intense debate is underway regarding the technical and economic feasibility of different target levels, which emission reduction opportunities should be pursued, and the costs of different options for meeting the targets. Countries that have accepted greenhouse gas emissions reduction obligations must submit an annual greenhouse gas inventory. Non–Annex I countries (developing countries) that have ratified the Protocol do not have to commit to specific targets because they face potential technical and economic constraints. Nevertheless, they have to report their emissions levels and develop National Climate Change Mitigation Programs (UNFCCC, 2010b).

Leaders in many nations are discussing ambitious targets for reducing emissions of greenhouse gases (GHGs). Some regions have already set reduction targets. The EU, for example, has set a target that 2020 emission levels should be 20 percent lower than those of 1990, and has stated its intention of aiming for a 30 percent reduction if other countries with high emissions also commit to comparable emission cuts (McKinsey and Company, 2009). Under Kyoto Protocol requires Annex I countries[9] to collectively reduce their emissions of the six main greenhouse gases (i.e. carbon dioxide, methane, nitrous oxide, hydro fluorocarbons, per fluorocarbons, and sulphur hexafluoride) to at least 5 per cent less than 1990 emission

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[8] UNFCCC adopts a principle of "common but differentiated responsibilities" on three board topics: (1) the largest share of historical and current global emissions of greenhouse gases originated in developed countries; (2) per capita emissions in developing countries are still relatively low; and (3) the share of global emissions originating in developing countries will grow to meet social and development needs

[9] Annex I countries include the industrialized countries that were members of the Organization for Economic Co-operation and Development (OECD) in 1992, plus countries with economies in transition (the EIT parties), including the Russian Federation, the Baltic states, and several Central and Eastern European states

levels. This target must be achieved over the five-year period from 2008 to 2012 (See also in Table 6).

Table 6 Emission Reduction Targets in the Kyoto Protocol for Annex I Countries

| Countries | Target (1990-2008/2012) |
|---|---|
| EU-15, Bulgaria, Czech Republic, Estonia, Latvia, Liechtenstein, Lithuania, Monaco, Romania, Slovak Republic, Slovenia, Switzerland | -8% |
| United States | -7% |
| Canada, Hungary, Japan, Poland | -6% |
| Croatia | -5% |
| New Zealand, Russia, Ukraine | 0 |
| Norway | +1% |
| Australia | +8% |
| Iceland | +10% |

Source: UNFCCC (2010a)

Although 172 countries and a regional economic integration organization (the European Economic Community) are parties to the agreement (representing over 61 percent of emissions), only a few industrialized countries are actually required to cut their emissions. The United States, the world's largest emitter, has conditioned its entry on further engagement of major developing country emitters, such as China and India. In countries that have begun to implement the Kyoto regime, this disparity in commitments has fueled a debate on issues of competitiveness and other economic impacts. The Kyoto Protocol remains the key international mechanism under which the industrial countries have committed to reduce their emissions of carbon dioxide and other greenhouse gases. The target agreed upon was an average reduction of 5.2 percent from 1990 levels by the year 2012. According to the treaty, in 2012, Annex I countries must have fulfilled their obligations of reduction of greenhouse gases emissions established for the first commitment period (2008–2012).

### 2.3.2 The Bali Road Map

After the 2007 United Nations Climate Change Conference on the island Bali in Indonesia in December, 2007 the participating nations adopted the Bali

Road Map as a two-year process to finalizing a binding agreement in 2009 in Copenhagen (UNFCCC, 2010d). The conference encompassed meetings of several bodies, including the 13th Conference of the Parties to the United Nations Framework Convention on Climate Change (COP-13) and the 3rd Meeting of the Parties to the Kyoto Protocol (MOP-3 or CMP-3).

The Bali Road Map includes the Bali Action Plan (BAP) that was adopted by Decision 1/CP.13 of the COP-13. It also includes the Ad Hoc Working Group on Further Commitments for Annex I Parties under the Kyoto Protocol (AWG-KP) negotiations and their 2009 deadline, the launch of the Adaptation Fund, the scope and content of the Article 9 review of the Kyoto Protocol, as well as decisions on technology transfer and on reducing emissions from deforestation. The Bali Action Plan highlighted the importance of "Measurable, Reportable and Verifiable (MRV)" greenhouse gas mitigation actions and commitments for a post-2012 climate framework.[10] The Climate Change Conference in Bali laid key foundations for negotiations on a post-2012 climate regime. It emphasizes the willingness of all Parties to contribute to a future climate regime in line with their respective capabilities and determines that all Parties must report on their measurable and verifiable activities. Together with a range of other decisions it forms the Bali Roadmap, the negotiation mandate. The negotiations are to be concluded at the Climate Change Conference in Copenhagen in 2009.

