THE POTENTIAL ROLE OF NUCLEAR ENERGY IN MITIGATING CO_2 EMISSIONS OF THE BUILT ENVIRONMENT IN THE UNITED ARAB EMIRATES

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A DISSERTATION

SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE

M.SC IN SUSTAINABLE DESIGN OF THE BUILT ENVIRONMENT

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CHAPTER 1: INTRODUCTION

1.1 OVERVIEW

This chapter constitutes a preface of the dissertation in order to present a superior preamble of the research merits. It highlights the catastrophe of global warming and climate change, and the carbon dioxide greenhouse effect along with the allied energy role. The need for alternative carbon free energy sources is illustrated within. Finally, it expresses the dissertation structure.

1.2 OUTLINE

The abundant traditional energy sources are massively impacting the planet's environment. These sources increase the Carbon Dioxide Greenhouse emissions which therefore increase the global warming and climate change. Currently CO_2 emission is a controversial topic in term of the cause whether it happened naturally or by human. Nevertheless, there is a fact that climate is changing. According to UN (2005), "Greenhouse gases are accumulating in Earth's atmosphere as a result of human activities……The changes observed over the last several decades are likely mostly due to human activities……" Hence, the Kyoto Protocol participant countries signed an agreement to reduce the CO_2 emissions to the 1990 level. However, some countries have fixed targets of reduction to even below 1990 level.

As an integrated measure to reduce CO_2 emission, Nuclear energy is presented as a Low-carbon energy which contributes to stabilize the CO_2 level in the atmosphere, and consequently diminishes the climate change and global warming. Uranium is the source of the nuclear power which is still available worldwide. It is not predicted to deplete promptly like fossil fuel which is expected to deplete after 8 decades. Another vital contributor to eliminating the CO_2 emission is the renewable energy sources, although, most of these sources are still immature and under development yet. Furthermore, renewable power has no self-sufficient coverage towards the ever-increasing energy demand which is directly proportional to the increased population. Thus, Nuclear energy – as an already developed energy - is capable to fill-in part of the transition gap from fossil fuel till getting a fully mature renewable energy.

1.3 GLOBAL WARMING AND CLIMATE CHANGE

“There is little time left. The opportunity and responsibility to avoid catastrophic climate change is in your hands,” said Mr. Ban Ki-Moon, the secretary-General of United Nations (UN), telling World Leaders at climate change summit in September 2009 (UN, 2009). The global warming can be defined as the steady increase in universal average temperature of the Earth’s near-surface in recent decades, which specialists believe that man-made greenhouse gas emissions are the main cause for (IPCC, 2007 and BBC, n.d). Global warming is a wide-ranging term which reflects a serious environmental problem and is, however, a leading cause to the climate change effect as liked to be refered to by scientests.

The Earth’s near-surface temperature is increasingly changing. The effect of climate change is currently a reality regardless the controversial views whether it is a human-made or an indirect result to unknown natural changes. The fact now is that burning fossil fuel is increasing the amount of green house gases and especially CO_2 in the atmosphere to significantly high levels. These gases form a barrier in the atmosphere which captures the absorbed heat within the near-surface of the earth.

The last two decades were remarkably ranking among the warmest years since 1850. The global temperature of land and ocean surface was 0.56°C higher than the 20th century average, tying with 2006 as the fifth warmest since 1850 (see Fig. 1-1) (NOAA, 2009; IPCC, 2007b; and Houghton, 2004).

Climate change effects are singnificant and widely spread. It is tangible in the new high temperature levels of ambient air and oceans in adition to snow and ice melting which causes an increase in the sea levels. The Intergovernmental Panel on Climate Change (IPCC) fourth report (2007b) pridicts that the warming rate is to continue at 0.2 °C per decade for the next two decades. While as, at the green house emissions scenario in the year 2000 the temperature irregularity rate was not anticipated to be less than 0.1 °C per decade. This means the climate change problem is rapidly compounded over the years.

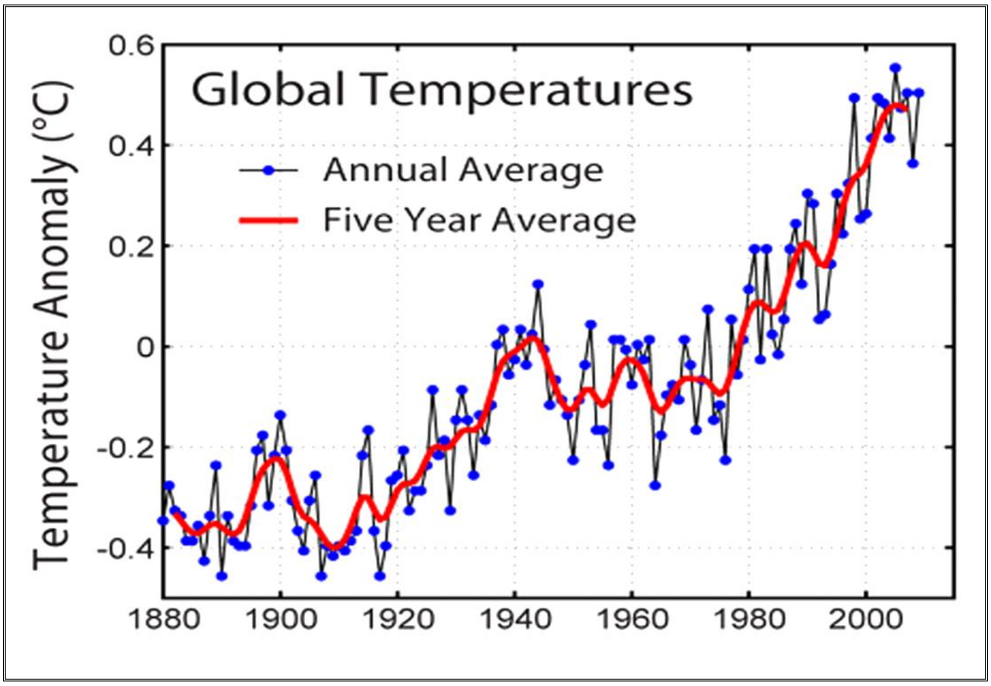


Figure 1-1: Global Temperature Anomaly. (IPCC, 2007b)

Furthermore, Bates et. al. (2008) expected that the continuitey of climate change will submerge huge areas of land due to sea level rising and loss of fertile land. This will encourage the migration of agricultural inhabitants who will, therefore, seek to survive in an alternative safe land. this process will affect the sustainable distribution of resources as the indiginous lives are sustainably adapted in their original habitats.

1.4 THE CARBON DIOXIDE GREENHOUSE GAS EFFECT

The green house effect from gases into atmosphere was first recognised by scientists in the 19 century. The phenomenon was introduced by Joseph Fourier in 1824 and was first quantitatively investigated by Svante Arrhenius in 1896. Researchers struggled to recognize the change in the level of carbon dioxide in the past, and the level influence was by chemical and biological forces. They found, however, that the CO_2 gas has an essential role in global warming and climate change, so that the steady rising level could seriously affect the future (Weart, 2009).

The greenhouse effect is known as the partial capturing process of the absorbed heat energy and infrared emitted radiation by atmosphere gases which lead to warming-up the lower atmosphere and Earth's surface (See Fig. 1-2).

The three most primary gases in the atmosphere constitute volumatic 99.9% of Earth's atmosphere are nitrogen (78.09%), oxygen (20.95%) and argon (0.93%) which exert almost no greenhouse effect. Instead, however, the greatest greenhouse effect occures from more complex rare trace molecules. Carbon dioxide is almost the second-most important one after Water vapour in addiotion to other small-amount existing greenhouse gases such as Methane, carbon monoxide, nitrous oxide and ozone which contribute minorly to the global warming effect (IPCC, 2007a; Hardly, 2001; and Houghton, 2004)

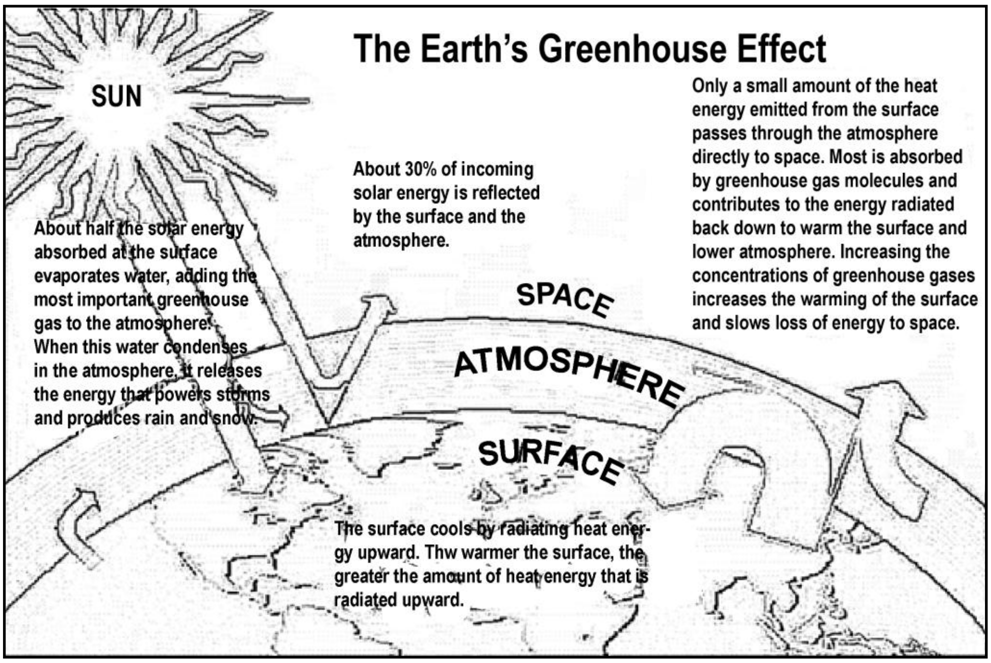


Figure 1-2: Greenhouse Gas Effect, (Samuelsohn, 2007)

The concentration of Greenhouse gases (GHG) in the atmosphere fluctuated slightly, historically, due to many natural processes like volcanic activity and temperature variation. However, human activities, subsequent to the Industrial Revolution, have significantly influenced the increase of GHGs in the atmosphere by burning fossil fuels for energy and heat, eliminating forests and other activities (EPA, 2007).

The global CO_2 concentration in the atmosphere has increased from almost 280 ppm (part per million) at the pre-industrial era to 386.6 ppm as of September 2010 determination (See Fig. 1-3). This level of atmospheric concentration considerably exceeds the natural fluctuation over the past 650,000 years (180 – 300 ppm) based on the period of reliable data from ice cores. In recent years, the annual concentration of CO_2 has increased to 1.9 ppmv/year in comparison to 1.4ppmv/year during the period from 1960 – 1995 taking into consideration the year-to-year difference in the increment rate (Loa, 2010; NOAA, 2010; IPCC, 2007b; and EPA, 2007).

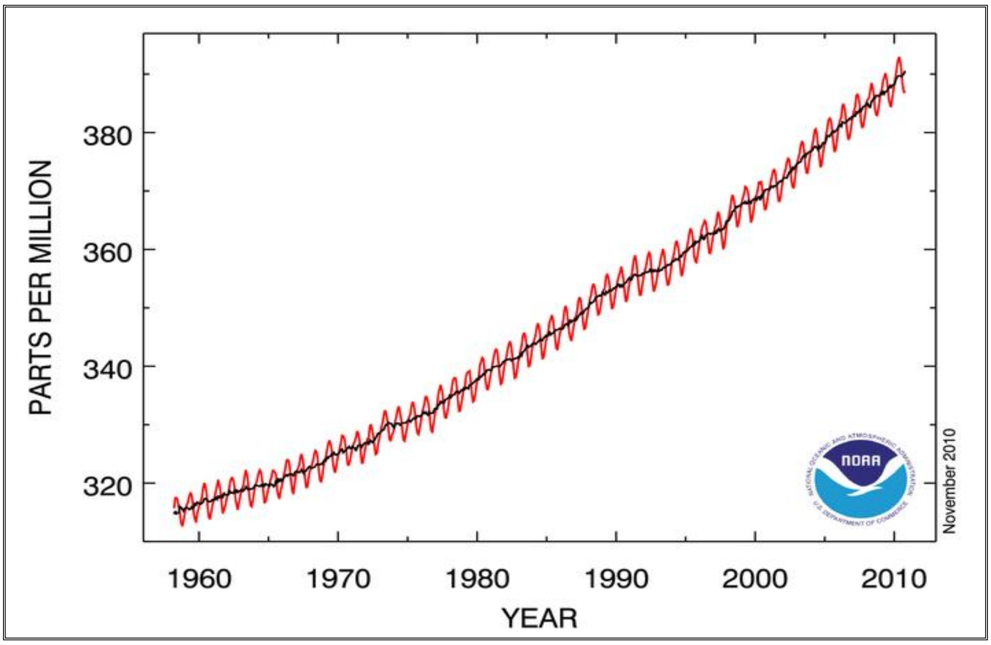


Figure 1-3: Recent atmospheric CO_2 Levels, Black line is the average. (NOAA, 2010)

The four key indicators to energy level related to CO_2 emissions are firstly: the carbon concentration (the proportion of CO_2 emissions over the total primary energy supply), secondly: energy intensity, thirdly: gross domestic product (GDP) per capita, and fourthly: population growth. The population growth and GDP per capita constitute the key drivers to the increase in carbon dioxide greenhouse effect in the last three decades (Kaya, 1990 sited in Rogner, et al. 2007).

Particularly, fossil fuel is the primary source of the steady rise in CO_2 concentration since the pre-industrial era. Land-use change, forestry and other minor factors also add into the CO_2 rise but in relatively small contribution (see Fig. 1-4). The annual emission of CO_2 from fossil fuel has increased from almost 23.5 $GtCO_2$ (Gegaton Carbon dioxide) in the 1990s to around 26.4 $GtCO_2$ in 2005. IPCC expected a projection of 37.2–53.6 $GtCO_2$ from energy use for 2030 (IPCC, 2007b; and Rogner, et al. 2007).

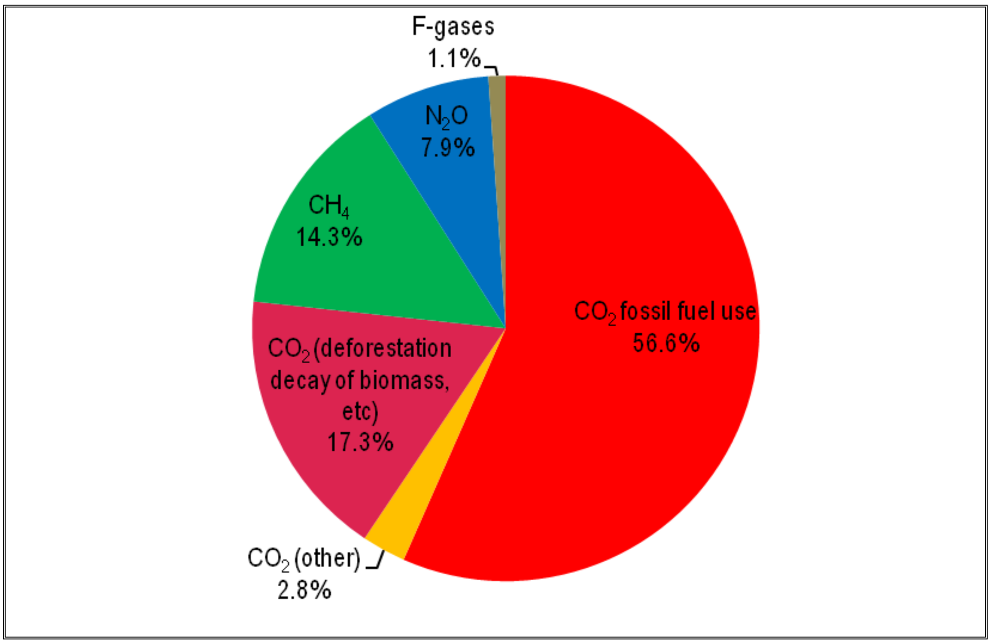


Figure 1-4: Global anthropogenic greenhouse gas emissions in 2004. (Olivier, 2005 sited in Rogner, et al. 2007)

The UAE's records of CO_2 emissions were 60.8 $MtCO_2$ in 1990. This amount has increased to around 94.2 $MtCO_2$ in 2002 (Embassy-of-UAE, 2009). The CO_2 level has almost reached 146.9 $MtCO_2$ in 2008 (IEA, 2010). The per capita emission has, however, decreased due to advanced technology application and focusing on natural gas use in power plants. The 32.6 ton per person a year in 1990 dropped to 25.1 ton per person a year in 2002. However, this drop has left the UAE to rank the fourth global CO_2 emitter per capita (Embassy-of-UAE, 2009).

The UAE endorsed the Kyoto Protocol agreement in the beginning of 2005. The UAE is classified, according to the protocol, as a non Annex I country - Annex I is a term proposed for industrialized courtiers who had to reduce their CO_2 emissions to 1990 levels by the year 2000 (UNFCCC, n.d). Therefore, UAE is not obligated to reduce its CO_2 emissions currently. The UAE is, however, willing to take precautionary steps for better sustainable environment in the country (Embassy-of-UAE, 2009).

1.5 ENERGY PROMINENCE

Energy is among the foremost factors for the economic development of any nation. It was always present in the alliance of development in developed countries. The energy sector of the developing countries is of critical importance due to the ever-escalating demand of energy for investment and industry. Various forms of energy are abundant in the Earth's planet; this was always realized by the mankind and used to facilitate the humans' wellbeing.

The nature of the Earth contains sources of primary energy. Ordinary primary energy sources are coal, oil, natural gas, wind, solar, uranium, geothermal and biomass, and ocean energy. These sources are the most principally converted into electricity and other secondary energy sources as shown in (Fig. 1-5). (Sims, et al. 2007; BEE, n.d).

The world's primary energy consumption has increased more than ten-fold between 1900 and 2000 versus only four-fold rise in the world's population from 1.6 billion to 6.1 billion. The energy demand is still expected to increase considerably in the future due to economic and population growth, particularly in developing countries while they pursue industrialization. The consumption of global primary energy was 238 Exajoule (EJ) in 1972 to rise to 464 EJ in 2004 (Sims, et al. 2007).

Secure, equitable, affordable and sustainable energy supply is essential to future prosperity. The end-user consumes energy as follow – approximately (Sims, et al. 2007):

- 45% of energy is for low-temperature heat activates (cooking, space and water heating),

- 10% for high-temperature industrial heat,

- 15% for lighting, electronics appliances and electric motors, and
- 30% for transport means.

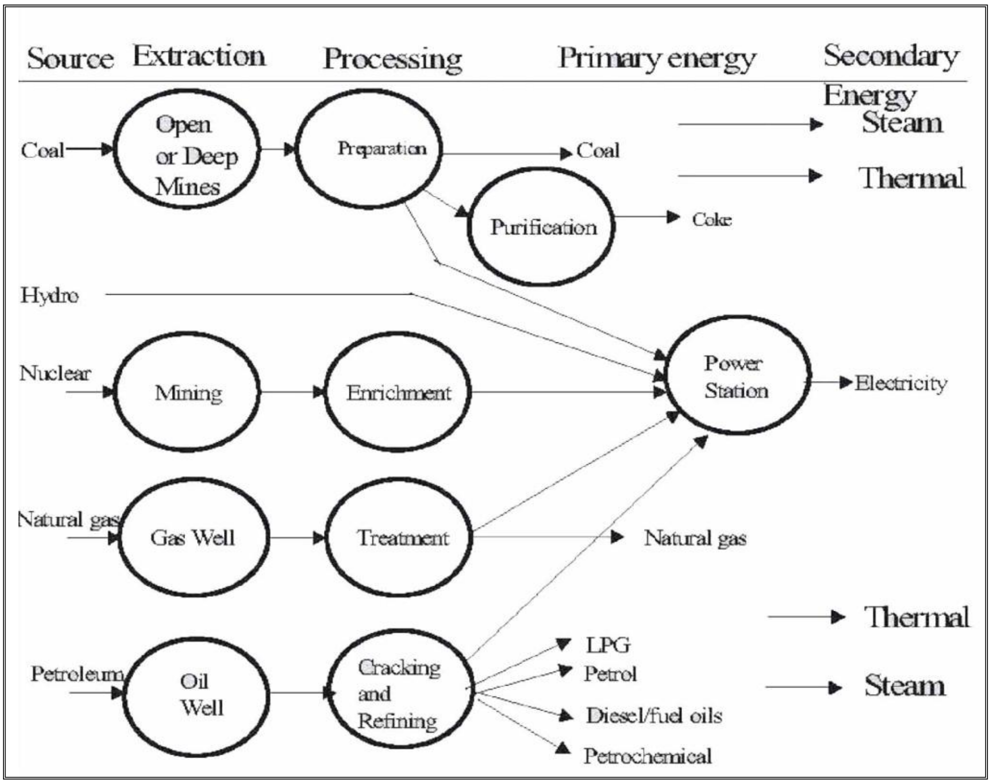


Figure 1-5: Major Primary and Secondary Sources. (BEE, n.d)

According to IEA (2006) sited in Sims, et al. (2007) these energy demands rely mainly on fossil fuel which is responsible for around 80% of CO_2 emission of total global emissions.

The United Arab Emirates (UAE) power sector is threatened by shortage of future energy supply. Steady increase in the electricity demand was factual during the economic boom from 2003 to 2008 even though, it continued rising during the recent financial crisis. The demand on the electricity has increased by 7% in the UAE from 2008 to 2009. The demand was – according to Abu Dhabi Water and Electricity Company

(ADWEC, 2010) - 14,385MW and rose to 15,426MW distributed as follow: Abu Dhabi 6,255MW, Dubai 5,622MW, Sharjah 1,840MW, and other Emirates 1,709MW (Lidstone, 2010). The gross generation capacity was, however, 17,369 MWe in 2007 (Moenr, 2008)

The demands for energy, hence, will definitely rise to meet the population growth and economic expansion in the world, especially in developing countries. Increasing standards of living plays another role in encouraging the increment of future energy demand. On the other hand, the consumption rates of fossil fuel will probably be reduced due to the currently rising prices, the possible source depletion after almost 8 decades, and the effects of climate change and global warming. Therefore, low-carbon and clean energy will be great demand for future energy scenarios.

1.6 REACTIONS TO GLOBAL WARMING

Based on the aforementioned highlights of global warming along with the energy role in the ever-increasing CO_2 emission, the following measures form mitigation responses to the global warming and climate change problem:

1.6.1 MITIGATION

Mitigation of climate change is the process of reducing the future amount of change in climate. According to IPCC (2007b), the mitigation is "Technological change and substitution that reduce resource inputs and emissions per unit of output ..., mitigation means implementing policies to reduce GHG emissions and enhance sinks". Molina et al. (2009) states that the mitigation processes are meant for reducing the greenhouse concentrations by reducing the source.

Figure (1-6) shows a view of estimated economic potential for global mitigation of CO_2 emissions by sector for different regions. While as, Table A-1 in Appendix A presents selected examples of chief mitigation technologies by sector, policies and measures, constraints and opportunities.