### 2.3.3 Copenhagen accord

The UN Climate Change Conference, held in December 2009 in Copenhagen, was a crucial moment in the international fight against dangerous climate change. Representatives from hundreds of governments and other organizations around the world gathered to make their voices heard. The Copenhagen Accord commits the world to limit temperature increases at two degrees Celsius (2°C)

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[10] Currently, experience with measurement, reporting and verification (MRV) of GHG mitigation has been focused in three areas: project-based reductions in non-Annex I countries through the clean development mechanism (CDM); entity-based emission levels in Annex I countries (e.g. through emission trading schemes); and national-level GHG accounting in Annex I countries.

and contains plans for finance reaching a hundred billion dollars a year by 2020 (Department of Energy and Climate Change, 2010; Verbruggen, 2009).

Since Copenhagen, over 100 countries have associated themselves with the Accord and as a result of the targets and actions put forward; around 80 percent of emissions are covered by the agreement. It is a political agreement, which includes a number of substantial commitments:

– Endorses the continuation of the Kyoto Protocol

– Underlines that climate change is one of the greatest challenges of our time and emphasizes a "strong political will to urgently combat climate change in accordance with the principle of common but differentiated responsibilities and respective capabilities"

– Recognizes that "deep cuts in global emissions are required according to science" (IPCC AR4) and agrees cooperation in peaking (stopping from rising) global and national greenhouse gas emissions "as soon as possible" and that "a low-emission development strategy is indispensable to sustainable development"

– Agreement to reduce global emissions and limit average increases in global temperature to no more than 2°C.

– Developed and developing countries pledge to put their emissions reduction targets and mitigation actions into appendices to the Accord by January 31, 2010.

– The developing nations (non-Annex I Parties) would "implement mitigation actions" (Nationally Appropriate Mitigation Actions) to slow growth in their carbon emissions, submitting these by 31 January 2010. LDS and SIDS may undertake actions voluntarily and on the basis of (international) support.

– The developing countries would report those actions once every two years via the U.N. climate change secretariat, subjected to their domestic MRV. NAMAs seeking international support will be subject to international MRV

– Recognizes "the crucial role of reducing emission from deforestation and forest degradation and the need to enhance removals of greenhouse gas emission by forests", and the need to establish a mechanism (including REDD-plus) to enable the mobilization of financial resources from developed countries to help achieve this

– A commitment from developed countries to provide approaching $30 billions of immediate fast start funding over the period 2010-2012 to support developing country action on mitigation and adaptation.

– A commitment from developed countries to work towards long-term public and private climate finance flows reaching $100 billion a year by 2020.

– Agreement to establish a High Level Panel to explore the potential sources of climate finance that would help achieving this $100 billion goal.

– Agreement to set up a new Copenhagen Green Climate Fund (the 'Green Fund') to deliver a significant portion of this finance to developing countries.

– Agreement to establish a technology mechanism to achieve greater coordination and scaling-up of global action on technology development and deployment.

– Agreement to establish a new mechanism to help developing countries tackles deforestation.

– A commitment to review progress in implementing the Accord by 2015.

### 2.3.4 Clean Development Mechanism (CDM)

Countries with commitments under the Kyoto Protocol (KP) to limit or reduce greenhouse gas emissions must meet their targets primarily through national measures. The Protocol does not prescribe how emission reductions should be met. As additional means of meeting these targets, the Kyoto Protocol introduced three market-based mechanisms, now known as the "carbon market." It does, however, propose three flexible mechanisms designed to help Annex 1 countries meeting their emission reduction obligations: namely emissions trading schemes (ETS), Joint

Implementation (JI), and the Clean Development Mechanism[11] (CDM) (Labatt and White, 2007).

The Clean Development Mechanism (CDM) is one of the two project-based flexible mechanisms of the 1997 Kyoto Protocol. The CDM allows industrialized countries to meet their emissions reductions targets in part through 'carbon credits' bought by investment in low-carbon projects in developing countries. CDM projects are also supposed to result in benefiting developing countries by helping them to achieve sustainable development (Volpi, 2005). The CDM enables the project owner to sell the ER credits, once they are certified, to an interested buyer. The CDM allows developed countries listed in Annex 1 of the UNFCCC to invest in greenhouse gas emission reduction projects in non-Annex 1 developing countries to claim Certified Emission Reduction[12] (CERs) to assist them in compliance with their binding GHG emission reduction commitments under the protocol (The World Bank, Ministry of Science and Technology. P.R. China et al., 2004).