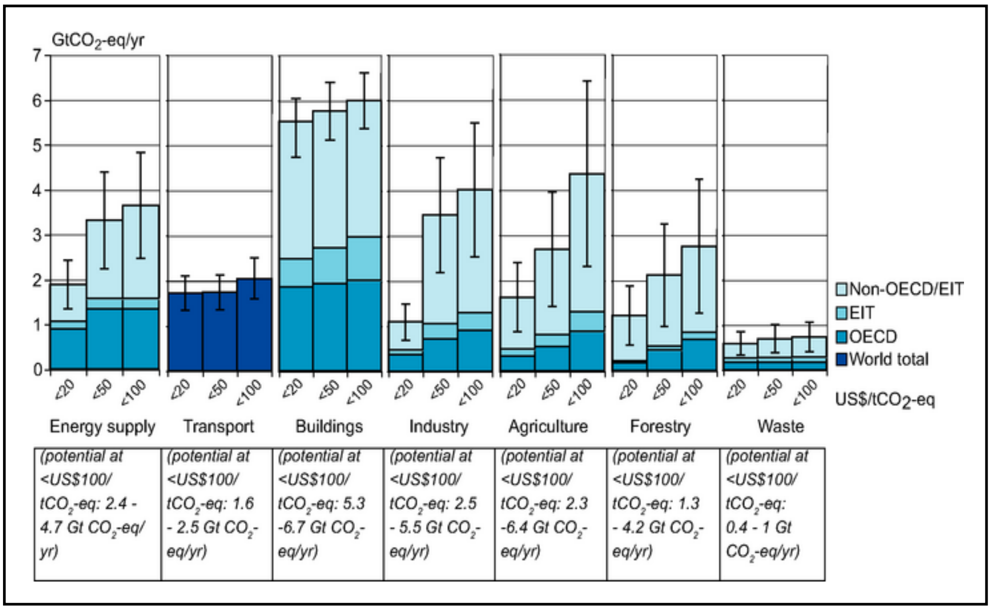


Figure 1-6: Estimated economic mitigation potential by sector and region using technologies and practices expected to be available in 2030. The potentials do not include non-technical options such as lifestyle changes, (IPCC, 2007c)

Developed and developing nations alike are looking for technologies and policies to mitigate CO_2 emission. According to IPCC (2007c), the policies of mitigation encouraged the use of renewable energy, carbon-free energy, and energy efficiency. Current research works anticipate substantial reduction in CO_2 emissions. However, Robinson (2010) still sees that fossil fuels will remain used for longer years despite of the mitigations steps. Mitigation processes could also include carbon capture and storage process.

1.6.2 ADAPTATION

Adaptation to global warming and climate change is another mechanism of reactions towards climate change. As per UNFCCC (n.d), adaptation is defined as an "Adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities".

The capacity of adaptation is intimately associated to social and economic development, although, it is unevenly distributed within societies. There are, however, barriers, limits and costs to the adaption measures. These complications are not yet fully understood so, it needs further investigation (IPCC, 2007c).

The adaptation mechanism is more important to developing countries as it seems less costly. The developing nations, moreover, still have the ability to bear the impacts of climate change effects.

1.6.3 GEO-ENGINEERING

It is a modern policy of engineering the climate which deliberately manipulates the climate to offset the effects of global warming from GHG emission. The National Academy Press proposed number of geo-engineering options such as large-scale environmental engineering to offset the effects of atmospheric changes. Most of the proposed options would possibly compensate the increase in global temperature by reflecting a fraction of the inward sunlight. Other options would deal with greening the planet to absorb more carbon from the atmosphere, diminishing carbon dioxide by direct absorption or capture, lessening halocarbons from the atmosphere atmospheric by direct destruction, and increasing the storage and natural sequestering of carbon in surface water like oceans (NAP, 1992).

IPCC (2007c) mentioned that geo-engineering options such as ocean fertilization to mitigate CO_2 from the atmosphere or sunlight blocking via inducing barrier material into the upper atmosphere still immature yet hence, its reliable costs are not available. According to the Institution of Mechanical Engineers (IME, 2009), geo-engineering is associated with mitigation and adaptation to form a 3-stranded “MAG” technique to reduce the effect of global warming.

1.6.4 CARBON CAPTURE AND STORAGE

Carbon capture and storage (CCS), or Carbon capture and sequestration as alternatively referred to, is a mechanism of capturing the pre-emitted CO_2 from fossil fuel power plants, factories and other sources and stored away of the atmosphere, usually tight underground structural reservoirs. According to Metz (2005), CCS can potentially reduce the overall mitigation costs and increase flexibility in reducing greenhouse gas emission. The widespread CCS application depends on mature development, costs, capacity to apply the technique, regulatory aspect, environmental matters and public perception

On the 20th January 2010, Masdar (Abu Dhabi’s multifaceted renewable energy initiative) signed a Memorandum of Understanding with the Ministry of Energy of the Government of Alberta - Canada to cooperate on carbon capture and storage (CCS) initiatives. Currently, Masdar is developing the first CCS project in the Middle East, one of the most ambitious large-scale CCS projects in the World. The CCS system is set-up to capture CO_2 from power plants and industrial facilities. The captured CO_2 will then be injected into oil reservoirs of Abu Dhabi for Enhanced Oil Recovery. The now under design and engineering project will capture 5 Mton (million tonnes) of CO_2 per year when completed in 2014 (Masdar, 2010).

1.7 LOW-CARBON ENERGY

Low-carbon energy is an energy source with minor CO_2 greenhouse effect in comparison with traditional energy sources. It includes renewable (wind, solar, biofuels, geothermal, etc) as well as non-renewable energy (i.e. nuclear power from Uranium) sources. The low-carbon power generation emits significantly minimal CO_2 amount while the fossil fuel power plants stand for extremely high amounts of CO_2 emission.

Globally, Kyoto Protocol which came into effect on Feb.16, 2005 was the early effective step towards low-carbon energy to stabilize climate change. By 2050, the universal social infrastructure part is likely to be replaced to some extent (Nishioka, et al. 2008). The policies by domestic governments should focus on momentous alteration towards low carbon societies.

Copenhagen summit 2009 (COP15) is a United Nations Climate Change Conference held from December 7 to 18, 2009 as the most serious conference since long time. The agreement was drawn by a limited group of countries (United States, China, India, Brazil and South Africa), and then formally accepted by the parties of the UN framework convention on climate change (COP15). The following months to the COP 15 witnessed a decisive period for all participants to set-up a motivated agreement to succeed the Kyoto Protocol (CCC, 2009; and Andersen, 2009).

Measures to eliminate global warming and reduce CO_2 emissions from buildings fall into one of three classifications: reduce the consumed and embodied energy in buildings, switch to low-carbon fuels energy, or rein the CO_2 GHG gases emissions. Low-carbon energy is possible to be supplied to buildings from the electricity grid or produced on-site by technology of generation means (Levine, et al. 2007).

1.7.1 Renewable Energy Sources

Renewable energy sources are generated from natural resources such as sunlight, wind, water and biomass which are all naturally replenished. These resources are abundant and vastly available in the Earth planet and free for use (non-considering the energy mechanism).

Contemporary technologies of renewable energy have steadily been developing since the late 1970s with adequate support from official and concerned people. The past five years witnessed the launch of a super-charged growth stage. Figure (1-7) shows the average annual growth rate from 2002-2007 for each energy source (Flavin, 2008).

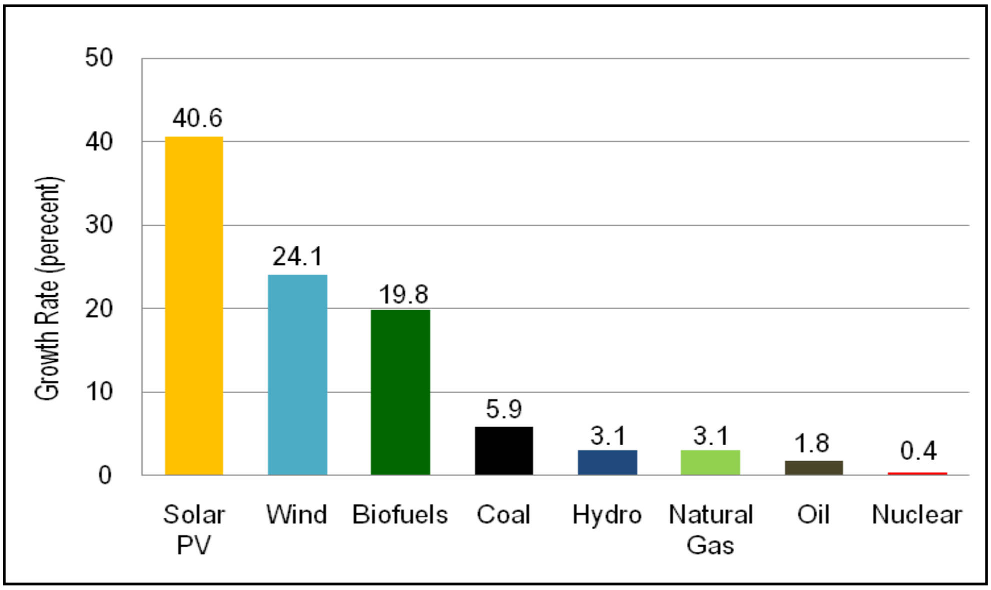


Figure 1-7: Average Annual growth rate by energy source from 2002-2007, (Flavin, 2008)

1.7.2 Non-Renewable Low-Carbon Energy

Non-renewable energy sources come from natural resources but, in contrast to renewable resources, they are not re-produced or grown again once consumed. These resources are often fixed in nature. The only common example of non-renewable resources for low-carbon energy is the Uranium which is the resource for nuclear power.

Vattenfall, a Swedish utility which produces electricity, carried-out a study of the full life cycle emissions of electricity generation sources (Nuclear, Hydro, Gas, Solar, Coal, Peat and Wind energy sources). The study results showed that nuclear power emits 8.3 gCO_2 per kW-hr of produced power. The natural gas and coal emit around 480 and 930 gCO_2/ kW-hr respectively (according to Vattenfall). Nuclear power is therefore, concluded as one of the least CO_2 emitters among the energy types included in the study (see Fig. 1-8) (Martin, 1999)

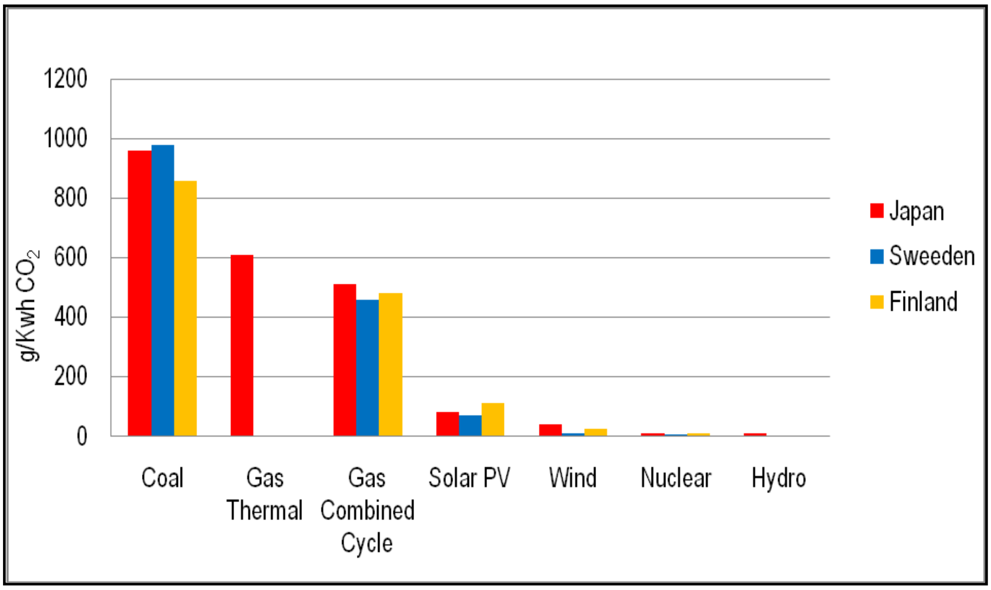


Figure 1-8: CO_2 emissions for electricity Generation per Vattenfall 1999, (Martin, 1999)

1.7.3 Electricity Usage

Electricity role in today's energy is the most essential. It is used for lighting, heating or cooling, power and vast industrial utilities. The importance of electricity grows-up with time due to growing demand and increasing welfare facilities. The electricity should, however, be produced by a low-carbon energy source to mitigate the current CO_2 emissions (Flavin, 2008).

Electric power from low-carbon energy is not a new technology in the world. Nuclear power – as a low-carbon energy - generates around 20% of United States of America (USA) gross power whereas hydroelectric generates almost 7% of the total grid power (Apt, et al. 2006). The global energy consumption of electricity is anticipated to increase from 421 quadrillion BTU (British Thermal Units) in 2003 to around 722 quadrillion BTU in 2030 (see Fig. 1-9) (EIA, 2006).

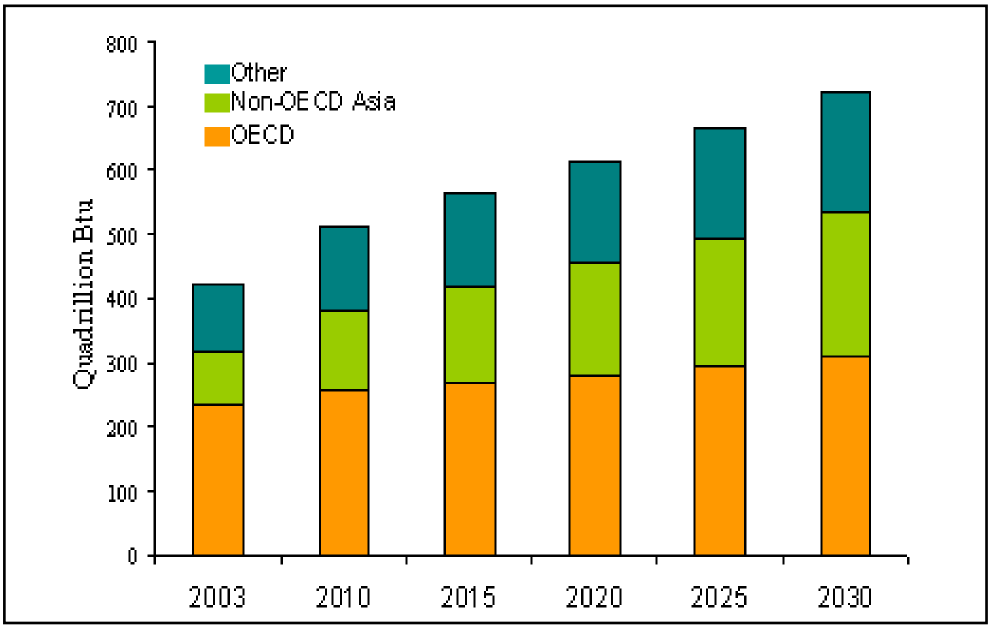


Figure 1-9: World Marketed Energy Consumption by Region. (EIA, 2006)

Non-OECD (Organization for Economic Co-operation and Development with 30 member countries like Australia, Austria, Belgium, Canada) countries are expected to have the fastest growth of energy demand (EIA, 2006). Therefore, substituting the conventional energy with low-carbon energy source encourages the growth of electricity, economic and population but, stabilizes the CO_2 levels.

1.7.4 Cost of generation

Cost of power generation is always a decisive factor for producers and end-users as illustrated in chapter 7. According to Kok (2009), electricity from coal power is the lowest while solar (photovolataic) is the most costly energy in construction phase and overall which still needs vast subsidies (see Fig. 1-10).

Introducing new low-carbon energy into the existing energy infrastructure will accelerate the transition and lessen its cost. Furthermore, a job market will be created which contribute significantly to recovery from the current economic crisis.

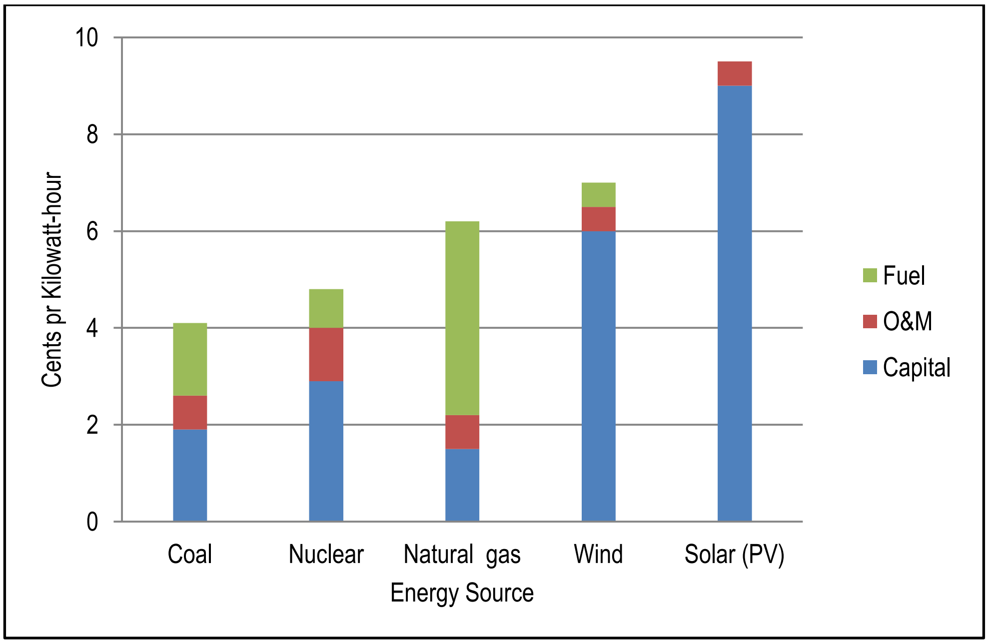


Figure 1-10: Cost of Electricity Generation by Source, (Kok, 2009)

1.8 DISSERTATION STRUCTURE

Chapter 1: Introduction of the Global warming and climate change problem along with the current CO_2 status, and energy role in contribution to the GHG mitigation.

Chapter 2: Literature Review, correlative study of precedent research works tackling the nuclear energy and reducing CO_2 emissions.

Chapter 3: Nuclear Energy as a low-carbon energy source, it includes: history, working principle, and development mechanism of the nuclear power.

Chapter 4: Methodology, this defines the research parameters, carried-out methodologies of similar researches and the selection of simulation methodology and software.

Chapter 5: Building the Simulation Model, the configuration and running the simulation. It focuses on the input data along with assumptions and constraints.

Chapter 6: Results and Discussion, a discussion of the results processed in Chapter 5.

Chapter 7: Economic Analysis of the nuclear energy consumption and CO_2 emission cost.

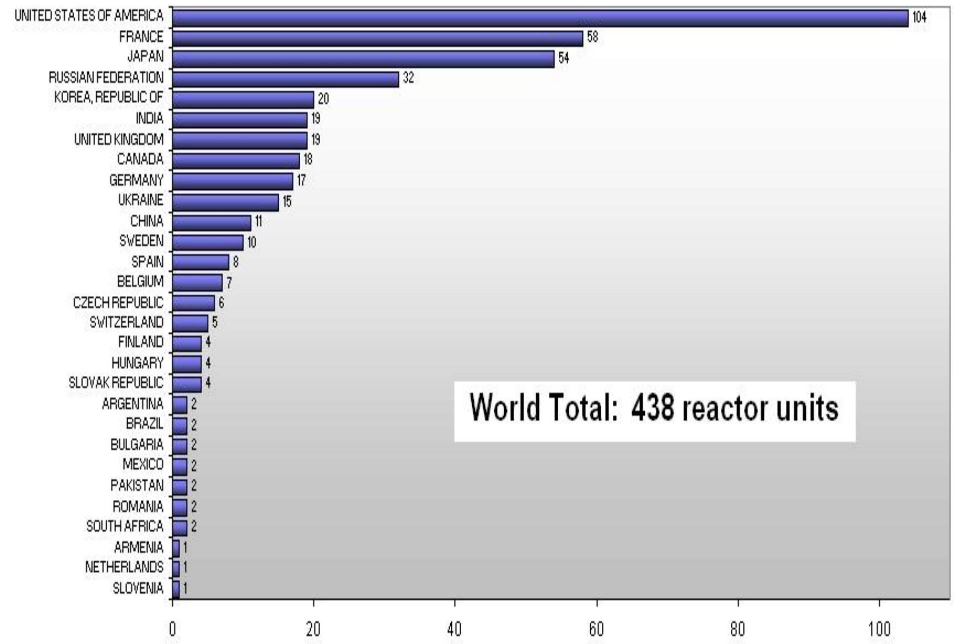
Chapter 8: Conclusion of the research and recommendations for future relevant work.

CHAPTER 2: LITERATURE REVIEW

2.1 INTRODUCTION

Nowadays, it is apparent that the environmentalists and scientists have deep concerns towards the increased Carbon Dioxide concentration in the atmosphere and its contribution to the climate change and global warming. According to this fact, all the environmental participants are seeking alternative options to reduce the emissions of CO_2. Fossil fuel is a conventional source for energy which is the main source of CO_2 emission into the atmosphere. The energy, in general, is a key contributor to the CO_2 emissions. Therefore, considerable development is needed for the energy prospects. For this reason, Nuclear energy was introduced as a CO_2 low emitting energy source in order to contribute for mitigating the increased CO_2 emissions.

Worldwide, there are about 438 nuclear power plants in operation; the USA has 104 operational plants out of them whereas five power plants were shutdown in 2009. Aside, there are Fifty Seven nuclear power plants under construction, 23 out of them are in China only (see Figs. 2-1, 2-2). The current nuclear energy supplies around 372 GWe of electricity which represents 14% of the universal energy consumption (see Table A-2 in Appendix A). Adamantiades and Kessides (2009) mentioned that the worldwide electricity generation from nuclear had declined from 16% in 2005 to 15% in 2007 after it was in a constant increase from 1960 to 1986. Lithuania and France are leading the nuclear countries in the proportion of electricity generated from nuclear energy. Lithuania produces almost 76% of its total electricity supply from nuclear energy whereas; France covers 75% of the country's total electricity demand from nuclear.



Note: Long-term shutdown unites (5) are not

Figure 2-1: Operational Power plants as of 2009. (IAEA, 2010)

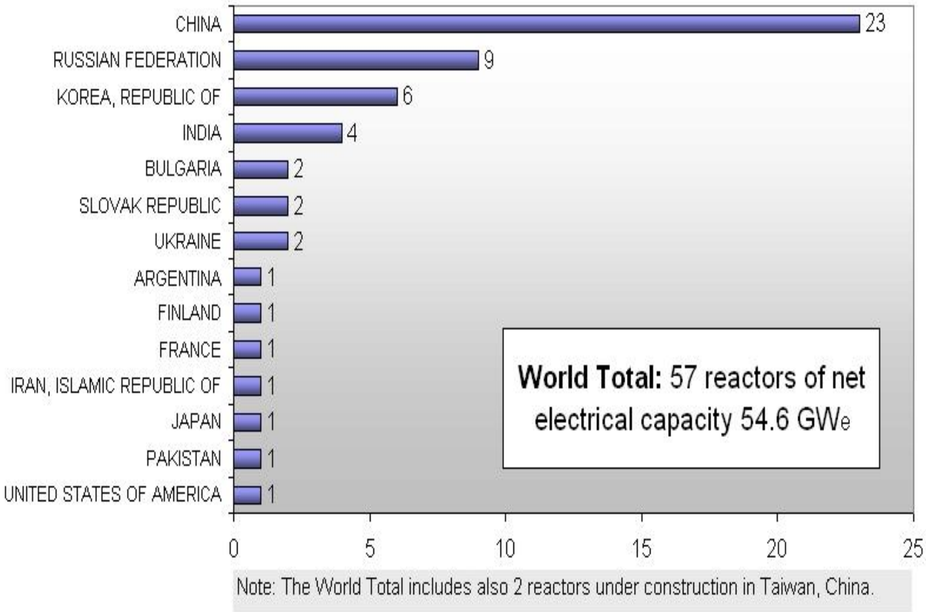


Figure 2-2: Under Construction Power plants as of 2009. (IAEA, 2010)

USA supplies 20% of the total electricity grid from nuclear energy nonetheless, it remains the foremost nuclear energy supplier at almost 100GWe (see Fig. 2-3). Noteworthy, the developed nations hold the biggest electricity generation from nuclear fission whereas developing countries have only 10% of the universal electricity generated by nuclear energy (IAEA, 2010; Adamantiades and Kessides, 2009).

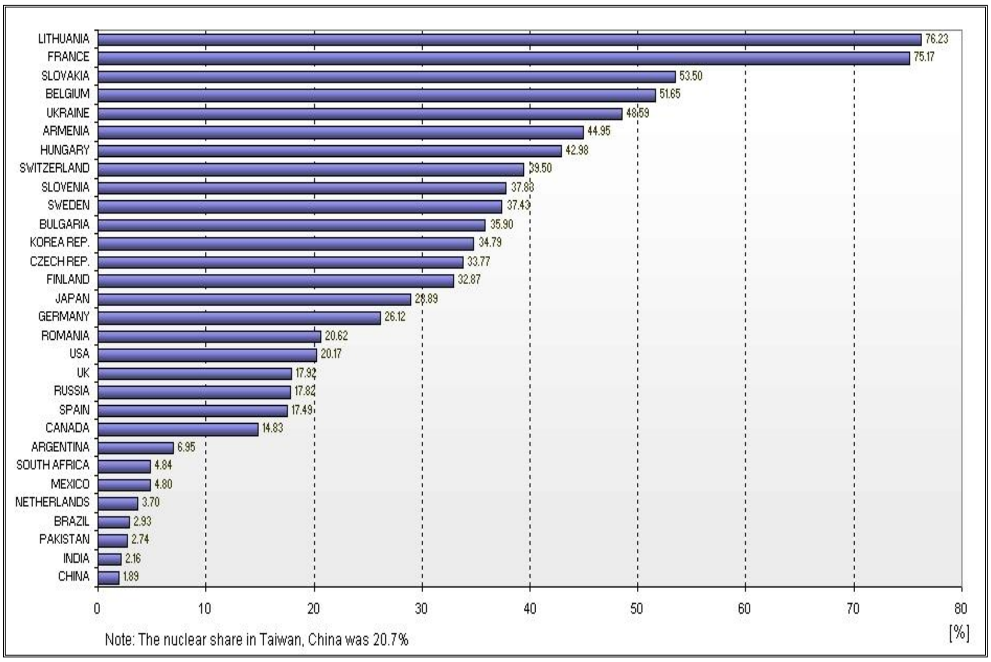


Figure 2-3: Nuclear Share in Electricity Generation as of 2009. Source: IAEA 2010.

The Middle East countries including the United Arab Emirates have plans to operate peaceful nuclear energy to meet the growing demand for energy and in the meantime to achieve the sustainable environmental goals. The reduction of CO2 emissions is one of the major aims for United Arab Emirates to use nuclear energy for generating electricity. There are researchers, however, researched the role of nuclear energy - as a substitute to fossil fuel - in reducing CO_2 emission, some of these researches are summarized henceforth:

2.2 ELECTRICITY CONSUMPTION AND CO_2 EMISSION

Electricity plays a vital role player in almost all life aspects; it is the associated feature of development and economic growth. The traditional way of generating electricity is from coal and fossil fuel. This trend has contributed to CO_2 GHG emission and consequently to global warming and climate change. The following researches were carried-out to check the accuracy of this legitimacy.

Qader (2009) researched the electricity consumption and GHG Emissions in Gulf Council Countries (GCC). At the beginning, he listed the four worldwide effective factors of climate change: economic growth, population ever-increasing numbers, increased use of transportation, and industrialization. The focus in the study paper is on the electricity generation phase. The electricity demand in GCC has increased at three fold the universal average in the few precedent years due to the high GDP rate and the policy of building mega construction and infrastructure projects, especially, UAE and Kingdom of Saudi Arabia (KSA). The air-cooling requirements and governments subsidize of citizen bills encouraged the electricity demand furthermore.

The demand in the GCC is, however, anticipated to grow by 80% in 2015 from the current installed capacity (Laura, 2008 cited in Qader, 2009). The GCC nations were identified by the United Nations Environmental program as the highest per capita energy consumers. The six GCC countries emit around 45 – 50% of the cumulative Arab region CO_2 emissions (ROWA, 2005 cited in Qader, 2009). KSA is leading the CO_2 emission followed by UAE (see Fig. 2-4). It is, however, noteworthy that the GCC population is less than 18% of the total Middle East population (USCB, 2010 cited in IWS, 2010).

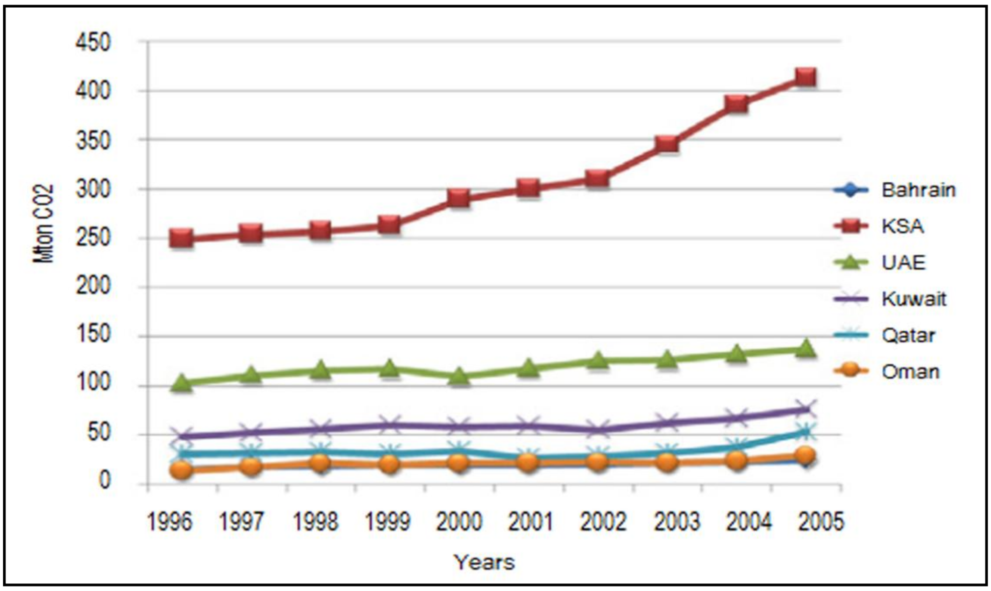


Figure 2-4: CO2 total emissions from consumption of fossil fuel for GCC countries. (Qader, 2009)

Qader (2009) continued comparing the six GCC countries for the relation of electricity consumption and CO_2 emission. Another relation he studied is the population with GHG emission. Thereafter, the research has a comparison between the GCC countries and other industrialized developing countries with relatively similar population and similar economic growth, especially, KSA versus Malaysia and UAE versus Singapore. KSA of 26 million population have significantly higher CO_2 emission –almost 2.5 times – than Malaysia of 23 million population. Malaysia has been showing a decline in its CO_2 emission since 2004. Similarly, UAE of 4 million population emits a marginally higher CO_2 than Singapore of 4.4 million population but, much less than the difference in KSA and Malaysia case (see Table 2-1).

Table 2-1: Comparison between KS, UAE, Singapore and Malaysia presents the total emission (CO2 Mton). (Qader, 2009)

Year	KSA	Malaysia	UAE	Singapore
1996	248.97	101.13	103	97.83
1997	254.05	101.52	111.34	99.46
1998	256.82	102.16	116.09	102.17
1999	262.68	105.85	117.62	104.05
2000	289.33	111.31	109.65	106.81
2001	299.89	124.16	118.13	107.6
2002	309.62	137.66	125.55	109.37
2003	344.78	148.68	126.38	111.54
2004	385.76	164.43	132.76	125.4
2005	412.35	155.51	137.82	133.88

As a conclusion of Qader (2009) research, the energy sector in the GCC is the main source of CO_2 emission due to fossil fuel (oil and gas) great usage. CO_2 gases per capita rates are rapidly rising the GCC countries especially KSA and Qatar. the current electricity consumption and CO_2 rates in the six GCC countries are higher than other developing countries of almost similar population and economic growth. The domestic governments are willing to fullfil the electricity future demand, and parallely to reduce the CO_2 emission. Examples on this trend are the solar village in Raas Al Khaimah, and the proposed nuclear power plant in Abu Dhabi in UAE.

Psomopoulos et al. (2009) stated in their study of electricity savings and CO2 emissions in buildings sector that mitigation policies are greatly becoming more important if the policy makers have an accurate picture of the CO2 sources and impacts. The current energy consumption constitutes future anticipation of the energy demand and CO2 future levels. It is necessary to dedicate a focal study of buildings due to their large number, significant percentage of energy consumption, and variety of networks.

Thus, the research focuses on the electricity networks' losses role in reducing the CO_2 emission once applying energy efficiency measures into buildings. Noteworthy, all electrical networks have losses during the transmission and distribution of power. Joule heating, hysteresis, and leakages are among the causes of these losses in the electricity networks. Figure (2-5) illustrates the division components of energy losses in European networks. An important factor affects the electricity losses calculation as a percentage of the total gross demand is the import and export of electricity.

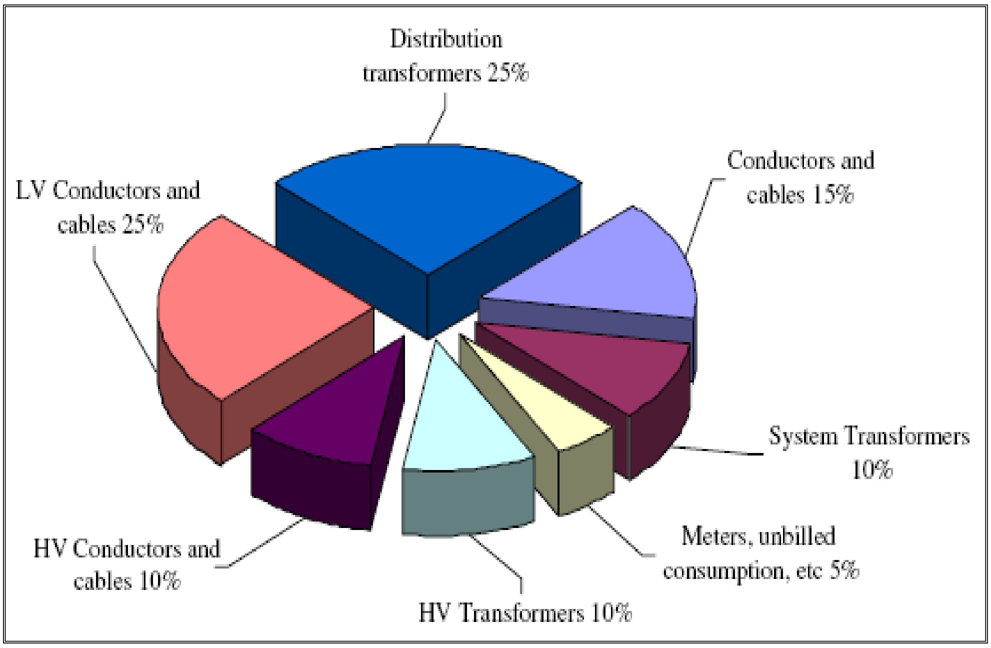


Figure 2-5: Electricity transmission and distribution loss components in European. (Psomopoulos et. al. 2009)

In conclusion, the calculations results showed that if the emission factor's calculation considered the electricity grid, the connection type in buildings (low or medium voltage) does not affect the electricity losses.

Romeo et al. (2009) studied the potential of electricity consumption of and carbon dioxide capture in Spain. They started mentioning that

Spanish economy has an important rising trend in practice for the last couple of decades. The GDP has increased 48.8% from 1990 –2004, 14 points higher than the average of the 30 founded OECD (Organization for Economic Co-operation and Development) countries.

Spain was permitted to increase its CO_2 emissions up to 15% of the 1990 level under the 1997 Kyoto Protocol. This has, however, changed now due to significant recorded rise of 52.2% CO_2 emission above 1990 level in 2005. In 2006, CO_2 value was reduced to 48.1% (MMdMA, 2006 cited in Romeo et al. 2009). Set of actions to eliminate CO_2 were put in place by the Spanish, these include: Improvements in energy efficiency, the use of renewable energy and carrying out mitigation projects. Now, electricity production emits 24.0% of CO_2 and 23.8% for transport. Carbon capture and storage (CCS) projects are expected to achieve secured power generation at low GHG emissions. The development of CCS projects in Spain, therefore, is necessary for sustainable development goals as well as approaching the post-Kyoto targets of CO_2 in Spain.

Figure (2-6) illustrates the paper's research methodology. The inputs included: Population, per capita GDP, energy intensity and contribution of electricity to the gross energy demand. The outputs present electrical demand scenarios. The targeted year of study is 2050 as predicting energy demand and policies beyond that might have large uncertainties which were not considered in the simulation.

The potential for CCS based on coal was defined by available prediction scenarios for the future technologies. Thereafter, evaluation of economic and emission for this potential gives lead to discussion of the cost of electricity, the CCS plant and the reduction of CO2 emission.

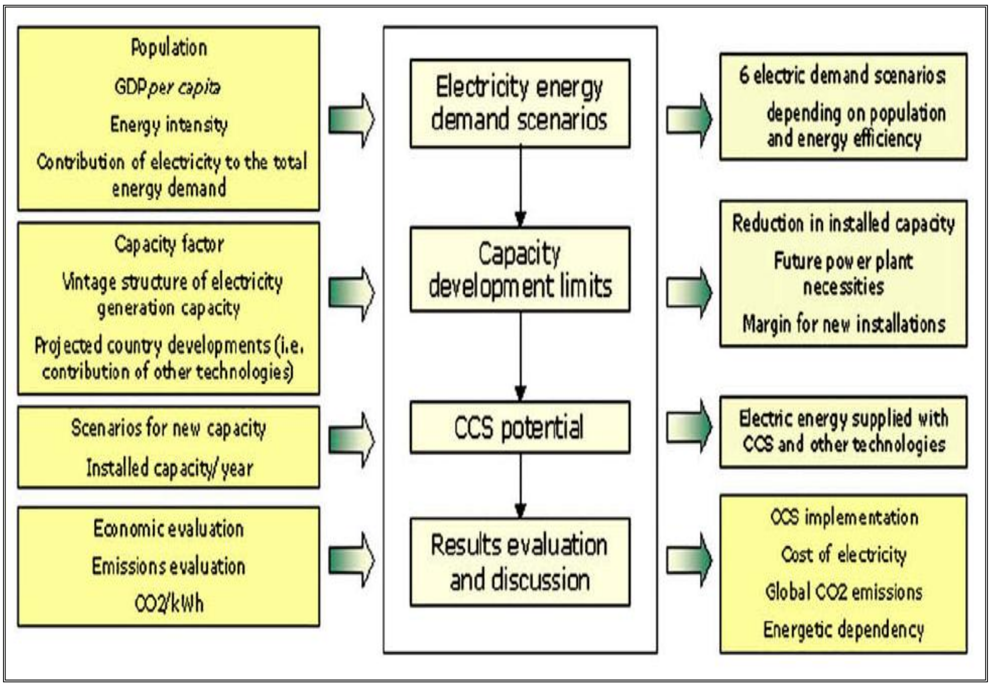


Figure 2-6: General methodology used for evaluating CO_2 capture potential in Spain. (Romeo et al. 2009)

The Scenarios for electricity demand was set as follow: Scenario 1 assumes a constant trend in immigration up to 2010 before it stabilizes. Scenario 2 presumes a decrease in immigration. Both scenarios, however, comprise an increase in population growth. Among the calculation of electricity demand, it is an essential to study the supply of energy. The Spanish electricity system is extremely relying on fossil fuels as 63.7% of the electricity in 2005 was generated by fossil fuels.

According to McCracken (2005), capacity factor is "the ratio of the electrical energy produced by a generating unit for the period of time considered to the electrical energy that could have been produced at continuous full power operation during the same period". Romeo et al. (2009) mentioned that the capacity factor for carbon capture in future is presumed to increase from 40% at 2005 to 50% in 2011, 59% in 2020 and to stabilize at 65% (5870 h/year) from 2025 onward. Nuclear energy has a constant capacity factor of 90% (7890 h/year). The availability of future renewable energy is anticipated to increase from 18% in 2005 to 31% (2720 h/year) in 2050 due to technological advances and development.

The researchers concluded that cutback of CO_2 emissions in 2050 will probably accomplish 90% in an efficiency scenario with medium population-economic growth and minimum CO_2 option. The contribution of energy sources will possibly consist of 50% renewable and Carbon-free energy and 50% CCS, therefore, the new capacity might reach 228 GW with a capital investment cost between of around 254,000 million euro. Hence, the development of energy storage for Carbon-free energy will occupy an essential place in future of Spain. The emissions of CO2 due to electricity production would reach 33% below the agreed Kyoto 1990 level with CO2 emission decrease of around 650 Mton CO2/year.

2.3 NUCLEAR ENERGY ROLE IN CLIMATE SCENARIO (CO_2 EMISSION)

Vaillancourt et al (2008) researched the nuclear energy role on the long-term climate scenario. They conducted a simulation of the nuclear impacts via computer software called World-TIMES (The Integrated MARKAL-EFOM System); this model of simulation has superior characteristics of MARKAL (Market Allocation), and EFOM (Energy Flow Model Optimization) systems. The database of this software associates about 1300 technologies used in the energy expenditure and demand. The research geographical area, however, covered 15 developed nations while the study period is set-up for a century from the year 2000 to 2100.

Two diverse CO_2 emission constraints were adopted in the research for correlation purpose; 450ppmv (parts per million volume) and 550ppmv of carbon dioxide levels in the atmosphere. Cost constraint of the simulation included: investment, welfare loss, and operation and maintenance cost. The chief expected outputs were future investment and technology activities at every interval.

The results of the research recorded larger nuclear energy demand under the 450ppmv scenario which is equal to almost 20-folds increase in the 2100 (see Fig. 2-7). The 550ppmv CO_2 scenario resulted with less demandable nuclear energy in 2050 (see Fig. 2-8). The researchers, hence, forecasted growing usage of the renewable and nuclear power plants following to the year 2050 to meet the future demand of clean energy. Consequently, nuclear energy could most probably become the major universal electricity production source in 2100.

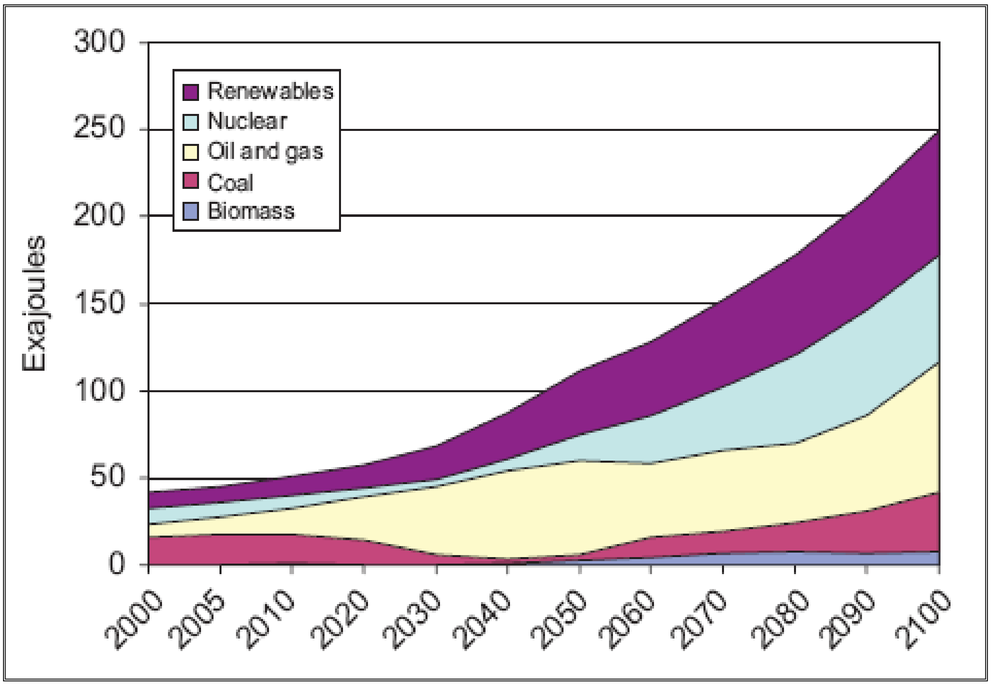


Figure 2-7: Electricity production by type under the 450-ppmv climate scenario, Vaillancourt et al. (2008)

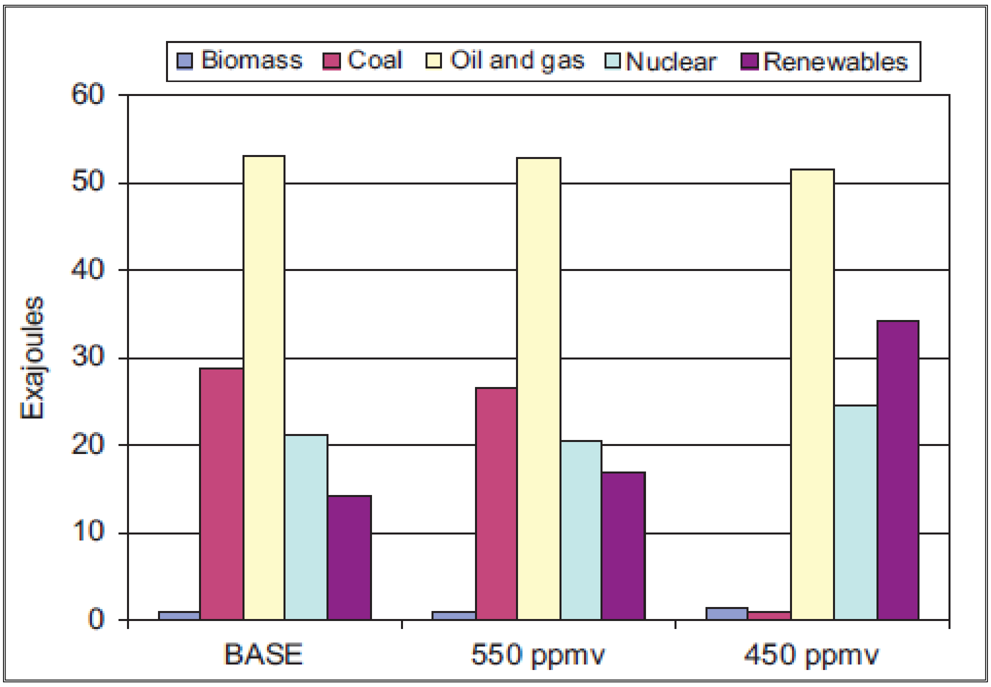


Figure 2-8: Electricity production by energy type in 2050, Vaillancourt et al. (2008)

The impact of nuclear energy on the climate mitigation at Lithuania -a European Union member– was researched by Streimikiene (2008). Lithuania is most probably capable to comply with the Kyoto targets in 2008 to 2012. The researcher discussed the possible mitigation of post-Kyoto climate change, and in which approach it could be achieved. The researcher explained the rule of three sustainability dimensions of for assessment 3As (Acceptability, Availability, and Accessibility) which can be read as environmental criteria, economic criteria, and social criteria consequently.