The CDM allows industrialized countries to invest in emission reductions wherever it is cheapest globally. Between 2001, which was the first year CDM projects could be registered, and 2012, the end of the Kyoto commitment period, the CDM is expected to produce some 1.5 billion tons of carbon dioxide equivalents ($CO_2$-eq) in emission reductions (Figure 6 and Figure 7 illustrate status of CDM in term of types and amount of CERs). Most of these reductions are through renewable energy, energy efficiency, and fuel switching. However, a number of weaknesses of the CDM have been identified. The benefits of CDM for the developing country are new financial resources, technological transfer, and achievement of its sustainable development objectives, while the benefit for developed countries is access to less expensive ER opportunities in a developing

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[11] The CDM is a financing instrument defined in Article 12 of the Kyoto Protocol. A project in a developing country that reduces GHG emissions, relative to a baseline project, generates emissions reduction (ER)

[12] Certified Emission Reductions (CERs) are a type of emissions unit (or carbon credits) issued by the Clean Development Mechanism (CDM) Executive Board for emission reductions achieved by CDM projects and verified by a DOE under the rules of the Kyoto Protocol

countries. As emissions have the same global effect irrespective of their geographical origin, CDM provides a cost-effective way of addressing the adverse effects of global warming (World Bank Carbon Finance Unit, 2006).

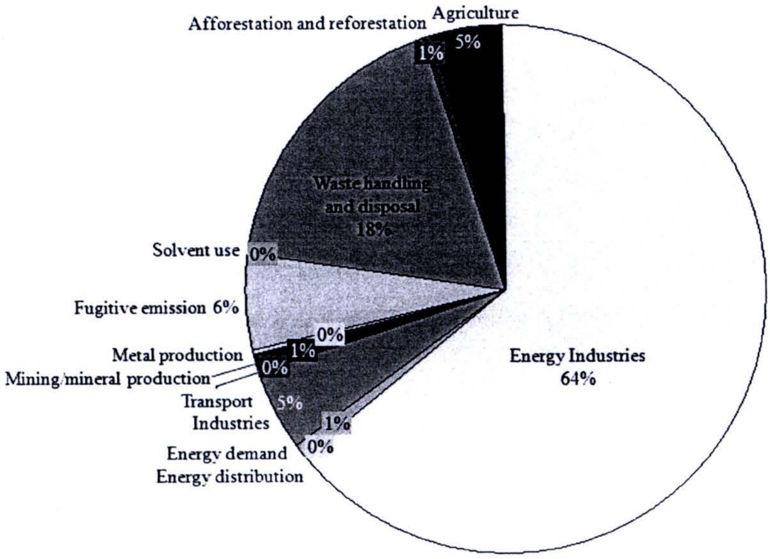


Figure 6 Distribution of Registered Project Activities by Scope

Source: Using data from UNFCCC (2010a)

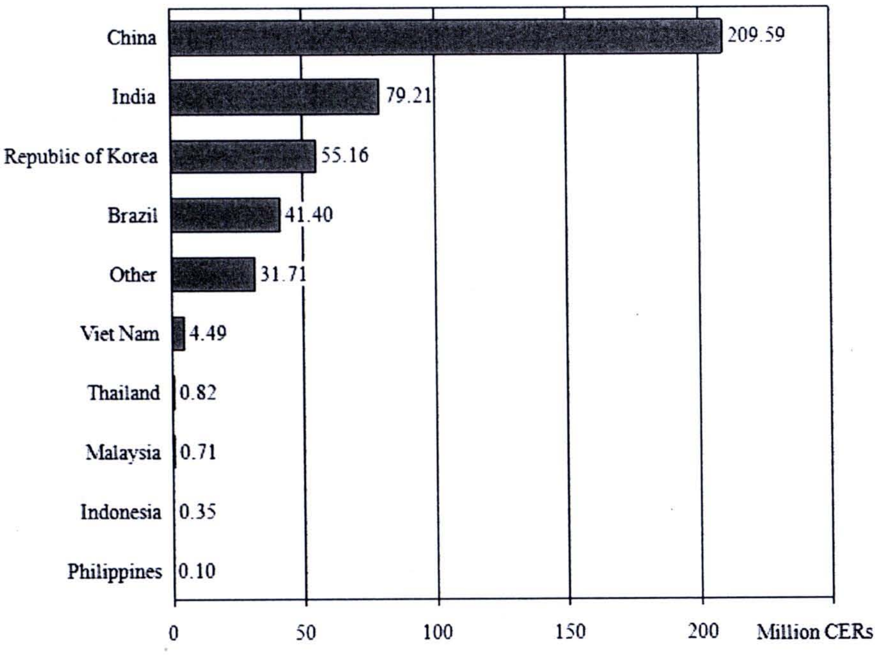


Figure 7 CERs issued by Host Party

Source: Using data from UNFCCC (2010b)