An almost 14% of Lithuania's primary energy demand is supplied by domestic resources. Nuclear energy – Uranium fuel comes from Russia – covers almost 70% of the total power consumption.

The existing nuclear power plant in “Ignalina” is scheduled to shut down by 2009 as it is no longer complying with safety standards. The fossil fuel energy is, hence, anticipated to substitute the shut-down nuclear power plant which consequently increases the CO_2 GHG emissions in Lithuania. There are vigorous efforts to construct a new nuclear power plant by 2015; nevertheless, these efforts are yet to be confirmed by the National Energy Strategy

As a summary, the highlighted target by the government is set-up to reduce the consumption of fossil fuel. The researcher, furthermore, strengthened his research by financial implications and statistical analysis of GHG elimination towards the compliance with the post-Kyoto climate change mitigation plans.

2.4 NUCLEAR ENERGY ROLE IN THE ECONOMIC GROWTH

Nuclear energy as all energy sources plays a significant role in the economic growth. As the economic growth relies on industry booming and commerce; it is then associated with the energy expansion to cover the demanded economic growth.

Wolde-Rufael and Menyah (2010) accomplished a research to investigate the consumption of nuclear energy in relation to economic growth in nine developed countries (Canada, Netherlands, Switzerland, France, Spain, United Kingdom, Japan, Sweden and United States). The researchers evaluated the casual relationship of nuclear energy consumption and factual GDP for the period of 1971 to 2005. The causality framework was classified into four main assessment hypotheses:

- Bi-directional causality
- No causality
- Unidirectional causality from energy consumption to economic growth
- Unidirectional causality from economic growth to energy consumption

Investment and manpower were fixed as supplementary variables to the nuclear energy-economic nexus. Wolde-Rufael and Menyah (2010) used two research options in the study; the first one is an upgraded version of Granger causality assessment test while as, the second option used a generalized variance decomposition assessment.

The results found a unidirectional causality in Japan, Netherlands and Switzerland from nuclear energy consumption to economic growth whereas, an opposite causality found in Canada and Sweden from economic growth to nuclear energy consumption. Nuclear energy consumption and economic growth have direct relation in Spain, United Kingdom (UK) and USA meanwhile; energy conservation might lessen the economic growth. Energy conservation measures in Canada and Sweden to reduce nuclear energy consumption may not affect economic growth.

As a conclusion, each country of the study sample is classified under one of the four assessment hypotheses. The study can advantage the policy makers in their decisions of constructing new facilities of nuclear power. As an example, Sweden found to have a negative association between the nuclear energy consumption and the economic growth; meanwhile, further improvement and progress is needed for more efficient nuclear power plants.

2.5 SOCIAL AND RISK ACCEPTANCE OF NUCLEAR ENERGY

Pidgeon et al. (2008) executed a mixed-methodology research to investigate the socio-technical risk of nuclear power in Britain in 5 years project time. The research was focused on the residents of closed communities to in-operation nuclear facilities. Three nuclear plants among British districts were covered by the survey (Oldbury, Bradwell and Hinkley Point).

The mixed-method study was divided into three sub-methods; 1) narrative interviews method: examines the voice-over risk in the close parameter to nuclear facilities. 2) Q-sorts: to examine people's opinions. 3) Survey applied for Oldbury and Hinkley Point: via a questionnaire of six parts including environmental concerns (i.e nuclear power, radio-waste and climate change), opinions corresponding with the preceding Q-study, risks and benefits, evaluation of trust in nuclear institute, etc. Three days after spreading the questionnaire on the targeted sample, around 1326 responds were received.

Noteworthy, there were some differences among the surveyed samples towards local power stations, and about nuclear power in common. The study showed less concern about nuclear power in very close proximity. Majority of people living in close proximities to nuclear plants consider the existing station as an ordinary day-life issue and are moreover supportive for nuclear power generally. The near-nuclear residents are, however, willing to be involved in all future decisions of nuclear power plants.

The social value of nuclear energy was measured in a survey research by Jun et al. (2009). They implemented a contingent valuation method (CVM), which often recognized as "stated preference" model. The study has been targeted to test the Willingness-to-pay (WTP) for nuclear energy in order to assess the social cost of nuclear energy due to irregularity or limited diffusion of information regarding the safety of nuclear energy.

The survey was set-up to be face-to-face interview to avoid possible bias. It covered eight different cities of South Korea in May 2007. Two sets of questionnaires were proposed, the first one was designed for participants without specific knowledge about nuclear energy whereas the second one included particular questions of nuclear energy. The second nuclear knowledgeable targeted questionnaire includes: risk and radioactive waste, economic-environmental benefits, concise accident history, electricity generation from nuclear, and CO_2 GHG emissions. Every participant was briefed about the topic prior starting the survey. The questionnaire has four main categories: perception, attitude, awareness, and willingness-to-pay. It was noteworthy from the survey results that the amount of WTP becomes almost 68.5% greater when appropriate information about nuclear energy is communicated with public than it is not.

The public acceptance of Nuclear Power was, furthermore, formerly researched by Otway et al. (1978). They assessed the people attitude "attitude model" towards nuclear power. The study focused on the social characteristics of risk (estimation, evaluation and management). As "Beliefs are the building blocks of attitudes", a particular intention to each belief was paid to assessment with the attribute in this attitude model. The process of investigation was carried-out at three phases; 1) Intended for a group of energy specialists. 2) Involved a heterogeneous sample of people in Austria, and 3) was a referendum study by choice of voting executed in USA.

For energy experts, a questionnaire was spread at university associated energy research institute in the USA. Thereafter, the questionnaire included 39 questions rather than 23 originally, and distributed in Austria to evaluate the attitude of 224 random heterogeneous people of the country. The amended questionnaire included four further resources of energy in addition to Nuclear energy.

In the survey of the research, four fundamental analysis factors were considered to simplify and limit the variety of beliefs; 1) psychological risk, 2) economic and technological benefits, 3) sociopolitical risks, and 4) physical and environmental risk factor. The feed-back in both questionnaires was, however, grouped of “for” for favorable towards nuclear power and “against” for negatives towards nuclear power. The results found to be largely reliable when compared to similar surveys applied in other countries.

2.6 NUCLEAR ENERGY ROLE IN SUSTAINABLE DEVELOPMENT

Matsui et al. (2008) conducted a simulation research to investigate the nuclear energy’s role in sustainable development. They adopted integrated analysis energy software called Global Relationship Assessment to Protect Environment (GRAPE) for the simulation study. The research was set-up for long-term energy supply to optimize and minimize the contingent energy cost for the hundred years from the 2000 up to 2100. The researchers considered an assumption of double energy demand of the CO_2 emission, 2% annual cost discount for energy, and 550 ppmv of carbon dioxide concentration. The research examined the following three types of energy sources:

- Exhaustible energy sources (gas, oil and coal).

- Renewable energy sources (biomass, wind, hydropower, geothermal and photovoltaic).
- Nuclear energy.

Figure (2-9) presents a comparison of two scenarios, the first is Wigley, Richles, and Edmons at 550 ppm CO2 (WRE550) Constraint and the second is the Extended Kyoto Protocol (EKP) – the same Kyoto Protocol 2010 with 5% reduction every decade in future- to reduce the carbon dioxide emission in Annex I and Non-Annex I countries. In Fig. (2-9a) WRE550 scenario, the both Annex I and Non-Annex I parties are intersecting in around the year 2030 which constitute a reduction point of CO2 emission by Annex I countries while Non-Annex I countries resume emitting higher CO2 to reach stabilization in 2060s. Figure (2-9b) EKP scenario, the Annex I parties started decreasing CO2 emission from 2000 and will continue till 2100 whereas, Non-Annex I countries resume emitting CO2 at higher levels than WRE550 scenario to start reduction after 2050s.

The research concluded to around 18% reduction in CO2 emission in Annex I (developed countries) versus 13% allowed increase of using fossils in the Non-Annex I (developing countries) in the 21st century. The developed countries are anticipated to have 91% growth of nuclear energy usage.

The researchers, furthermore, confirmed that the nuclear energy is important for sustainable development while it has been introduced to the world by the Clear Development Mechanism (CDM) under Kyoto Protocol.

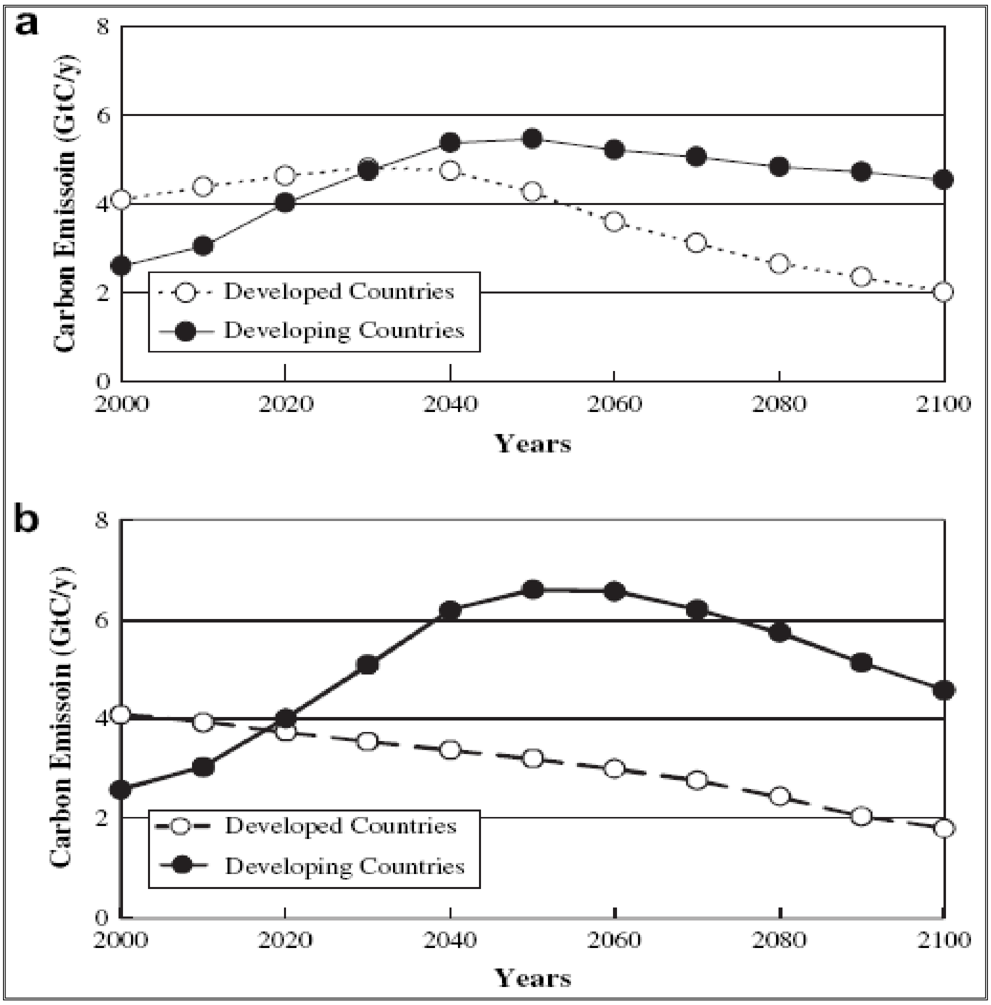


Figure 2-9: carbon dioxide emission. (a) Only Wigley, Richles, and Edmons at 550 ppm CO_2 scenario (WRE550) Constraint. (b) Extended Kyoto Protocol. (Matsui et al. 2008)

Mourogov (2000) explored the contribution of nuclear energy in sustainable development. At the beginning of the research, two opposite points of view were argued about the sustainable role of nuclear energy:

1. The first viewpoint constitutes a drawback to the sustainability on nuclear energy. The groups of people who adopt this opinion relate it to the two earlier nuclear accidents in Three Mile Island (TMI) and Chernobyl.

2. The second perspective encourages nuclear energy usage in sustainable development. This group of positive opinion towards nuclear power accumulate their approach due to the following reasons:

   a. Nuclear power does not have CO_2 emission opposed to the fossil-based energy.

   b. Nuclear energy is an already technologically developed energy which is not the case for the still at demonstration stage renewables (wind, solar, biomass).

   c. Nuclear power is the appropriate energy contributor to the countries without fossil fuel prosperity.

   d. The constant development of nuclear power encourages further advance expansion in science, industry, agriculture and so on.

The researcher continued arguing the theoretical evolutionary view of nuclear power rather than the revolutionary vision. The safety stand and concerns, radioactive waste disposal and non-proliferation issues were addresses in the research. He, moreover, discussed the task of the innovative technologies in conditions of safety, radioactive waste disposals and non-proliferation.

The research concluded the following: the current nuclear power acquire enhanced technologies that guarantee sufficient safety level and harmless radioactive waste disposal. The International Atomic Energy agency (IAEA) is effectively supporting the non-proliferation of nuclear components by the safeguards system. It had further recommended that nuclear industry should witness further innovative technologies in order to: firstly, reduce the energy costs for future challenge in energy market and secondly, present more transparency to the citizens for more acceptances by public. The successful in achieving those factors will lead to large-scale growth of nuclear energy in the near future.

Kanoh (2006) researched the nuclear energy as a vital option for sustainable development with intensive focus on the global economy. The research gathered both logical and interpretive methods for investigation purpose. The forehead of the research represented an illustration of the economic status of developed and developing countries. Followed by, an argument of the challenges of post-Kyoto protocol climate changes and the greenhouse gas emissions. From a viewpoint, the researcher presented a debatable question of the Kyoto agreement in terms of whether major contributors of CO_2 are not participating. The research represented statistical data for those carbon dioxide contributors (see Fig. 2-10). Another debatable question was raised regarding the effectiveness of the Kyoto policy and the potential of the CDM within the Kyoto protocol in the application of nuclear energy. This argument discussed the possible restrictions by the antinuclear environmentalists in Europe. A further third question presented about the Kyoto Protocol itself. The researcher argued herein the efforts to comply with the Kyoto agreement along with the various differences of participant countries. A correlation between CO_2 and the economic growth was presented along with the biggest CO_2 contributors (see Fig. 2-11).

Furthermore, a controversial debate of anti-nuclear supporters was managed logically. The anti-nuclear concerns believe that, in spite of the fact that nuclear energy is set as a non-CO_2 emitting in the operation phase, it emits CO_2 from using fossil fuel in the construction of power plant, uranium mining and waste disposal. The discussion was strengthened with chart of the CO_2 emissions versus other fuel types. The chart represents almost negligible CO_2 amounts emitted from nuclear energy in contrast to fossil fuel. Finally, the research figured-out a predicted view of the nuclear energy among the electricity demand in the 2050 in order to achieve the targeted CO_2 GHG reduction.

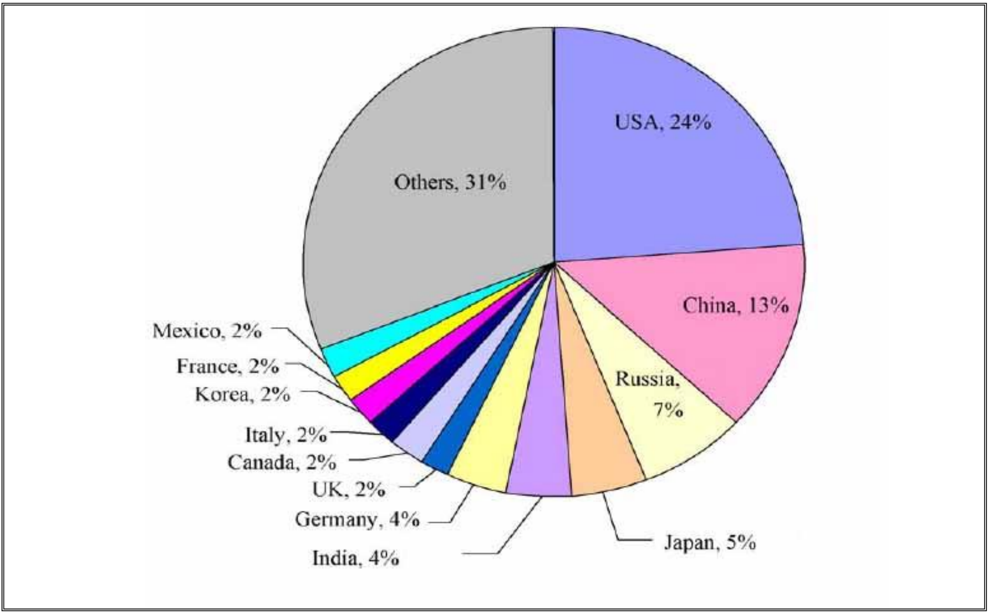


Figure 2-10: Shares of CO2 emission by country in 2001. (Kanoh, 2006)

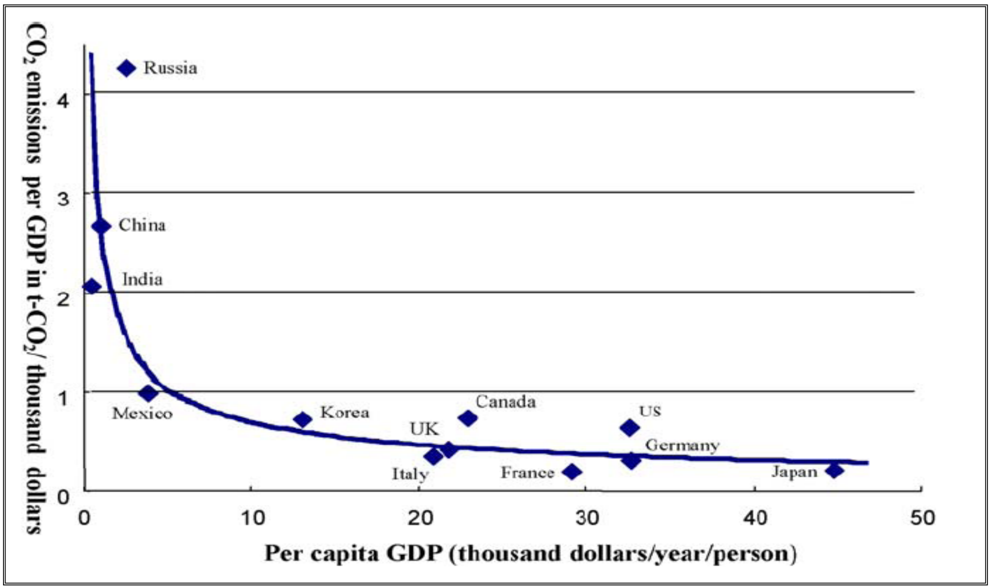


Figure 2-11: Correlation between economic growth and CO2 emission (12 biggest CO2 emitters), (Kanoh, 2006)

Omoto (2005) has a research on the nuclear power for sustainable development and relevant IAEA activities for the future. The research intended to present the aspects for sustainable energy and the nuclear power. The research, therefore, was sub-divided under this part into two sub-parts. The first sub-part focused on the importance of sustainability options as declared in the Agenda 21 in the earth summit 1992 where three sustainable mechanisms were glared “environmental protection, economic growth and social equity”.

The researcher, thence, mentioned that the low greenhouse gas emitted from the nuclear energy remains even fewer than that emitted from renewable energy sources. Moreover, the research tackled the outlook projections of energy future demand and the projected nuclear growth in 2050. Comparison was presented between the developed and developing countries for the current disruption in energy consumption. Furthermore, the research was strengthened by illustration examples from the past.

As A conclusion; the research discussed the expected actions by the IAEA and some suggestions were provided by Omoto (2005). IAEA should spread-out inclusive and accurate information in order to acquire proper public understanding of the nuclear power. The researcher also proposed some proposals for the IAEA to bridge the gap between the current and future nuclear energy supply.

2.7 AIM AND OBJECTIVES

From Literature review, the principal aim of the dissertation is focused to investigate the potential role of nuclear energy in mitigating the ever-increasing levels carbon dioxide emissions in the built environment of the United Arab Emirates. This study is highly needful in terms of contribution to sustainable development in the built environment by eliminating the CO_2 emissions.

CO_2 is noticed to be a primary contributor to the dangerous phenomenon of global warming and climate change. The targeted goal is to produce low-carbon energy into the built environment - as a substitute energy source to fossil fuel – to mitigate the ever-increasing CO_2 emissions. On the way of achieving the research aim, the following objectives need to be attempted:

- Acknowledge the need for lessening the CO_2 emission as to protect the planet's prosperity from the global warming.
- Highlight the role of different energy sources in contribution to CO_2 emissions.
- Investigate the need for mitigating CO_2 emission in the UAE.
- Simulate the predicted contributions of nuclear energy to CO2 mitigation up to 2050. This includes the cradle–to–grave stages.
- Evaluate the difference can nuclear energy make in the demanded energy and economic growth.

CHAPTER 3: NUCLEAR ENERGY

3.1 INTRODUCTION

Due to the incompetence of the conventional energy sources in the eco-environment, alternative energy sources became strongly needed. Nuclear energy has first been used regrettably for war purpose in the World's war II before its introduction into the peaceful civil utilization which helps to wipe out the preceding black history of nuclear. The fission technology was first discovered in 1938 by coincidence. The reaction thence developed from single to chain reaction to produce more amounts of energy with different reactor types. Nuclear energy is well-known as environmental clean energy as it has negligible GHG emission.

This chapter highlights sufficient features of nuclear energy. It represents the historical brief of the energy resource. Construction of nuclear power plants to generate electricity was launched in USA and few other countries in 1951 and continued in the 1950s according to (Abdul-Salam, 2009) and (IAEA, 2004a). Two meltdown accidents were, thereafter, occurred to the nuclear energy industry in 1979 and 1986 at Three Mile Island and Chernobyl subsequently. Those accidents caused negative growth of the nuclear energy development for about two decades till the late 1990s.

At present, there is a strong return of nuclear energy development due to the frightening global warming and climate change issues. Advanced generations of nuclear reactors are in the pipeline for more sustainable and reliable source of energy. The scientists – supported by governments and international associations – are focusing on safety and security, proliferation resistance, and economic competitiveness. Generation IV is now under intensive study, and is anticipated to be available commercially by 2030 which is predicted to extend the life of nuclear energy by more than 3000 years and to diminish the bad universal environmental and social impacts.

3.2 HISTORY OF NUCLEAR ENERGY

Aligned with economic development and population growth, Energy sources gain escalating importance due to the ever-increasing demand. The last decades, nuclear energy witnessed further revolution of development at many life's aspects. In this part of the chapter, using the nuclear fission reaction in producing electricity is focused as CO_2 emitting sources.

3.2.1 NUCLEAR DISCOVERY

Remarkably, the year 1895 had witnessed the commencement of atomic researches (Abdul-Salam, 2009). In 1934, the Italian physicist Enrico Fermi recorded astonishing experimental results on Uranium with neutrons which leaded to greatly lighter elements than Uranium. the German scientists, Otto Hahn and Fritz Strassman, experimented neutron-bombarded uranium in 1938 to find - un-expectedly - that lighter elements in the outstanding substances such as barium (atomic number 56) comprise about half of the uranium atomic mass. The both German scientists jointed their results with the Austrian Lise Meitner whom carried further examinations on the uranium with Bohr and others afterwards; they published their innovation as the "Fission" process which makes almost two equal atoms of uranium while the original atom is neutron-bombarded. Meitner exercised Einstein's theory $E=MC^2$ (E is energy, m is mass, and c is the speed of light in a vacuum) to confirm that the lost mass is converted to energy (DOE/NE, n.d; CHF, 2005; and Bob, 2009).

3.2.2 THE FIRST SUCCESSFUL CHAIN REACTION

Bohr shared the uranium reaction discovery with Einstein in 1939 in America, and further, he discussed with Fermi the probability of achieving self-sustaining reaction. In 1941, a tentative design for self-sustaining uranium chain reactor was proposed by Fermi in association with Leo Szilard. In 1942, the fission theory was developed by Femi leading a team of scientists at the University of Chicago and they were prepared to build the world's first nuclear reactor "Chicago Pile-1"(DOE/NE, n.d).

In 1944, Otto Hahn was granted Nobel's prize for chemistry on his detection of the nuclear fission. Noteworthy, the detection was liaised with Meitner and Strassman whom excluded from the award (Sime, 1997 and 2005).

3.2.3 THE PEACEFUL NUCLEAR ENERGY

From its invention and till the year of 1945, the nuclear reactor was only used to manufacture an effective nuclear weapon for World War II. Following to the over left damage from nuclear weapon in the war; the phrase "peaceful nuclear energy" began into sight as a focal trend. United States government leaded the peaceful tendency in the 1946. in the 1953, Eisenhower - the US president – recorded the stand progressive point in his speech of "Atom for Peace" for the launch of peaceful use of nuclear energy (Abdul-Salam, 2009 and DOE/NE, n.d).

Electricity from nuclear fission reactor was first generated on 20th December 1951 in the Unites States of America. Subsequently, generating commercial electricity from fission reaction was the focal concern amongst the mid-1950s (Abdul-Salam, 2009; DOE/NE, n.d and IAEA, 2004a)

The first universal's nuclear plant connected to power grid was constructed in 1954 in the Union of Soviet Socialist Republics (USSR) to produce about 5MW of electricity (IAEA, 2004a). then, England built the first commercial nuclear plant in 1956 at an initial production capacity of 50MW and upgraded later to produce 200MW (e) (Abdul-Salam, 2009)

Noteworthy, this era witnessed the establishment of the International Atomic Energy Agency (IAEA) in 1957 to ensure and maintain the peaceful usage of nuclear reactions (IAEA, 1997 and Abdul-Salam, 2009). Afterwards, lightweight water introduced to the self-sustaining chain reaction for cooling purpose which enhanced the opportunities of further development of the nuclear reaction process. Hence, the fission produced electricity became widespread in the developed nations as a share of the total produced electricity (Abdul-Salam, 2009 and DOE/NE, n.d)

Nuclear plants were, thereafter and particularly following to the oil crisis in 1973, constructed in many countries. Only USA built 41 nuclear power plants in the 1973, and further 72 plants in the 1979. The nuclear became to produce almost 12% of the total USA electricity grid (Abdul-Salam, 2009 and DOE, 1996). The fission produced electricity continued escalating to reach 360GW (e) in the 2005 to comprise around 16% of the universal's demand of electricity (see Fig. A-1 in Appendix A)

3.2.4 DEPRESSION OF THE NUCLEAR DEMAND

Heyday during the steady development of nuclear energy, the evolution entered a cloudy period. Unfortunate happens on ground directed to social fear and economical unwillingness. These events founded an opposition attitude towards the nuclear energy usage.

The year 1979 sighted the first nuclear accident at the Three Mile Island nuclear reactor in Pennsylvania, USA. It had left about 2000 injured persons by Gamma radiation (Rambo, 1996). A further nuclear tragedy occurred in the 1986 when meltdown at Chernobyl nuclear reactor in Ukraine, a former USSR country almost 50 folks were killed, 336,000 citizens evacuated, and three countries were the most affected (Ukraine, Belarus and Russia). The residents of these three countries are believed that still threatening by the radioactive effects of the nuclear meltdown (Rhodes, 1993 and Finn, 2005). Moreover, according to Abdul-Salam (2009) the oil price had dropped down in the 1980s which encouraged the dependence on oil for producing energy.

All of the aforementioned factors combined leaded to a recession age of nuclear industry. Furthermore, there was an escalating panic towards further safety and health shield against nuclear industry.

3.2.5 STRONG RETURN OF THE CLEAR ENERGY

The late decades witnessed a strong return of the nuclear energy development following to an important improvement to the security and safety levels of nuclear plants. Global warming and the ever-escalating oil process constituted significant factor for the strong return of nuclear energy (Abdul-Salam, 2009). Scientists, environmentalists and governments are keen to lodge a clean energy to alter the conventional energy sources and to mitigate the CO_2 emissions into the atmosphere. Besides, developing countries (i.e. China and India) are essentially dedicated to energy to practice economic growth a fortiori, clean energy is in demand.

3.3 THE FISSION WORKING PRINCIPLE "SPLITTING ATOMS"

Fission reaction is on among the two main processes in nuclear industry whereas the other is Fusion. Nuclear fission is known as the process of splitting large atom into two different smaller atoms with energy in the output (Wright, 2008). The Uranium represents the principle element in the nuclear reaction, uranium-235 (U_{235}) isotope in particular. The following equation is an example of fission reaction which generates energy by adding a neutron to the reaction (Thinkquest, 1998b):

$$U_{235} + 1\ \text{neutron} \rightarrow 2\ \text{neutron} + Kr_{92} + Ba_{142} + \text{Energy} \qquad (3\text{-}1)$$

Upon bombarding one neutron into the heavy nucleus U_{235} it outcomes $_{236}U$ and splits into two smaller equal masses. This process emits further neutrons in addition to energy (see Fig. A-2 in Appendix A) (Thinkquest, 1998a and Takada, 2006)

3.3.1 CHAIN REACTOR

Chain reaction is identified as a continuous avalanche of fission reactions when fission bombard exceeds one level of reaction. In the case of two or more free neutrons are charged into the fission of U_{235}, this promotes more fissions of uranium ore U_{235} (Takada, 2006).

It is worthy to note that uncontrolled speedy reactions lead to atomic blast or nuclear bombard which is almost certainly used in military purpose. The released neutrons into the reaction, hence, have to be properly controlled to ensure sustained reactions producing energy for peaceful uses. Thus, boron or cadmium, as a neutron absorbing substances, has to be added into the fission process to control the number of released neutrons. Furthermore, heavy water, ordinary water or graphite is essentially required in the reaction as slowing substance capable to rein the extra rapid kinetic neutrons (see Fig. A-3 in Appendix A) (Takada, 2006; Griffith and Rossenfeld, 2008)

3.3.2 FISSION POWER PLANTS

The adopted technology in the fission power plants is the conversion of thermal power using the enriched uranium as an input fuel to produce electricity. Various types of fission reactors were built to achieve this mechanism. Uranium patches normally contain U_{235} and U_{238} isotopes so, enrichment is needed to reduce the amount of U_{238} and enhance U_{235} ratio in the fuel patch used in the chain reaction inside the nuclear fission plant. The U_{238} is a non-fissile isotope and absorbs neutrons so; it has to be extracted from the fuel patch as it obstructs the chain reaction process. Water is introduced into the reaction process as a coolant and slowing agent. Control rods are added to absorb extra free neutrons to avoid probable overheating and melting. Uranium fuel heat up water and convert it into stream, this drives the turbine to run the generator which eventually release electricity (see Fig. A-4 in Appendix A) (Shultis and Faw, 2008; Brain and Robert, 2000; Thinkquest, 1998b)

3.4 NUCLEAR REACTORS TECHNOLOGY

Nuclear reactors are various in type and design. Some reactors were developed using graphite and heavy water with natural uranium U_{235} isotope. However, the fission reactors are currently using almost 3% of enriched uranium techniques (Shultis and Faw, 2008). The following nuclear reactors types are characteristically used or researched for generating electricity.

3.4.1 TYPICAL NUCLEAR REACTORS

The nuclear reactors have been developed and built in variant designs and prototypes. Most of the nuclear countries started with graphite or heavy water moderated reactors while these reactors operate with natural uranium of 0.711 weight of U_{235} whereas, the most of the current reactors use 3% enriched uranium. The steam supply moderates are among the important types of nuclear reactors as outlined below (see Fig. 3-1) (Abu-Khader, 2009; ECSSR, 2009; Shultis and Faw, 2008):

Pressurized Water Reactor (PWR): is commonly used in nuclear power plants with two water loops. Water is pressurized at high level inside the reactor to avoid any probable boiling.

Boiling Water Reactors (BWR): cooling water is permitted to boil in the reaction core to allow steam to pass into the turbine. The reactor has one loop system with lower price substance than that in PWR.

Heavy Water Reactors (HWR): heavy pressurized water in primary loop is designed for cooling the core. Pressure tubes contain the uranium fuel and pass it into the moderator vessel. In the secondary loop, light weight water is used in steaming water to.

Gas Cooled Reactor (GCR): the cooling agent in reactor is carbon dioxide or helium gas, this gas is pumped into the graphite moderator while as, the hot gas is released through steam generator. The graphite rods are provided to avoid using costly pressure vessel.

Liquid Metal Fast Breeder Reactors (LMFBR): this reactor adopts the technology of fast neutrons for controlling the chain reaction. Liquid metals from either sodium or potassium are used as a coolant to exclude low atomic mass material from the reactor's core. The distinguished advantage is multi-folding the production of fissile fuel.

Graphite-Moderated Water Cooled Reactor (RBMK): Russians designed this reactor as a high powered chinned reactor. Uranium fuel is contained in graphite containers shaping the core. Light water is pumped into pressure tubes for cooling and into steam barrel. The steam is, then, released into the turbine

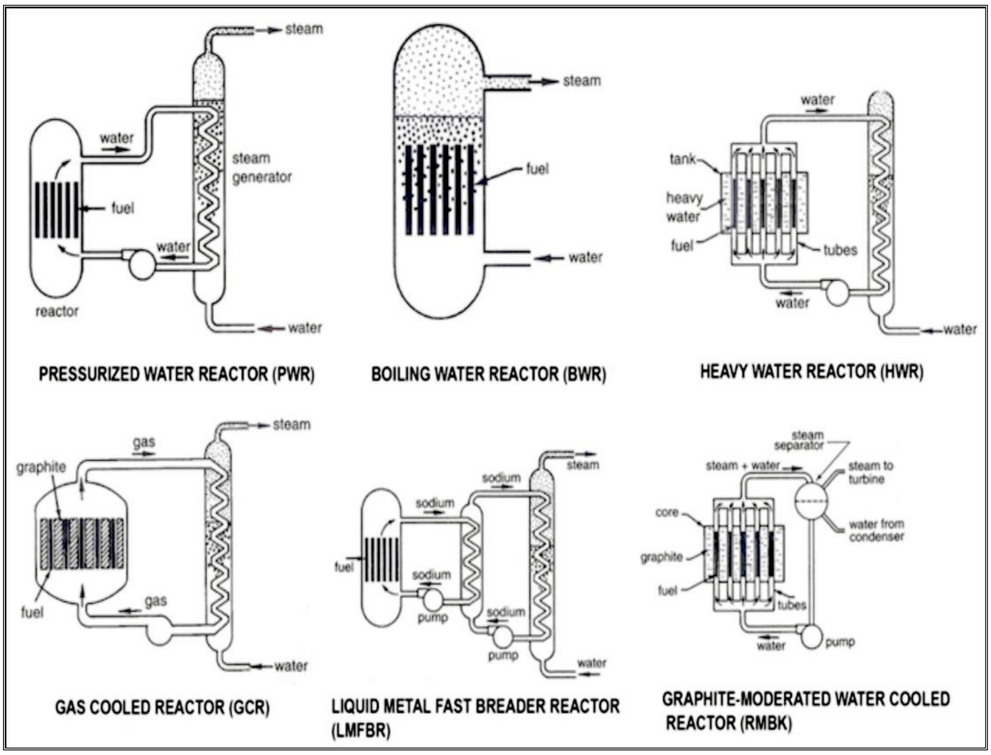


Figure 3-1: Typical Nuclear Reactors, (Shultis and Faw, 2008)

3.4.2 GENERATION II

Subsequent to the operation of first peaceful nuclear reactor generation in 1950, the development of second generation “Gen II” followed thence for supplying electricity. The currently in-operation fission nuclear plants are predominantly using Gen II reactor. They were built in 1970s and are still anticipated to remain supplying energy for the coming 20years. The power plants of Gen II have a capacity of supply ranging from 150 MWe to 1500 MWe. Among the prominent Gen II reactors, Pressurized Water Reactor (PWR) and Boiling Water Reactors (BWR) are the most common (Shultis and Faw, 2008; Wright 2008).

3.4.3 GENERATION III AND III+

The 1990s witnessed the evolutionary commencement of improvement efforts in nuclear reactors' design and installation. The Gen III recognized as an evolutionary design ranges of an approximate 100,000MWe from 103 nuclear fission plants. Gen III+ is a more advanced category within Gen III developed in 2000. Gen III+ involved "passive safety" as ultra-safe characteristics. These safety characteristics adopted key forces for cooling such as gravity, natural circulation, and pressurized gas. The following are two evolutionary plants design (Light Water Reactors) and three passive plants design (Advanced Light Water Reactors) respectively (Shultis and Faw, 2008; ecssr 2009; Adamantiades and Kessides, 2009; WNA, 2010b):

ADVANCES BOILING WATER REACTOR (ABWR): The design of this reactor was developed by GE nuclear energy with Hitachi and Toshiba to produce about 1,350 MWe. It uses digital logic and control, and enhanced electronics turbine and fuel technology which improve the availability, operation, safety and reliability of the nuclear power plant (NPP). Tokyo Electric Power Company own two ABWR reactors in operation while Taiwan Power Company has two similar plants under construction.

THE SYSTEM 80+ DESIGN AND APR 1400: APR 1400 is an advanced PWR design developed by South Korea from the US System 80+ with enhanced safety features. It generates between 1,350-1,400MWe with two loop primary circuit. The first power plant of APR 1400 is expected to operate on 2013 with Plant life of 60 years. The APR 1400 has been purchased for the use in the United Arab Emirates nuclear program due to its competitive cost and reliable building schedule.

AP600 REACTOR: is a pressurized water reactor generates about 600MWe.

AP1000 REACTOR: is a pressurized water reactor generates more than 1000MWe.

ECONOMIC SIMPLIFIED BOILING WATER REACTOR (ESBWR): it produces around 1,550MWe.

3.4.4 GENERATION IV "ADVANCED"

Looking ahead to satisfy the future's demand, the Generation IV International Forum (GIF) was found in 2001 by ten active countries including the United States to carry further development on six selected nuclear reactors known as Gen IV reactors (see Fig. A-5 in Appendix A). The participant countries agreed to develop new advanced generation of nuclear reactors for commercial use by 2030. The GIF aims to accomplish four main goals in developing the new generation of reactors, these goals are: 1) proliferation resistance and physical protection (PR&PP), 2) energy sustainability, (3 safety and reliability, and 4) economical competitiveness of nuclear energy. The six types of Gen-IV reactors are (see Fig. 3-2) (Shultis and Faw, 2008; Adamantiades and Kessides, 2009; Bennett, 2007; Pomeroy et al. n.d; and GIF, 2001):

VERY HIGH TEMPERATURE REACTORS (VHTR): the subsequent advance of Gas-cooled reactors. It is able to create hydrogen via thermo chemical iodine-sulfur from heat and water.

MOLTEN SALT REACTORS (MSR): is generated in a circulating molten of sodium, zirconium, uranium or fuel mixture of plutonium fluorides.

SODIUM-COOLED FAST REACTORS (SFR): rapid sodium reactors with closed fuel cycle.

SUPERCRITICAL WATER-COOLED REACTORS (SCWR): a high temperature and pressure reactor operates over (374ºc, 22.1 MPa) which is the thermodynamic critical point of water.

GAS-COOLED FAST REACTOR (GFR): rapid helium cooled reactor with closed fuel cycle.

LEAD-COOLED FAST REACTORS (LFR): the used cooling agent is lead bismuth.

similar to the GIF efforts, IAEA developed a project called INPRO (International Project on Innovative Nuclear Reactors and Fuel Cycles) to ensure the ease accessibility of the nuclear energy as a sustainable source of energy in the 21st century. The INPRO share, nearly, the same aims of the GIF charter.

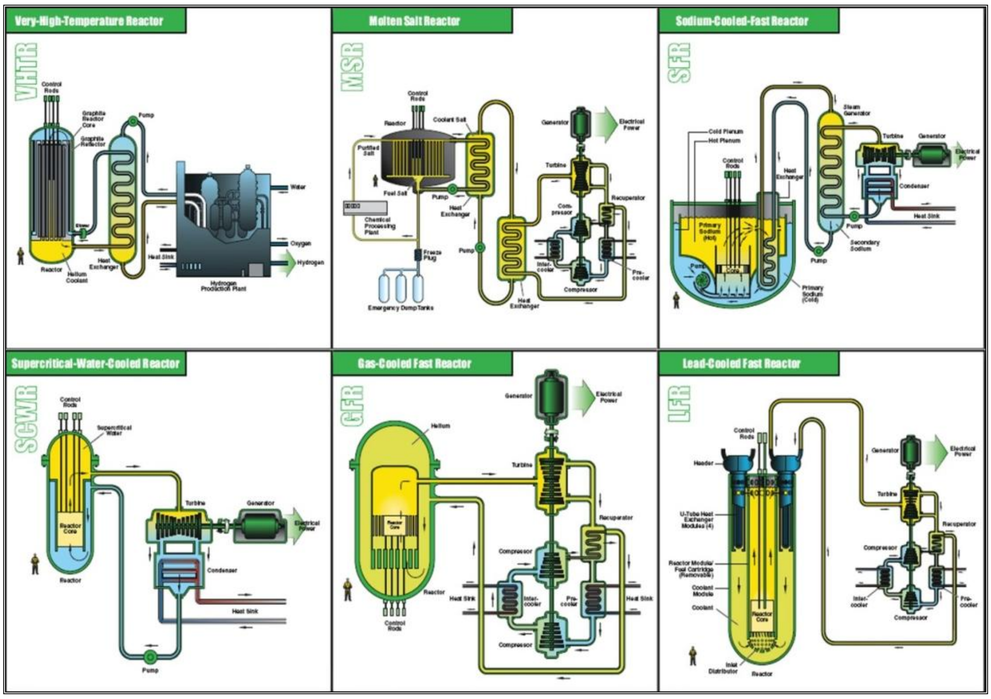


Figure 3-2: Six technologies of Generation IV selected for further research. (Bennet, 2007)

3.5 CURRENT STATUS OF FISSION TECHNOLOGY

The nuclear has strong return into sight as it has the capability to contribute for clean environment, and has significant safety improvements to the nuclear reactors. As elaborated under sub-sections "3.4.3" and "3.4.4" above, the third generation of reactors Gen III and Gen III+ is the currently operational technology. The fourth generation Gen IV is yet under research and development for superior sustainability and safety targets.

3.5.1 IMPROVEMENTS OF OPERATION PERFORMANCE

Safety, economy and advanced nuclear techniques were not allocated as a priority at the former building of nuclear power plants, while, they occupy significant concern in the nuclear industry nowadays. this importance of improving nuclear techniques were especially astonished after the public fear of possible nuclear accidents beside to the need of competent nuclear energy source. Since then, the safety performance of nuclear plants was put under prospect of international and governmental acts that periodically orient the nuclear improvement and safety requirements. Nevertheless, the energy accessibility and productivity recorded a slight decline to 79.3 % over the last decade (see Fig. A-6 in Appendix A). USA and Russia, then, leaded the universe in improving the capacity of nuclear energy production.

Operation performance can be improved at more than one level such as: management practices, personnel characteristics and training, plant's operation, maintenance, and technical support, and reactor surveillance and diagnostic (IAEA, 1999; and Lillington, 2004).

Outage time achieved reduction in number of operating plants via technical and administrative improvement. Computerised systems are added to improve the outage planning and management. The scheme of fuelling has significant influence on outage planning such as the general trend towards fuel cycle. However, the outage might have significant impacts on safety so; it should be avoided in peak demand times (Lillington, 2004). Extensive improvement occurred to the duration of refuelling outage while; serious efforts were gathered to increase the refuelling and lessening the outage period (see Fig. A-7 in Appendix A). This technique enhanced the productivity of nuclear plants along with the revenue (Lillington, 2004; and Adamantiades and Kessides, 2009).

3.5.2 Extending the Operation Life of Nuclear Power Plants

The original licenses are usually issued for 30 to 40 years of commercial power reactors operation which is so called the initial lifespan of NPP. The lifespan can be extended to 20 more years. Fifty two licenses of nuclear power plants were renewed in USA in 2009 (Nikitin and Kudrik, 2006; Wachter, 2007; and Adamantiades and Kessides, 2009). There are few countries including USA have renewed the operation licenses for selective old nuclear power plants (Adamantiades and Kessides, 2009). According to Nikitin and Kudrik (2006), Russia extended the lifespan for 7 NPPs in 2005 and another 4 NPPs in 2008 beyond a 30 years engineered life span. Also, Newsroom (2010) mentioned that UK extended the lifespan for two NPPs in 2009. Such regulations of extension add significant enhancement to the economic growth if the efficiency and the performance competency of these plants is ensured.

However, there is no generic reason to limit the lifetime of operating NPP. All the currently at initial lifespan operating NPP are planning to apply for extension as mentioned by Brian Holian, director of license renewals for the US Nuclear Regulatory Commission at PLIM/PLEX conference in Chicago. The NPPs with extended lifespan are interested in a second lifespan extension beyond 60 years to 80 years of lifetime. Garry Young, Entergy's head of business development stated saying “We do have a precedent for this–there are some hydro plants that were built over 100 years ago". The Electric Power Research Institute in USA is currently preparing a research and development strategy to examine related issues to NPPs life-beyond-60. This research is planned to be completed by 2014 (NEI, 2010). The lifespan extension, especially for the first generation reactors, is still questionable in terms of economy and safety and cases not feasible in most.