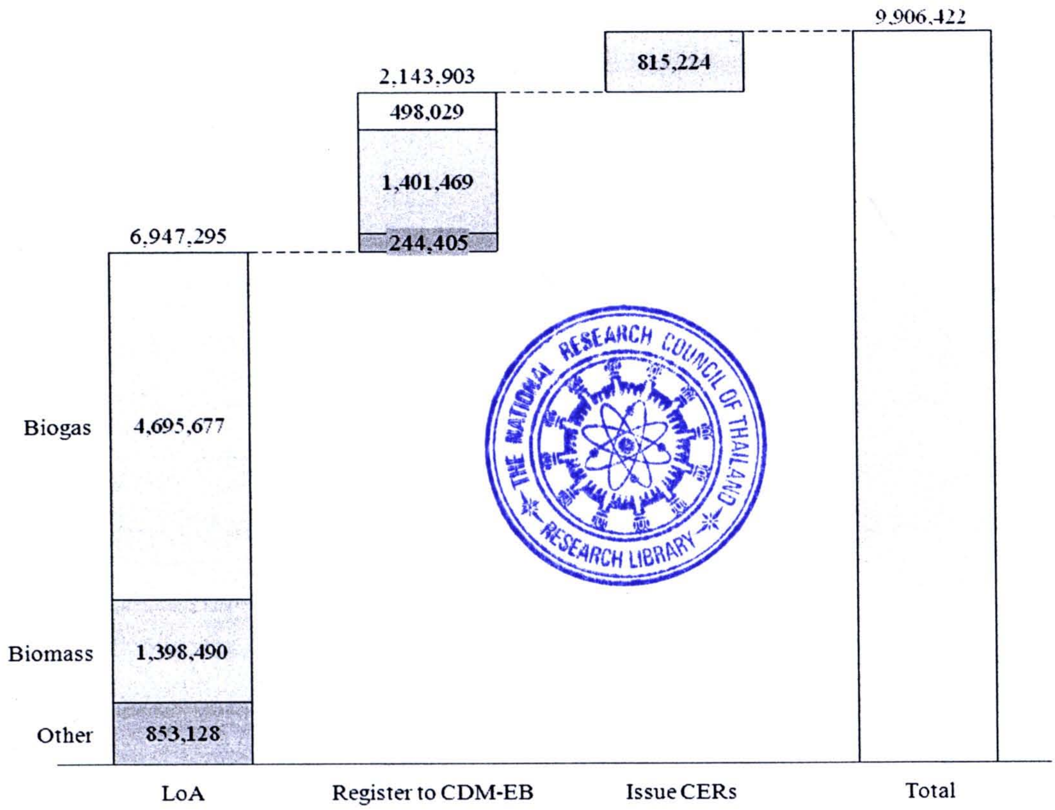




Figure 8 Status of Thailand CDM

Source: Using data from TGO (2010)

2.3.5 Nationally Appropriate Mitigation Actions

While the Bali Action Plan[13] suggests the possibility of linking GHG mitigation action in developing countries with support for such action, in a "measurable, reportable and verifiable (MRV)[14]" manner, it does not specify the relationship between nationally appropriate mitigation actions (NAMAs) in developing countries and support for such actions. In particular it leaves open the question of whether or not the two should be explicitly linked, or whether progress in

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[13] Paragraph 1(b) (ii) of the Bali Action Plan calls for: "Nationally appropriate mitigation actions by developing country Parties in the context of sustainable development, supported and enabled by technology, financing and capacity-building, in a measurable, reportable and verifiable manner".

[14] In defining a framework for MRV of action and/or support, many issues still remain to be addressed. Still to be defined for the post-2012 regimes are the scope of what needs to be measured (e.g. GHG outcomes, intermediate outcomes, or inputs), how it should be measured, when MRV is required, and who should be responsible for doing it.

one area might be dependent on progress in the other area (e.g. actions are dependent on financing or financing is dependent on actions). It also remains unclear whether the MRV requirements apply to the link between NAMAs in developing countries and mitigation support, or to one or both of the separate elements. However, the Bali Action Plan does not specify the relationship between NAMAs in developing countries and support for such actions. In particular it leaves open the question of whether the two should be linked or whether progress in one area is dependent on progress in the other area (e.g. actions are dependent on financing or financing is dependent on actions). It also remains unclear whether the MRV requirements apply to the link between NAMAs in developing countries and mitigation support, to one or both of the separate elements or to all three dimensions of the linking notion.