3.6 NUCLEAR FISSION CHARACTERISTICS (PROS AND CONS)

Besides the incessant technical development of nuclear energy to, public opinion towards nuclear energy usage has two contrary directions. The melt down nuclear accidents opened a non-yet endless debate; the anti-nuclear people, on one side of the debate, are more worried about the negative impacts and safety precautions of the nuclear energy versus the nuclear supporters. According to ESCCR (2009), the public belief has complex constituents of opinion, attitude and values. The majority of the nuclear energy concerned people are willing to accept both the pros and cons in each side’s view.

3.6.1 THE ADVANTAGES OF THE NUCLEAR FISSION ENERGY CAN BE CONCISED AS FOLLOW:

LOW ENVIRONMENTAL IMPACTS: when compared with conventional energy sources, the nuclear energy has the least GHG emission and the least atmospheric pollution. Therefore, nuclear energy contributes a responsible integrated solution to the worrying global warming.

LIMITED LAND USE: by comparison with the other energy sources especially, renewable like wind and solar energy which need huge areas of land for the same supplied amount of electricity, nuclear need fairly small piece of land. According to ANS (n.d); the land area needed to produce of 1000 MWe from nuclear energy is around 4 Km^2 whereas solar energy needs almost 40 Km^2, biomass requires 6,000 Km^2, and wind energy needed land to for the same produced electricity is almost 100 Km^2.

SECURED ENERGY SUPPLY: the reserves of uranium are expected to cover the next 50 years demand at the current consumption rate whereas, undiscovered and unconventional sources of uranium would cover the demand for almost 100 years. Recycling plutonium isotopes and advance reactors technologies would, however, offer 70 times of today's uranium reserves which cover not less than 3000 years of demand on the current using rate (IAEA, n.d).

According to Rauf and Vovchok (2009), there is an approach as a recent move by IAEA towards securing national operations via assurance of fuel supply, uranium-enrichment, separation technologies of plutonium, and storage or disposal of spent fuel. This is due to increasing demand of nuclear option by number of countries.

HIGH AMOUNT OF ENERGY FROM SMALL PELLET OF URANIUM: the fissile U_{235} isotope produces relatively very high amount of energy. According to ENEC (2010d), 1 Uranium fuel pellet equals to almost 907 Kg of coal and equal to 474 liters of oil.

THE AVAILABILITY OF INEXPENSIVE URANIUM SOURCES FOR NUCLEAR FUEL: the uranium is enormously available for pulling out from open-cut areas.

LOW COST ELECTRICITY: the electricity generated by nuclear energy ranges from 2 to 8 US&/MWe - excluding the construction capital cost and decommissioning - which is somewhat the cheapest sources from other energy sources (see Fig. 3-6).

LOW WASTE AMOUNTS: apart from its radioactivity, the released amount waste from the fission reaction is low if compared to the produced energy or to the ash produces from coal and wood.

TECHNOLOGY IS ALREADY DEVELOPED (Mourogov, 2000): nuclear can start mitigating global warming at immediate action upon plant construction as it is commercially available. Other clean energy sources, especially renewable, are still under investigation and development.

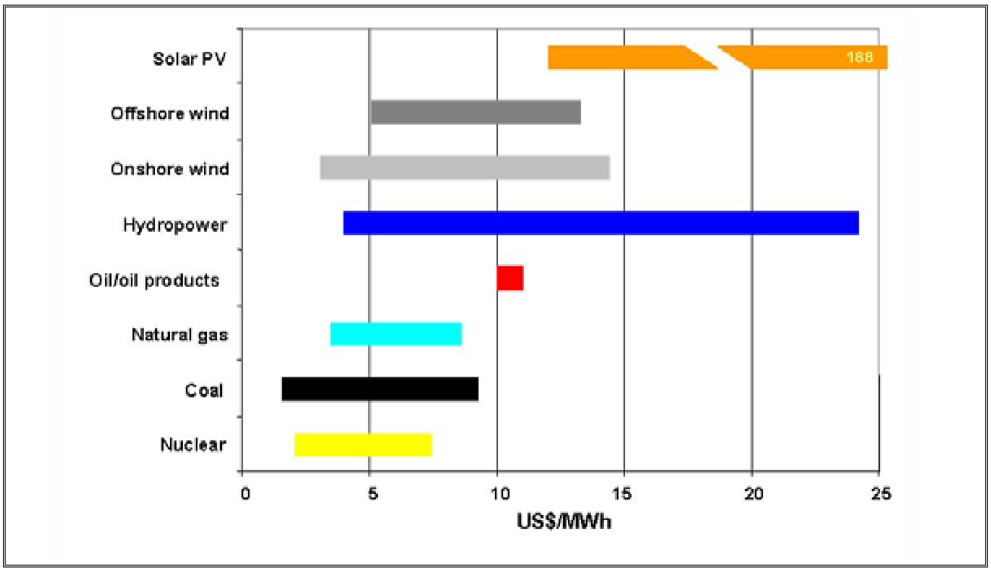


Figure 3-3: electricity cost estimates from studies completed in 2003-2005. (Sokolov, 2008)

3.6.2 THE DISADVANTAGES OF THE NUCLEAR ENERGY CAN BE SUMMARIZED AS FOLLOW:

EXPOSURE TO RISK: public fear towards nuclear has increased subsequent to the two accidents in Chernobyl and Three Mile Island.

Although energy supply plants are not used for research like Chernobyl and Three Mile Island, there is still high possibility of explosion in absence of the appropriate safety and control measures. The risk exposure is, however, decreasing due to significant scientific applications in the advanced reactor generations.

HEFTY INITIAL CAPITAL COST: the nuclear power plant's (NPP) construction stands for almost 60 - 70% of the overall cost whereas 20% stands for operation and maintenance (Sokolov, 2008). Other shares of capital remain for the decommissioning. However, final construction estimates have some uncertainty.

DIFFICULTY OF SAFE WASTE STORAGE IN LONG TERM: storing the radioactive waste in a safe and well sealed storage is required for 10 to 20 decades. In spite the low mass waste; there is no firm assurance against geological disaster such as earthquakes and volcanoes rather than the possibility of leak.

LONG TIME CONSTRUCTING PROGRAM: building nuclear power plant lasts from 6 to 16 years after proper permits and before electricity production (IAEA, 2007a). Today's decision to connect nuclear electricity to the grid should be a planning for minimum 12 years ahead

NOT FOREVER SUSTAINABLE SOURCE: the nuclear energy is correlated to the availability of exhaustible uranium source; meanwhile, there is a time limit for using nuclear fission before it stops.

HIGH CONTROL MEASURES ARE NEEDED: international organisations like IAEA need to ensure the peaceful civilian use of the nuclear at regular basis. They have to keep open eyes on the participant countries or associations to remain using nuclear peacefully and far from terrorism.

3.7 Nuclear Energy in the United Arab Emirates

As discussed in chapter 1 under section 1.4, the CO_2 level in UAE has reached almost 146.9 $MtCO_2$ in 2008 according to IEA (2010). Kyoto Protocol determined that this level is still within the allowed range for UAE as a Non-Annex I country. However, UAE willingly decided to commit to Kyoto Protocol and take a proactive step in this area by introducing low carbon energy sources to promote the environmental sustainability of the country (Embassy-of-UAE, 2009).

Therefore, UAE pursued a peaceful nuclear energy program as an option to mitigate the CO_2 emissions and sustain the UAE's environment. According to Stanton (2010), Abu Dhabi decided to turn to nuclear power which is expected to cut the carbon emissions in the country by 32 Mton CO2 annually once the nuclear plant operated. This quantity is almost equivalent to the total carbon footprint of Bahrain which represents between 16% and 20% of UAE today's CO_2 emission. However, this amount found underestimated according to the simulation results in this research as discussed in Chapter "6".

According to Radan (2010), reference to a recently published report on "Climate Change - Impacts, Vulnerability and Adaptation in UAE" published recently, the UAE strategic planning will focus on the climate change. This is expected to be planned for 2050. Nuclear energy is, however, expected to occupy a significant part of the UAE strategic planning due to its believed impacts on lessening the climate change. Furthermore, the 2030 economic vision has stressed on sustainable development and growth via the expansion of energy as one of the strategic economic sectors (TGOAD, 2008). Therefore, the economically favourable Nuclear energy, as verified in Chapter "7", should be play a significant role in the Abu Dhabi economic vision of 2030.

3.7.1 ELECTRICITY DEMAND

ENEC (2008) and Embassy-of-UAE (2009) stated that official UAE entities have recently conducted an analysis of electricity projected demand. The analysis concluded that annual peak demand for electricity is expected to go beyond 40,000 MW's by 2020 at an approximate cumulative annual growth rate of 9% (see Fig. 3-3).

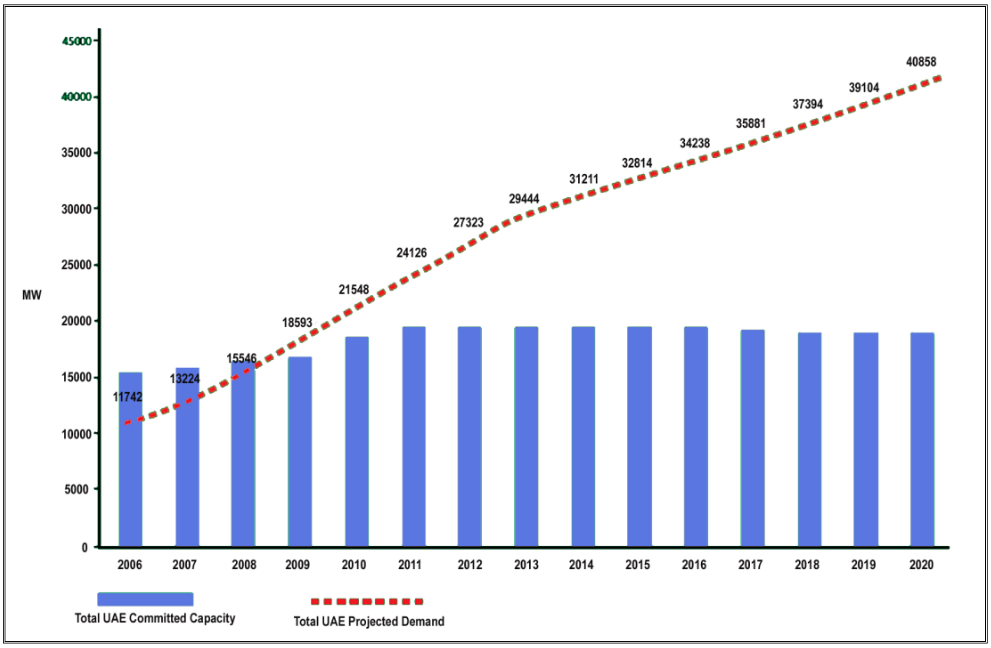


Figure 3-4: UAE committed capacity and projected demand of electricity till 2020, (ENEC 2008)

According to the electricity projections, the UAE evaluated the feasible options to cover the future's inability of electricity supply. The feasible options included the following (ENEC, 2008; WNA, 2010a; and Embassy-of-UAE, 2009):

- The possibly available natural gas quantities would be insufficient to meet future demand of electricity. It supplies merely 20,000-25,000 MWe of power generation capacity by 2020.

- Although burning liquid fuels (i.e. crude oil, diesel) found logistically viable, heavy reliance on liquids in future is economically costly environmentally harmful.

- Coal-fired power generation is comparatively cheap but, it has negative environmental impacts in addition to thorny issues of security of supply.

- Alternative energy sources (i.e. solar, wind) would supply a maximum of 6-7% of UAE's peak electricity demand by 2020 in the best cases of development. Masdar has started developing alternative renewable energy especially, solar power.

Therefore, nuclear has proposed as a better option for environment and economic competitiveness to generate electrical power in the UAE. It could contribute significantly to the base-load improvement of future economy and energy security (ENEC, 2008).

3.7.2 NUCLEAR POLICY STATEMENT

Further to relevant studies and analysis, the UAE has established a Nuclear Energy Program Implementation Organization (NEPIO) according to IAEA recommendation. This was followed by an evaluation of a peaceful nuclear program for civilian accessibility of nuclear energy by UAE people. Noteworthy, The UAE government emphasizes that nuclear energy is one of several integrated energy sources for future power generation. The UAE aims to meet future energy demands in addition to developing diverse and secure resources of power-generation. Therefore, the following policy statement - of a peaceful civilian nuclear energy program - was formally endorsed by the UAE government in April 2008 to form a basis on the potential establishment of the program (ENEC, 2008):

- “The UAE is committed to complete operational transparency”.
- “The UAE is committed to pursuing the highest standards of non-proliferation”.
- “The UAE is committed to the highest standards of safety and security”.
- “The UAE will work directly with the IAEA and conform to its standards in evaluating and potentially establishing a peaceful nuclear energy program”.
- “The UAE hopes to develop any peaceful domestic nuclear power capability in partnership with the Governments and firms of responsible nations, as well with the assistance of appropriate expert organizations”.
- “The UAE will approach any peaceful domestic nuclear power program in a manner that best ensures long-term sustainability”.

The aforementioned policies and actions are either being implemented or planned to be implemented during deploying nuclear facilities within the UAE (ENEC, 2008). They are, furthermore, included in the UAE Nuclear Law which was issued in late 2009.

Moreover, the UAE has signed with the IAEA a Comprehensive Safeguards Agreement (SCA) in April 2009 as an Additional Protocol. The SCA forms a methodology for surveillance of nuclear facilities and operations. This is viewed by UAE as an important factor to achieve operational transparency and the highest non-proliferation standards according to the first two policies of having a peaceful civilian nuclear energy program. The UAE has endorsed cooperation agreements with many countries (i.e. Korea, France, and the United States) in the field of peaceful nuclear energy (Embassy-of-UAE, 2009).

3.7.3 Design Characteristics

The project is planned to consist of four APR 1400 reactor units for generating power (this is discussed in sub-section “3.4.3”). Each unit is designed to produce up to 1,400 MWe for a total capacity of 5600 MWe. Every nuclear power plant (NPP) contains a reactor building for the reactor and related safety and non-safety systems needed to generate steam supply. The turbine building is next to the reactor building is where thermal energy from the reactor is transformed to electrical energy. The NPP Power Block consists of the three main following parts (Rizzo, 2010):

Nuclear Island: contains structures, operating systems, and supporting components for the nuclear reactor operation. These supporting components include associated steam supply, uranium fuel handling and storage, heat removal, and maintenance equipments. The four reactor buildings are the tallest on the site at almost 63 meters (m) height. Each one is of cylindrical solid structure, with spherical dome cap. Further supporting facilities for operation include standby diesel power units; supplementary power and cooling water in addition to control systems (see Fig. 3-4).

Turbine Island: contains the turbine of steam, equipment for generating electricity, transformers, and other supporting components. All the units are connecting to a switchyard.

Switchyard: includes interconnection equipments of the main generators and transformers to the national electrical grid. They are interconnected via two independent 400 kilovolt (kV) transmission lines as a minimum.

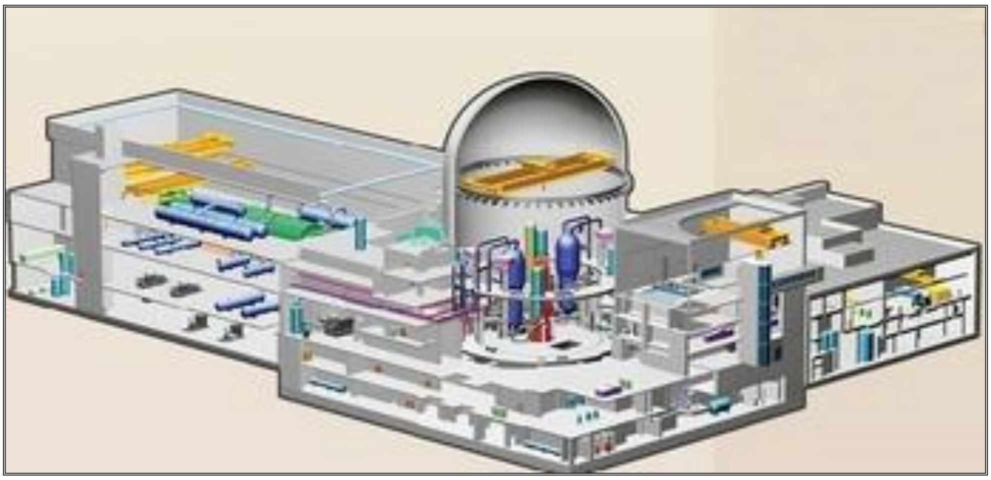


Figure 3-5: Features of APR 1400 Reactor, (NEImagazine, 2010)

3.7.4 THE PREFERED SITE

Site selection for NPP has certain requirements and characteristics. There are factors to be considered to evaluate the site such as: Reactor design and proposed operation including (intended use and radioactivity, special features, safety features), Population (density, site neighborhood, population zone and center distance), Physical characteristics (seismology, meteorology, geology, hydrology), and so forth (CNSC, 2007; and Salman, n.d). According to Gürpinar (2010) site selction process includes screening the possible sites, then ranking the candidate sites, and arbitrary exclusion criteria. For instance, sites within tsunami occurance must be excluded at survey stage. Furthermore, the screened site should be located within 10 km from the coastal or, within 1 km from a lake or a fjord shoreline or, at less than 50 m elevation from the water level.

A process of site selection for the UAE NPP began in mid-2008 to identify the best suitable site in terms of safety criteria and minimum environmental impacts. Selection process followed the site selection standards of IAEA which discussed earlier in this sub-section, the Electric

Power Research Institute (EPRI) in USA and United States Nuclear Regulatory Commission (NRC). The entire UAE was proposed at the beginning as the region of interest. Unsuitable regions were then excluded after constant evaluations, and almost 10 candidate sites remained and fully detailed in the study. Finally, the studies showed that the Braka site on the Arabian Gulf at approximately 53 km southwest of the town of Ruwais in Abu Dhabi's Western Region is the preferred site to build UAE's first nuclear power plant (see Fig. 3-5). The Braka site preference accomplished due to the encouraging characteristics such as its low seismicity, Isolated from settled cities, No tectonic plate boundaries, Satisfactory distance to road network, Proximity to sea water for cooling purpose, etc (ENEC, 2010b; ENEC, 2010d; and Rizzo, 2010).

The selection process was relatively similar to three sites selection in Syria which predicted to start construction after 2018 at a start-up capacity of 1,000 MWe as documented by Othman and Mashfej (2010). The selection process is also similar to selection process of NPP in Thailand where they have five prefered sites (Sirindhorn, Phanom Rok, Mai Root, Khantulee, and Pak Nam Lamae) with a predicted start of construction by 2014 (Ratanakorn, 2010).

ENEC received two licenses from the Federal Authority for Nuclear Regulation (FANR) for work related to the construction of features of the preferred site at Braka on July 2010. Those both licenses are for limited construction for manufacturing and assembling safety equipments (ENEC, 2010a).Construction Environmental Permit to start the civil work is still must be obtained from Environmental Agency – Abu Dhabi (EAD). That is why the Braka site is still called the preferred site as the relative legal approval are not completed yet (ENEC, 2010c; and 2010b).

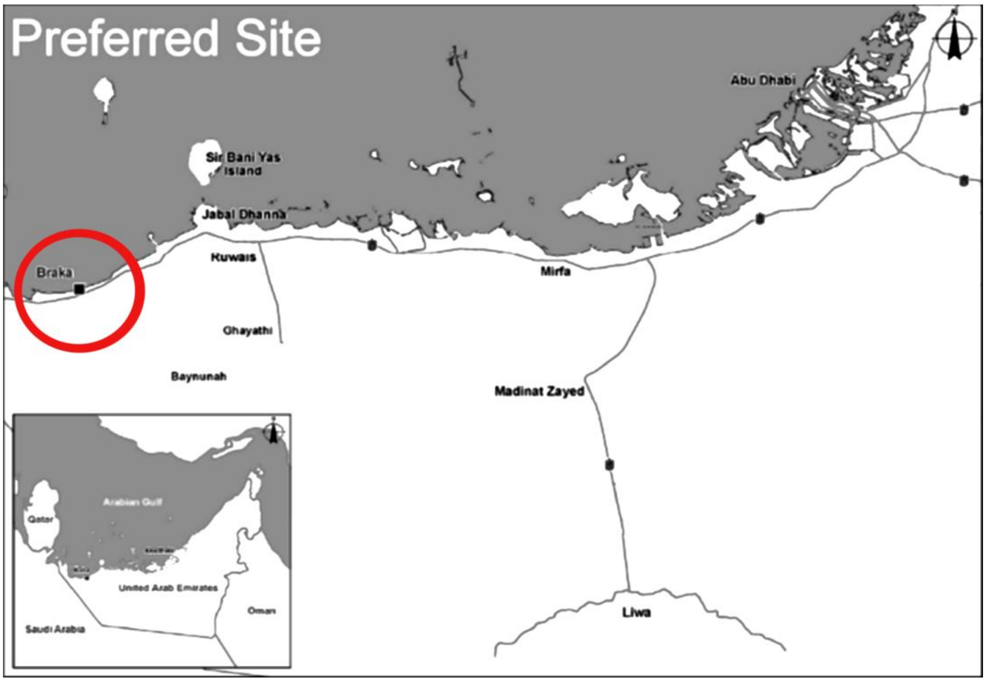


Figure 3-6: The preferred site “Braka” map of the UAE’s first Nuclear Power plant, (ENEC, 2010b)

3.7.5 CONSTRUCTION PROGRAM

The program of constructing the UAE’s first nuclear power plant at Braka site in Abu Dhabi has started its roadmap on April 2008 which was publically announced on May of the same year. The timeline program, however, displays the key milestones and objectives for NPP construction to feed electricity in the UAE. The program is developed according to guidelines established by the IAEA. The current plan is setup to operate the first commercial unit by 2017 at 1400 MWe. The following three units are planned to generate power by 2018, 2019 and 2020 successively to operate the NPP at its full capacity of design (ENEC, 2010d; ENEC, n.d) (see table 3-1). It is noteworthy that Korea Electric Power Corporation (KEPCO) was selected on 27 December 2009 as the prime Contractor to design and build NPP (Rizzo, 2010).

Table 3-1: Timeline for the construction and first operation of the UAE's 1st NPP, (ENEC, n.d; ENEC, 2010d)

Date	Activity
2008	Roadmap for UAE Nuclear program completed on April. UAE Nuclear energy program announced on May. Appointment of managing agent on November
2009	Prime contractor selection on April. Technology and prime contractor down-select on June
2010	Preparation of Unit 1 construction on March. Nuclear and "Safety culture" training begins on July. Submittals for relative licenses and approvals
2012	First safety related concrete poured for unit 1 on March. Submit Construction License application (CLA) to FANR.
2013	Pour unit 2 power block concrete.
2014	Operational training underway on March.
2015	Control room simulator completed on March. Submit operating license application for unit 1 and 2 to FANR.
2016	First fuel delivery for unit 1 on July.
2017	First electricity to the grid on June for Unit 1. Submit operating license application for unit 3 and 4 to FANR.
2018	Unit 2 Commercial operation
2019	Unit 3 Commercial operation
2020	Unit 4 (the last of the UAE's 1st NPP) Commercial operation

3.8 Future Challenge Prospects

Parallel to the optimistic prediction of an increasing nuclear demand, sustainability of nuclear energy has to be strongly examined. Although, it is introduced as a successful substitute to conventional energy sources, the nuclear energy remains having some key challenges to be fulfilled for a future competitive and sustained energy source, these challenges include the following:

3.8.1 Safety

Subsequent to the two past accidents, vast nuclear developments were occurred on safety. Technological perfection of reactors is concerned of preventing future's accidents and protecting health of lives. The safety is, therefore, constitutes a key factor for sustaining nuclear energy. According to (IAEA, 2002b), there are three basic objectives to ensure the safety of nuclear plants. These objectives are: 1) general nuclear safety via effective defence measures to protect people, societies and environment, 2) Radiation protection, and 3) Technical safety to prevent accidents by ensuring all the reasonably practical measures. Adamantiades and Kessides, (2009) mentioned that exposure to reactors' radiation during the operation phase has an immense concern. Therefore, the NPPs might have physical barriers as an essential technique to capture any possible radiation inside a limited space. Any possible radiation must not be released into atmosphere in any case. Proper design and periodic maintenance should be ensured to the core structure of the plants. Furthermore, safe measures have to be set-up for human errors and uncontrolled fission chain reaction.

As mentioned in sub-section "3.7.4", UAE has committed to ensure nuclear safety to the highest robust standards. The design integrated proper features and systems to protect the facility against accidents during operation and to prevent radiation in the occasion of a terrorist attack. The associated national authorities and safety marshals are also well trained professional safety support. Hence, strict regulations and safety management rules are set-up across all operational aspects of the nuclear sector. The measures are purposed to prevent accidental radiological discharge and to lessen the consequences of any such discharge. It has believed by the UAE that the selected APR 1400 from the Generation III+ have enhanced safety prospective such as: longer plant life (normally 60 years), enhanced user-friendliness, and higher burn-up rates which reduce fuel consumption and waste. Safety improvements in the UAE included extremely robust concrete suppression structures to protect the reactor and prevent radiation discharge in the occasion of an accident, design simplifications to ensure lower disruptions risk, and 'passive' safety systems to rein intervention and avoid accidents in case of breakdown. Furthermore, necessary border and protections is designed to insulate the NPP, transportation infrastructure and storage blocks from external threats or sabotage (ENEC, 2008).

3.8.2 SECURITY AND NON-PROLIFERATION

The geographical location is an important factor accrediting new nuclear plants while nuclear reactors have to be well protected from any predictable terroristic attacks. Hence, unstable geographical areas are considered as not appropriate surroundings to own nuclear energy. NEAC (2008) pointed-out that further security options like 1) Anti-threat design, 2) accountability and 3) safeguard are to be adapted against security hazards. The safety and security should be examined by the nuclear operators and government at periodic intervals.

The public have a steady fear of the nuclear association with plutonium production and the nuclear weapon increasing terroristic danger. As aforementioned - under the sub-section "3.2.3", (The Peaceful Nuclear Energy), the IAEA stands for peaceful organization since 1957. About 180 countries agreed that IAEA monitoring their nuclear activities in order to not attain nuclear weapons. Even though, some countries like

Iran and North Korea are still uncertain in their nuclear plans (IAEA, n.d; ecssr, 2009), with continuous calls from the world nations to remain inline back under the IAEA non-proliferation program. For that reason, sufficient security and non-proliferation guarantee has to accompany further nuclear development.

The UAE is committed to high standards of non-proliferation. The political commitment was made by UAE in 1995; this was followed by a commitment to non-proliferation of the IAEA Comprehensive Safeguards Agreement in 2003. The UAE is repeatedly and assertively stating that the government is against the existence of weapons of mass destruction in the Middle East. The UAE carried-out a number of legal and institutional measures to execute non-proliferation initiatives such as preventing non-state actors to acquire or develop nuclear, biological and chemical weapons. Unlike other countries having civilian nuclear energy programs, the UAE will not practice nuclear fuel-cycle and enrichment activities (ENEC, 2008).

3.8.3 WASTE DISPOSAL AND MANAGEMENT

Waste disposal almost occupies the most noteworthy troubles in front of the nuclear development and its public acceptance. It has an immense concern due to its hazardous radiation effect. The waste problem is accumulating following to the growth of the nuclear plants. Adamantiades and Kessides (2009) mentioned that, comparatively insignificant low and intermediate radioactive waste levels are generated within the nuclear fuel cycle.

Management of radioactive waste is an imperative tool for future's development. The current universal rate of nuclear waste volume stands for almost 12,000 tons annually which is relatively low if compared with fossil fuel waste of an approximate 8.5 billion tons of polluting CO_2 in addition to large amounts of ash. Nuclear waste has, however, to be geologically isolated and sealed in ceramic or glass containers. It, furthermore, has to be enclosed with containers with corrosion resist specification. Scientific researchers are, moreover, continuing to reduce the quantity and toxicity of nuclear waste (Adamantiades and Kessides, 2009).

Yucca Mountain is a current proposal by the USA as repository of spent nuclear fuel and high level waste. It has a capacity of 70,000 tons of waste with extension allowance to 12,000 tons. The waste has to be deeply buried above the water level which reduces the exposure to blasting risk (NEAC, 2008). This model of safe repository at deep level is technically preferable to many countries, [especially UAE] which started studies and investigations to have their own repositories (Adamantiades and Kessides, 2009).

This improvement has its way to application, although, it remains a controversial matter particularly to the anti-nuclear supporters. There are worries of potential underground leakage at these repositories whereas; the burying will stay for several years prior the fading of radioactive toxicity. Furthermore, the radioactive waste repositories have to be allocated in safe places from earthquakes, volcanoes, and terrorism in order to ensure long time safety and security.

The UAE would prefer, at short-term fuel storage, to source nuclear fuel through fuel leasing or similar measures that relieve it of the long-term requirements of safeguarding spent fuel. In the event of long-term storage is required, the UAE would build and manage the suitable facilities according to the international safety standards of waste disposal under strict regulations. The UAE will use fueling services by foreign suppliers to reduce the volume of spent fuel which leads to reduction in the permanent storage requirements. These services are planned be conditioned that all reprocessing activities to be done outside the UAE. Noteworthy, the UAE would always support international efforts to develop a network of multi-lateral fuel secured supply. This support might include a “last resort” fuel bank, which would insure constant nuclear fuel supply for nations without local enrichment facilities.

Additional to the abovementioned challenges, there are few further concerns for more competitive nuclear energy. These concerns include:

- Diminish poverty and improve living standards.
- Maintain economic growth.
- Contribute to clean energy scheme.
- Substitute efficiently the fossil fuel
- Ensure financial plan to build nuclear plants.

CHAPTER 4: METHODOLOGY

4.1 Introduction

This dissertation is set-up to investigate the potential role of Nuclear energy in mitigating the carbon dioxide emissions in the United Arab Emirates. Several research methodologies can be conducted to investigate similar roles of nuclear energy in different countries or worldwide. The four most widely used research methods are discussed herein as follow:

4.2 Case study

As identified by researchers, case study methodology concerns with a realistic prominence. Groat and Wang (2002), citing Yin (1994), have mentioned that case study research is defined as "... an empirical inquiry that investigates a contemporary phenomenon within its real-life context, especially when the boundaries between phenomenon and context are not clearly evident."

Davidson (2010), for instance, carried over a case study research of nuclear energy in Alberta City in Canada. The motivation of study was the proposal of building a 4,000 MW nuclear power plant in the city. He studied the current and anticipated energy supply and demand in Alberta. The current sources of electricity are almost only coal and natural gas. The anticipated electricity consumption in 2037 is three and half times the 2007 amount. The researcher also studied the current status of nuclear power in Canada along with its attractions and summary of associated risks. Economic viability was researched including financing plant construction, construction and operation costs, decommissioning, and costs of uncertainty. Furthermore, the social dimensions study included the perception of risk as a key factor influencing the political acceptability of compound technologies, the policy climate, and host communities of nuclear plants. Additionally, the ethical implications of nuclear power development were outlined by the study. As a summary, the research highlighted that the ethical implications of nuclear power development are ambiguous. However, two chief conclusions came in the study; first, the associated challenges with nuclear power are social rather than technical second, decision-making process can be enhanced by concentrated attention to these social issues.

Bruhn-Tysk and Eklund (2001) performed a case study to verify the environmental impact assessment (EIA) for bio-fuelled energy plants in Sweden. The EIA is a tool for promoting sustainable development which was introduced as part of the country's Environmental Protection Act in 1981. The study adopted an environmental impact statements (EISs) for Swedish bio-fuelled energy plants to analyze if the components of EIA are vital to meet intra-generational and intergenerational equity, local and global impacts, resources management, public participation in plants development, and alternative design options. The study examined the associated EISs for 55 applications of bio-energy sector of Sweden. These applications are of development consent which made according to the Environmental Protection Act from 1995 to 1998. The applications vary in their objectives to include: new construction of energy plant, capacity enlargement, continued operation of an energy plan and so on. Thereafter, the researcher concluded that the 55 EISs for the Swedish bio-fueled energy plants showed few positive signs of EIA to function as a promoting tool of sustainable development. However, EIA practice in Sweden, as a full extent, might not be the proper tool to promote sustainable development.

Further researchers performed case study methodologies to study relative issues to nuclear energy and its role of sustainability in the built environment. However, using a case study or field study, in this dissertation, as a research methodology to serve the research question requires certain actions in steps. These actions include the followings in sequence:

- An already in-operation or ready to operate nuclear fission energy plant.

- Comprehensible records of CO_2 levels in the atmosphere (i.e, from the conventional energy supply prior introducing nuclear energy as a mitigation strategy).

- A nearly unlimited Access to the available data and information of energy plants in terms of power capacity, maintenance requirements, operation constraints and production cost.

- Appropriate calibration instruments to measure the CO_2 emissions from fossil fuel plants.

Accordingly, the results of the study – after introducing nuclear power plant – has to be compared to the previous CO_2 levels in the atmosphere thence; the difference will constitute the shares of nuclear energy contribution to the CO_2 emissions.

The case study research methodology remains viable with a number of constraints like, the population growth, increased demand on the energy, different CO_2 levels in peak demand in summer than lower energy demand in winter. Therefore, using a case study need a comparatively long time, and still incapable to provide accurate results for future due to many reasons. Furthermore, there is no built nuclear power plant in the UAE so; this methodology is not practically suitable for the dissertation purpose.

4.3 LOGICAL ARGUMENT

Logical argument method of research relies on a wide status of knowledge and negotiates a solution for open controversial subjects. According to Groat and Wang (2002), logical argument research is set-up for conceptual framework grouped with basics and powerful techniques to deal with an argument.

Kanoh (2006) conducted a logical argument research to verify the essential role of nuclear energy for sustainable development, precisely the global economy. He proposed three debatable questions of Kyoto agreement, its contribution to mitigate CO_2, and the effectiveness of CDM within Kyoto agreement. Among the most effectively argued variables is the statement of anti-nuclear people towards the CO_2 emission from nuclear plants in the construction phase and the disposal of radioactive waste. The researcher directed the debate in a logical manner and supported his argument with meaningful statistics and proofs. He pointed-out the nuclear role in mitigating 40% of CO_2 emission by 2050. In summary, the researcher stressed that nuclear is the proper needed option to pursue the sustainable development of the economy as a global view. Remarkably, this research paper was discussed in chapter “2” in section 2.6 “nuclear energy role in sustainable development”.

Omoto (2005), which also discussed in section 2.6 “nuclear energy role in sustainable development”, performed a research on the role of nuclear power for sustainable development and relevant IAEA activities for the future using a logical methodology in combination with an interpretive approach. The research highlighted the nuclear power as an important option for sustainable development along with a discussion of the Agenda 21 in the earth summit 1992, and the 2002 Johannesburg’s World summit on sustainable development (WSSD). The focus in the research was on the three dimensions of sustainability (economic growth, environmental protection and social welfare). He further pointed-out the principle drivers of energy demand (population and economy) along with the demand projection of energy by 2050. The IAEA role of nuclear development was discussed along with other relevant activities of the agency such as: bridging the gap between the current and forecast nuclear capacity along with safety and cost, nuclear energy as a driver for economy in developing countries, advanced reactors technology, life management planning of existing NPP, peaceful use of nuclear energy, and public access to credible and reliable information.

Jacobs and Haber (2003) logically researched the safety of organizational processes and nuclear power plant. They highlighted the integrated effort towards NPP safety organizational factors. Previous studies of safety in operation of NPP and other high reliability industries were reviewed in the research. A survey was included in the research design to support the logical argument.

For the dissertation, logical argument research can, however, serve the research's purpose via well supported rational framework. The following are some steps needed to fulfil the logical argument research methodology to determine the CO_2 mitigation in the built environment:

- Wide range of data collection from accredited and reliable academic research administrations.

- Comprehensive analysis of the nuclear impact in the built environment along with the CO_2 reduction values.

- Proper access to data in nuclear data centres (i.e. IAEA, ENEC (Emirates Nuclear Energy Corporation)...etc).

- An Accurate awareness of all relevant mathematical, cultural and discursive ranges of the research matter (Groat and Wang, 2002), nuclear energy contribution to the CO_2 mitigation in this dissertation.

- Secondary research question and then drive a principal logical argument methodology to tackle the contrary point of view in a suitable scientific way.

4.4 SIMULATION METHODOLOGY

The methodology of simulation research contributes to composite research prospects. Specifically designed computer software is usually used to simulate complicated models to ease a comprehensive study.

As its suitable role for composite researches such as nuclear energy, many researchers had adopted simulation research methodology to assess the nuclear energy role on reducing the CO_2 emission to the level of year 1990 or lower. Streimikiene (2008), for instance, carried over a case study research of Lithuania to examine the role of nuclear power in reducing the climate change. He mentioned that Lithuania – as an Annex I country - committed to reduce the GHG emission by 8% below the 1990 levels from 2008 to 2012. He overviewed the status of the energy sector in the country in terms of domestic and imported resources of electricity generation. He also mentioned the national energy strategy in targeting 20% of renewable energy by 2025 along with the forecast primary energy supply. The used simulation software was developed al Lithuania energy institute (LEI). This software was based on the MESSAGE mathematical model which was produced by the International Institute of Applied System Analysis (IIASA) in Laxenburg, Austria (http://www.iiasa.ac.at/) and thereafter improved by IAEA. The study scenarios included the CO_2 emission per capita, CO_2 emissions from industrial processes and waste management by the year 2050. This research paper was discussed in chapter "2" in section 2.3 "Nuclear Energy Role in Climate Scenario (CO_2 emission)".

Vaillancourt et al. (2008), discussed in chapter "2" in section 2.3 "Nuclear Energy Role in Climate Scenario (CO_2 emission)", used further simulation software called "World –TIMES" to explore the role of nuclear energy under set-up CO_2 emission scenarios. Furthermore, Matsui et al. (2008), discussed in chapter "2" in section 2.6 "nuclear energy role in sustainable development", used an integrated simulation model called "GRAPE" to examine the role of the nuclear energy in sustainable development.

Further simulation research performed by Kurosawa (2000) to evaluate the role of long term nuclear power under CO_2 emission constraint from 2000 to 2100. The research used the GRAPE model of assessment. Five sub-models included in the GRAPE to assess energy, climate, land use, macroeconomics and environmental impacts. The study covered 10 regions with maximum limit of CO_2 emission according to the Kyoto protocol. According to the population prediction and the energy outlook, the regional population and energy demand were two constraints of the simulation. The research comprised almost all the obtainable energy resources. The simulation was run for four test cases on the impacts of nuclear phase-out and certificate trade under the CO_2 constraints (BAU, No trade, Annex I trade, and No trade plus no nuclear). The allowed CO_2 emission was set, according to the Kyoto Protocol, to a percentage of 1990 CO_2 levels. The simulation pointed-out the importance of nuclear energy as an option of alternative energy source in the next 100 years. Therefore, nuclear energy should maintain a competitive cost to achieve more social acceptance.

Simulation research methodology is predicted to be beneficial in addressing the question of this research as it assesses the nuclear mitigation's role of the CO_2 emissions in the built environment. To achieve this purpose of assessment, few steps are required to be set-up as follow:

- Suitable simulation software is needed to measure and predict the future energy demand and the related CO_2 emissions in the targeted year of the study.

- Full access to the country's input data which are needed for meant software from an accredited source of information.

- Former conducted studies or published information for correlation purpose.

4.5 QUANTITATIVE METHODOLOGY

Design of quantitative research is classified amongst the excellent scientific research approaches. It usually advocates precise data, measures and analysis. Data collection technique can be determined by the researcher in a suitable matter to the research question and the way to be answered (Jenkins 2009). Jenkins (2009) citing Atieno (2009) suggests: "quantitative research paradigm...is empirical in nature; it is also known as the scientific research paradigm".

Li (2009) performed a quantitative analysis of sustainable energy strategies in China by using the econometric method. The research quantitatively discusses sustainable strategies in China toward energy-related issues. He conducted a reference scenario via simulation methodology on the country's economy, energy and environment up to 2030 under the name of 3Es-Model which developed by the researcher.

This model was made-up of 761 equations with 113 of them for macro-sub model and the rest of equations for energy and environment sub-models. Thereafter, the researcher performed alternative scenario simulation and discussed the national strategies in relation to energy. The results of energy consumption, electricity generation, energy security, energy pollutants and CO_2 emission were quantitatively discussed in terms of actual status in 2005, reference scenario and the alternative scenario by 2030.

Ohnishi (2003) proposed a methodology to predict the future tendency of quantitative variables related to the public acceptance of nuclear energy. The environment of public acceptance was decomposed into a limited number of basic elements. Thence, the interactive formulas between the quantitative variables were carried-over by using precedent actual values of the variables. The estimated values of exogenous variables were put into these formulas to obtain the forecasted values of endogenous variables. The quantitative methodology was used to assess the public acceptance of nuclear in Japan to include public sector, environmental society and socio-psychology sectors. The public sector classified into three categories: the general public, the near-nuclear inhabitants and the advocates of anti-nuclear movements. The environmental society and socio-psychological sectors categorized into four and three groups, respectively, such as news media and emotional factors, 27 endogenous and 7 exogenous variables were introduced to quantify these categories. Thereafter, growing features of the endogenous variables, such as the pro- and anti-nuclear fractions were quantitatively estimated in public opinion poll and the occurrence of anti-nuclear movements.

The quantitative research methodology can be conducted via either structuring a statistical model and evaluate the outputs or collecting the obtainable statistical data from data centers, former researches, or national offices in order to satisfy the research topic. Statistical modeling for nuclear is an excessive consumption of time and cost. Therefore, collecting data from existing data provider would be the most appropriate to compete for time and cost. Hence, the needed data for collection would include records of the CO_2 emissions from each energy source, nuclear energy capacity, energy demand and the coverage via nuclear...etc.

Further the abovementioned methodologies, historical and interpretive research methodologies can set-out either individually or side-a-side to the logical argument or simulation research. Combination of either research methods is potential to confirm the role of nuclear energy in mitigating the CO_2 emissions in the built environment of the UAE.

4.6 SELECTED METHODOLOGY

The process of finding the most suitable research methodology which addresses the research question or problem is not an easy task. The selected research methodology has to be useful in terms of tackling the research variables (Ismail 2005).

As an eventual choice from former research works dealt with similar subjects and research problems; simulation (Streimikiene, 200; Vaillancourt et al., 2008; Matsui et al., 2008; and Kurosawa, 2000 discussed in section 4.4), logical argument with literature review and interpretive (Kanoh, 2006; Jacobs and Haber, 2003; and Omoto, 2005 discussed in section 4.3), and quantitative (Li, 2009; and Ohnishi, 2003 discussed in section 4.5) research methods seem to be appropriate to satisfy the research question. Simulation methodology of research would, however, be the best to investigate the potential role of nuclear energy in mitigating the CO_2 emissions in the built environment of the United Arab Emirates.

Noteworthy, performing a case study research of an operational nuclear plant results with realistic readings. This process would, however, consume much longer time than the standard allocated for dissertation. The study has to allow for plant's construction time and energy production records, this range from 10 – 12 years. Moreover, nuclear power plant is not available within the regional borders. Case study is, however, remains possible to be adopted within a simulation research to predict the nuclear energy future's records for the country.

Simulation research methodology by means of computer software is thought to properly satisfy the aim of the research question. Its advantages are significant in terms of time and cost; the following are few advantages of the selective simulation methodology:

- Simulation software should be able to predict trusty measures of CO_2 mitigations in the targeted study years in comparatively limited time by using the published accurate data inputs.
- Simulation is much cheaper than physical modelling as main asset is the computer software.
- Encouraging outcomes of the simulation to use nuclear energy in sustainable environment can form the future outlook. Meanwhile, it helps in decision making of planning for nuclear plants.
- Discouraging results can direct the tendency of future's plans, and alternative energy sources can be selected at earlier planning stage.

- The awareness of appropriate measures for sustainable the environment in advance saves any potential waste of efforts, capital and protects the current essential resources.

- Computer simulation methodology is a comparatively safe approach versus experimental modelling of nuclear energy which might have unforeseen risk exposure during research.

- Presents several scenarios by manipulating different constraints and variables. This assists in selecting the best affordable scenario out of the possible.

- Satisfies the components of research cycle within reasonable time and cost. Meanwhile, for unsatisfactory results, there is wide convenience of options to re-frame the research question, re-collect proofs or re-draw the inference to accomplish suitable answers. The followings are little possible options to satisfy the research cycle if change is needed due to any logistic or technical reason:

    a. Limit the definition of simulation to fundamental mathematical equations and persist the proxy process.

    b. Alternate the research methodology to comply with the obtainable constraints (quantitative, Logical argument...), and re-explore the interference to maintain the proxy process and get revisit objective answers.

    c. Re-define the research topic or question and frame new objective to re-start the research cycle.

- Simulation research methodology has strong relation with correlation research especially for comparing the output data.

4.7 Simulation Software Programs

Accredited and satisfactory computer simulation software intended to be a compulsory key feature to perform the simulation research. Virtually there are very little commercially or academically available computer software programs fulfilling the research purpose while few others are only available for governments use only. The following sub-sections outline some simulation softwares which can satisfy the research aim:

4.7.1 GRAPE (Global Relationship Assessment to Protect Environment):

GRAPE is integrated energy analysis software. It is recognized model by the Intergovernmental Panel on Climate Change (IPCC) for trial estimates of energy. Kurosawa et al. (1999) first published the GRAPE model which is run by General Algebraic Modeling System programming language (GAMS). GAMS, however, has to be downloaded from its source website (www.gams.com), and GRAPE model is then available from the publisher. Matsui et al. (2008), Kurosawa (2000) and other researchers used the software in simulation studies for nuclear energy as discussed in sections 2.6 of chapter 2 and 4.4 in this chapter.

Main Features: GRAPE has the ability to simulate the emitted CO_2 values and environmental impacts of energy.

Availability: upon contact with the GRAPE publisher, he showed his willingness to provide the software with signing a business agreement and license outside Japan at cost to be agreed later. The GAMS modeling language will separately cost AED 4,710 Dhs for academic user (2,355 Dhs for the base model plus another 2,355 Dhs for GAMS/CONOPT as advised by the GRAPE publisher). Additional charges are expected for cargo

4.7.2 MESSAGE (Model for Energy Supply Strategy Alternatives and their General Environmental Impacts):

This model of simulation has been prepared by the IAEA among their number of models for nuclear energy planning. It was used in 2004 for a case study research by the IAEA for Lithuania (IAEA 2004b). The operation principle and detailed description are discussed later in this Chapter.