In the international climate negotiations preceding Copenhagen in December 2009, nationally appropriate mitigation actions, (NAMAs) were used as the solution of many open issues and with very different interpretations of what the term actually stands for. The negotiations have so far failed to define what NAMAs actually are. Views also differ on the institutional structure needed for providing support to NAMAs as well as ways to measure, report and verify actions. Due to this vague approach, the negotiations surrounding NAMAs are still generalized, making it difficult to work on concrete implementation issues. In many discussions and submissions, NAMAs have been categorized as follows:

– Unilateral NAMAs: mitigation actions undertaken by developing countries on their own

– Supported NAMAs: mitigation actions in developing countries, supported by direct climate finance from Annex I countries (in the following called 'directly supported NAMAs')

– Credited NAMAs: mitigation actions in developing countries, which generate credits to be sold on the carbon market (e.g. sectoral crediting).

## 2.4 Summary of Findings

Climate change is now a scientifically established fact. The exact impact of greenhouse gas emission is not easy to forecast and there is a lot of uncertainty in the science when it comes to predictive capability. But we now know enough to recognize that there are large risks, potentially catastrophic ones (Watkins, Ugaz et al., 2007). Climate change, and more specifically the carbon emissions from energy production and use, is one of the more vexing problems facing society today. It is not just an environmental issue. It is fast becoming one of the defining facts of economic development in the 21st century. It will shape investment, technology deployment and human development around the world and no sector will be more profoundly affected than energy. Energy is central to sustainable development and poverty reduction efforts. It affects all aspects of development.

Currently, electric power production is largely based on the combustion of fossil fuels, predominantly coal and natural gas, except in countries with abundant hydropower. This inevitably leads to the emission of $CO_2$, since carbon capture and storage and renewable energy sources are not feasible or available yet on a large scale. Decarbonisation of energy supply is among the key issues facing policymakers in the years ahead. To address the problem requires careful consideration and balance among multiple dimensions, technical, economic, social, and political. Electricity is versatile not only in its applications but also in its energy sources. It is the only practical way that we can currently use coal, nuclear, hydro, wind energy, and solar photovoltaic on a large scale, and we can actually use any other form of energy to produce it, including oil, natural gas, biomass, solar thermal, and geothermal, among others. Although electricity is still our most expensive form of energy, electricity prices have remained relatively stable during the past 30 years when fossil fuels prices have been extremely volatile (Randolph and Masters, 2008).

Electricity price does not truly reflect include externality to the world ecosystem. Energy fuels our economy and quality of life, but it is costly both in monetary terms and in impacts to the natural and human environment. These impacts are part of the "cost of doing business" but to a large extent they are not included in the costs of energy. They are termed externalities. Externalities are social costs borne by users and non-users alike, but not internally by the producer and thus are not reflected in the price of goods or services produced (Randolph and Masters, 2008). To achieve sustainable energy, we must consider these costs over the fuel or system's life cycle. These environmental impacts include air pollution from the combustion of fossil fuels, radioactive materials involved in the nuclear fuel cycle, impacts on lands and waters of fuel extraction, and transport and construction of conversion systems. Before addressing these impacts, the section below discusses what appears to be the major environmental constraint facing fossil energy—global climate change triggered by greenhouse gas emissions, primarily carbon dioxide from fossil fuel combustion.

Looking at the various factors influencing carbon emissions to find an efficient path for reducing carbon emissions, one might expect marginal cost of reducing $CO_2$ to be about the same for all alternative options. To find the most economically efficient path, it is important to seek and pursue opportunities for carbon reduction that have the lowest costs among all the sectors of the economy. In this context, it is not economically efficient, for example, to pursue high-cost but low-carbon opportunities in the electricity generation sector if electricity conservation can produce the same results at lower costs. By the same token, if low-cost opportunities exist in the transportation sector, these must be pursued before higher-cost opportunities in electricity generation are captured. Renewable energy is considered generally as sustainable energy. Nonetheless, environmental and social issues of renewable energy technologies do arise with increasing significance, increasing project size, and energy-related trade. Guidelines and recommendations for sustainable practices in renewable energy applications are becoming increasingly important.

In next chapter, current situation of Thailand's electricity generation system was presented, followed with evolution, current status, generation capacity, electricity demand, characteristics and fuel mixture in electricity generation.