Main Features: a model for utilizing and optimizing environmental impacts of energy sources.

Availability: it is usually available for governments. After back-and-forth communication with the IAEA, they agreed to supply the software for academic purpose only at free cost.

4.7.3 TIMES Climate Model:

World-TIMES (The Integrated MARKAL-EFOM System) bottom-up model was used by Vaillancourt et al. (2008) for investigating the nuclear energy impacts on the climate. The Integrated MARKAL-EFOM (Market Allocation), and EFOM (Energy Flow Optimization Model) System is available from ETSAP (Energy Technology System Analysis Program). It was first appeared in Fishbone and Abilock (1981) and was, since then, improved for a range of applications.

Main Features: it tracks of CO_2 and other emissions from fuel combustion and processes. It also simulates the CO_2 changes in three reservoirs (atmosphere, lithosphere and hydrosphere)

Availability: MARKAL/TIMES is not available for commercial use, but could be obtained for academic use only.

4.7.4 DECADES:

Databases and Methodologies for Comparative Assessment of Different Energy Sources (DECADES) for Electricity Generation is also prepared by the IAEA for governmental use. It is an analytical software assist in decision support studies. It permits an access to the Reference Technology Database (RTDB) which contains a set of technical, economic and environmental data on energy chains for electricity generation, and the Country Specific Database (CSDB) which contains regional database to evaluate cost and environmental analyses from energy. it was established in 1992, and is a short running software with extensive reporting capabilities over several decades (IAEA 1995).

4.8 SELECTION OF MESSAGE SIMULATION SOFTWARE

The Model for Energy Supply Strategy Alternatives and their General Environmental Impacts (MESSAGE) was selected to be the software for running the simulation in this research due to many reasons. At the first instance, it was recommended by the IAEA as a capable model to optimize the CO_2 emissions from energy. It ranks as the most multipurpose and sophisticated simulation software of all programs available at the IAEA, and could principally fulfill the targeted objectives of all the IAEA softwares family of energy planning tools. Therefore, the software gains high credits to be used as recommended simulation software in this research.

4.8.1 SOFTWARE OVERVIEW

MESSAGE software is designed to optimize alternative strategies consonant of energy supply under a set of user-defined constraints such as: investment limits, penetration rates for technologies in market, fuel accessibility, and environmental emission. The software was initially developed at the International Institute for Applied Systems Analysis (IIASA) in Laxenburg, Austria (http://www.iiasa.ac.at/). Thereafter, the IAEA acquired the latest version and enhanced the MESSAGE software, especially adding a user-interface, to facilitate its applications. The principal purpose of the MESSAGE is to optimize an objective function under user-defined constraints which define the feasible region or county along with the possible solutions of a problem (IAEA, 2007b; and IAEA, 2008).

The MESSAGE's main backbone is a technical flexible framework that describes the energy modeled system. This has the definition of certain energy levels included in energy forms (primary and final energy, technologies producing these energy forms, and energy resources), these forms of energy actually used such as oil and nuclear, as well as energy services such as space heat or hot water. Inputs and outputs, efficiency, and the degree of variability are factors defined under technologies. These energy technologies are combined to form what is called energy chain which is started from energy supply to demand (IAEA, 2007b; and IAEA, 2008) (see Fig. 4-1).

The model considers the existing installations and their useful life span. This determines the requirements of extra capacity under different technology scenarios which helps in assessing the energy growth on the economy. Environmental impacts can be analyzed by tracking the emitted amounts of pollutants by technologies for all steps of the energy chains (IAEA, 2008).

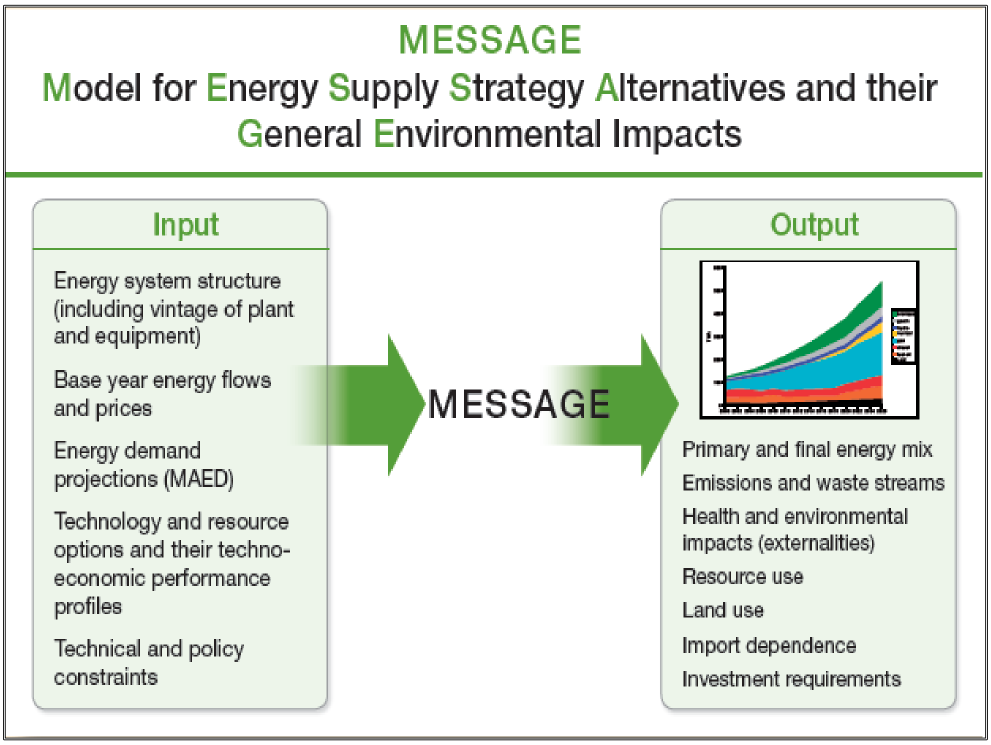


Figure 4-1: Major inputs and outputs of MESSAGE, (IAEA 2009)

The user can limit or bound an energy resource or a technology (i.e. maximum capacity of a technology, or maximum and minimum levels of technology output). It is significantly noteworthy that MESSAGE can model relationships of technologies and resources. It is flexibly define a variety of relationships types such as (IAEA, 2007b):

- Limiting a technology in relation to other technologies (i.e. a maximum share of wind energy in total prime electricity production).
- Technologies prediction limit (i.e. maximum limit on CO_2 emission in millions tons of CO_2).
- Production and installed capacity constraints (i.e. ensure take-or-pay clauses in gas contracts determining the minimum level of consumption)

4.8.2 SOFTWARE COMPONENTS

The following comprise the key components of the MESSAGE software. Figure (4-2) illustrates the Interrelationship between these components in execution of the software:

- A user-interface for model building.
- Databases.
- A matrix generation program (mxg).
- An Optimization program (opt).
- A program for solution post processing to extract results (cap).

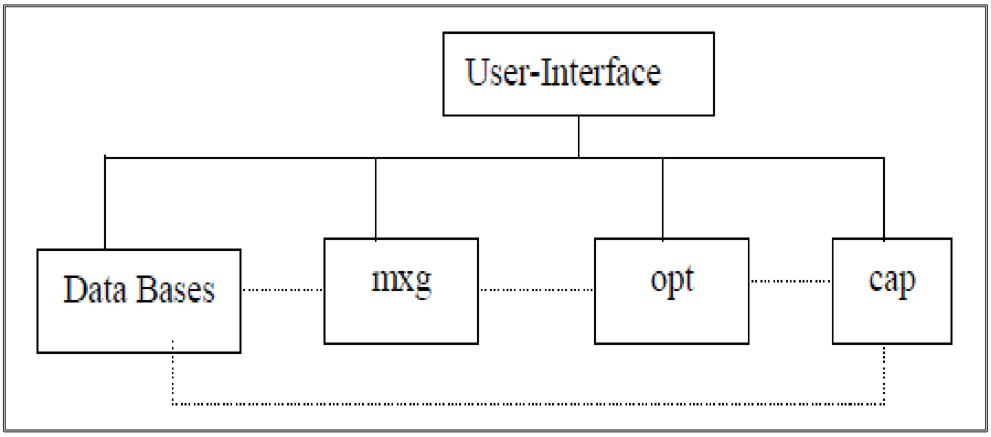


Figure 4-2: Interrelationship between MESSAGE components, (IAEA, 2007b)

4.9 RESEARCH PARAMETERS AND MATRIX

As the MESSAGE simulation model is created for the entire study, simulation variables and constraints will be manipulated within the process to assess the potential role nuclear energy in mitigating CO_2 emission of the built environment in the UAE. Electricity consumption and its related CO_2 emission from energy sources will be the main output of this study. The base year will be used as a reference for comparisons in addition to further comparisons between the proposed scenarios.

4.9.1 PARAMETERS

The following parameters constitute the main variables in the simulation which will influence the outputs:

CARBON DIOXIDE EMISSION RATES: the current CO_2 emission as published by the IEA (2010) will be used as a reference for comparison. The published rate of CO_2 from conventional energy sources will be lodged into the simulation at different scenarios to predict the future's CO_2 emission and the way to mitigate this emission.

NUCLEAR ENERGY: It is the main parameter in this study as the results must verify if the nuclear energy is a viable option for mitigating CO_2 emission or not. The currently proposed APR 1400 by the UAE will constitute in a separate case of study which will be used as a reference case in the comparison. Further four proposed scenarios of nuclear energy will be simulated to examine its role in addressing the research question.

RENEWABLE ENERGY: by itself is considered clean energy without CO_2 emission. Subsidizing activities for generating electricity from renewable energy such as plant construction, maintenance and refurbishment are consuming energy and thus emitting some fractions of CO_2. These fractions are assumed as nil in the simulation of this research due to its comparatively negligible amounts.

Carbon Capture and Storage: as announced by Masdar (2010), the project of carbon capture and storage will be ready by 2014 at a capacity of capturing 5.0 Mton CO_2 from UAE power plants. Accordingly, CCS tool will be considered in the simulation as effective from the year 2014. This will be added (in negative figure) to the total emitted amount of CO_2 from electricity.

Energy Growth Demand: the expected demand of electricity was issued by the Moenr (2007) till 2020. The prediction till 2050 will be assessed according to the scenario assumptions. It will be different at the Business As Usual (BAU) scenario than the other scenarios.

Oil energy: currently, it forms around 33.5% of electricity generation sources. As it is the major CO_2 emitter from electricity therefore, the target is to wipe-out this source from generating electricity. Almost all the proposed scenarios propose an alternative energy to displace the oil energy.

Natural Gas energy: it forms around 66.5% of electricity generation sources most of it is imported by the UAE from neighbor countries. As it is the second major CO_2 emitter from electricity and is cheaper than oil therefore, the target is to lessen this source from generating electricity.

Population growth is the identical for the entire study; the expected population was set-up according to projections made by the United Nations (2008).

4.9.2 RESEARCH MATRIX

<table>
<tr><td rowspan="2">1st Case</td><td colspan="5">BUSINESS AS USUAL (BAU)</td></tr>
<tr><td colspan="5">Energy growth rate is 9% till 2050, Same rhythm of energy consumptions to continue</td></tr>
<tr><td rowspan="2">2nd Case</td><td colspan="5">UAE PROPOSED SIMULATION CASE (APR 1400) *</td></tr>
<tr><td colspan="5">· 1 NPP by 2020
· 7% Renewable Energy by 2020
· 5 Mton of CCS by 2014</td></tr>
<tr><td rowspan="8">3rd Case</td><td colspan="5">THE CASE OF CLEAN ENERGY ERA (CEE) **</td></tr>
<tr><td colspan="2"></td><td colspan="3">Main Scenarios</td></tr>
<tr><td colspan="2"></td><td>Nuclear Energy Scenario</td><td>Renewable Energy Scenario</td><td>CCS Scenario</td></tr>
<tr><td rowspan="5">Sub-Scenarios</td><td>the APR 1400</td><td>1 NPP by 2020</td><td>7% by 2020</td><td>5 Mton once</td></tr>
<tr><td rowspan="4">Extreme scenarios Moderate scenarios Influenced from</td><td>2 NPPs (2020, 2040)</td><td>15% by 2035</td><td>5 Mton/6yrs</td></tr>
<tr><td>4 NPPs (2020, 2030, 2040, 2050)</td><td>25% by 2040</td><td>5 Mton/3yrs</td></tr>
<tr><td>8 NPPs (2020, 2025, 2030, 2035, 2040, 2045, 2 units by 2050)</td><td>35% by 2050</td><td>10 Mton/3yrs</td></tr>
</table>

* All variables are introduced together according to the UAE actual proposal.

** Only one variable within each scenario at a time whereas, the other scenarios are at default value (highlighted in yellow).

CHAPTER 5: Simulation Model Configuration

5.1 INTRODUCTION

Energy planning studies should consider several aspects like fuels availability (fossil fuels, uranium, etc.) and their supply reliability, domestic supply sufficiency in meeting the increasing demand, energy capacity of supply, elapsed times for maintenance outages, grid size, peak to base load demand, and the current and future development of the energy infrastructure. General selection of energy supply options will be according to certain economic driving forces (i.e. capital availability and cost of energy services), and some constraints like fuel availability, sustainable approach to limit pollutions and GHG emissions (IAEA, 2008).

Worldwide available nuclear power plants have an output capacity range from around 300 MWe to 1500 MWe. These plants could, for economic reasons, be operated at a high capacity factor to supply from almost 2 TWh to 10 TWh of electricity per year, subject to the plant size and power grid size. The capacity factor for nuclear energy is set-up in the simulation to be 90%. Detailed data and tables of this Chapter can be found in Appendix B.

5.2 BASE YEAR

The base year in this research, which stands for the reference year of model configuration, is calibrated to be 2008. This is due to the availability of the most needful input data (energy and CO_2) from the IEA statistics up to this year. The research focuses on the next four decades till 2050. Therefore, future energy outlooks and the CO_2 emissions mitigation are projected to the 2050 horizon using various drivers of growth such as population, economic growth, public invitations for energy saving, and availability of fuel.

5.3 COUNTRY OVERVIEW

Population and gross domestic product are essential factors for growing the energy growth. This section presents statistic data of those two factors in the UAE which will be considered in the simulation as a measure to the energy growth and therefore the CO_2 emission.

5.3.1 POPULATION

The population in the UAE has rapidly grown at an un-precedent rate due to the fast booming economy which encouraged the migration of expats into the country. The expats in UAE constitute in the recent years almost 81% of the total population of the country. The total population recorded 5.066 millions in 2009 which is almost nine-folds than the year of 1975 (MOE, 2008a) (see Fig. 5-1).

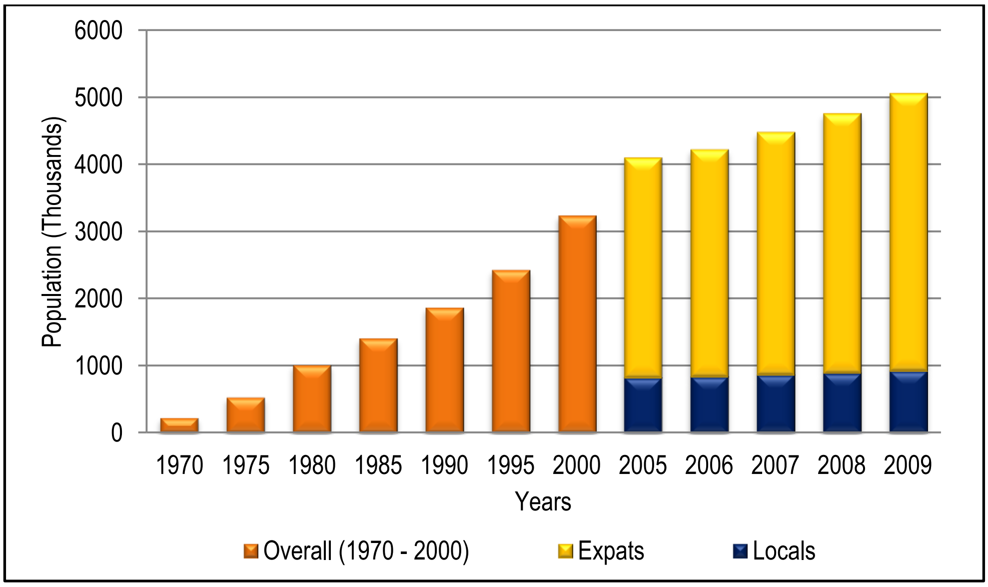


Figure 5-1: Population (Thousands) of the UAE. From 1970 – 2000 is shown as overall population while, from 2005 – 2009 is shown as per citizenship status, (UN, 2008; and MOE, 2008a)

The projected population in the target year (2050) can be estimated according to the mathematical equation of compound population as a geometrical growth $P_n=P_o\ (1+r)^n$ whereas; (P_n) is the predicted population in certain year, (P_o) is the population in the base year, (r) is the growth rate, and (n) is the numerical difference of years. The growth rate (r) in the UAE is 2.31% for locals and 0.58% for expats. (DIE-G, 2010). On the other hand, the United Nations (UN, 2008) have a database of population projections till the year 2050 (see Fig. 5-2). However, both of the projections are very close. Therefore, the UN projection will be adopted in the simulation as it is assumed to be more accurate in terms of population forecast. Thus by 2050, the UAE population is expected to reach 8.2 millions.

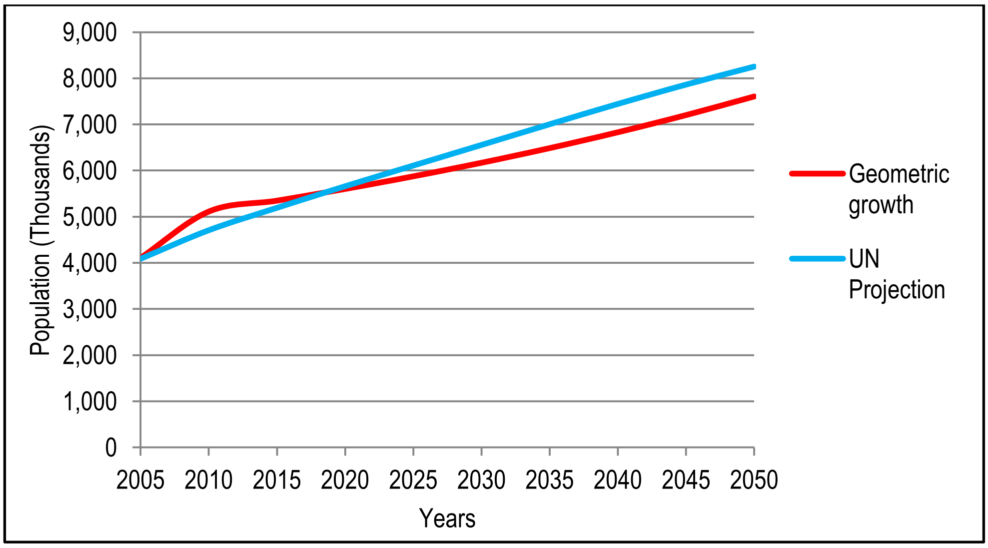


Figure 5-2: Total Projected Population (Thousands) after applying a geometric growth equation and another prediction by the United Nations, (DIE-G, 2010; and UN, 2008)

5.3.2 GROSS DOMISTIC PRODUCT (GDP)

The UAE economy recorded rapid growth in the past few years, with real GDP growth of almost 8% as an average. The UAE became a favourable country for business industry in the Middle East. The GDP rate has sharply increased since the year 2000. However, there is an ambiguity in the published readings of the national GDP. The data were collected from two different sources; the first is the Ministry of Economy (MoE, 2008b) which shows almost 18% growth rate of the GDP from 2000 to 2008 whereas, the second source is the International Energy Agency (IEA, 2010) which shows an annual growth rate of around 8% for the same period (see Fig. 5-3).

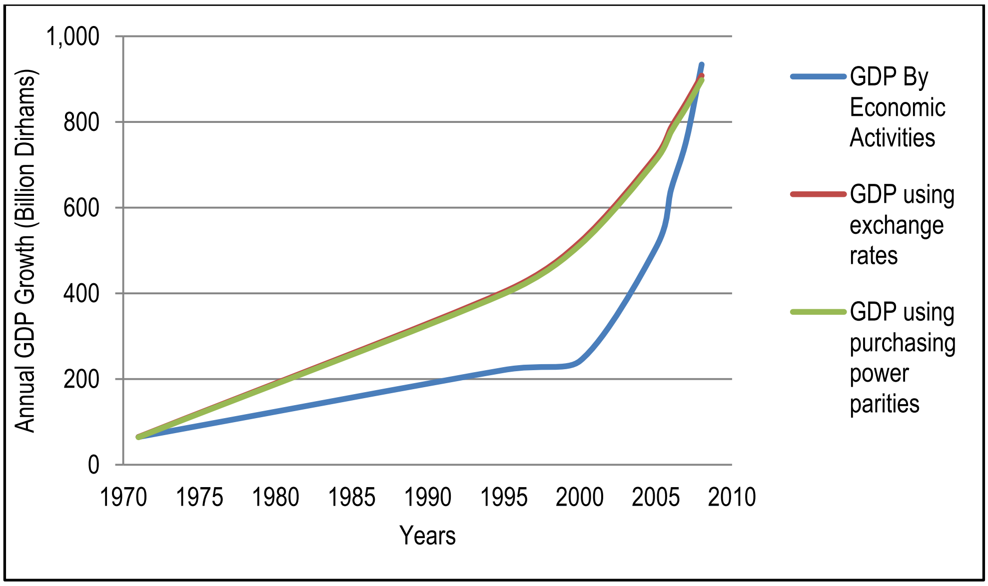


Figure 5-3: GDP rate in the UAE from 1971 – 2008, (MoE, 2008b; and IEA, 2010)

Although, the Ministry of Economy of the UAE is more official source of economic information as they are the official legislator for economy; the data from IEA seem to be more reliable due to the logical GDP growth rate. This is also supported by a report posted on 15th November 2010 from (UAEInteract, 2010) mentioned that Abu Dhabi is targeting 6 – 7 % growth in the GDP from 2008 to 2012, and confirmed that the GDP growth rate was almost 8.1% in recent years. Therefore, the data from IEA (2010) is thought to be more reliable.

5.4 Electricity

The simulation prospects in this dissertation focuses on the electricity used for the built environment (residential, commercial, and light industrial) activities which is responsible for almost 49.4% of the total CO_2 emission in the UAE according to IEA (2010). As mentioned in Chapter 1 under section 1.5 “Energy Prominence”, the electricity demand recorded an increase of 7% between the years 2008 and 2009. According to Moenr (2008), the average growth from 2001 to 2009 is almost 9%. The 2007 gross generation capacity was 17,369 MWe and the generated electricity was 74,717 GWh. The fuel source for this electricity is divided between 66.35% of gas and 33.5% of oil with negligible fraction of diesel in the Emirate of Sharjah. Figure 5-4 shows the electricity generation capacity from 2001 to 2009 according to fuel source.

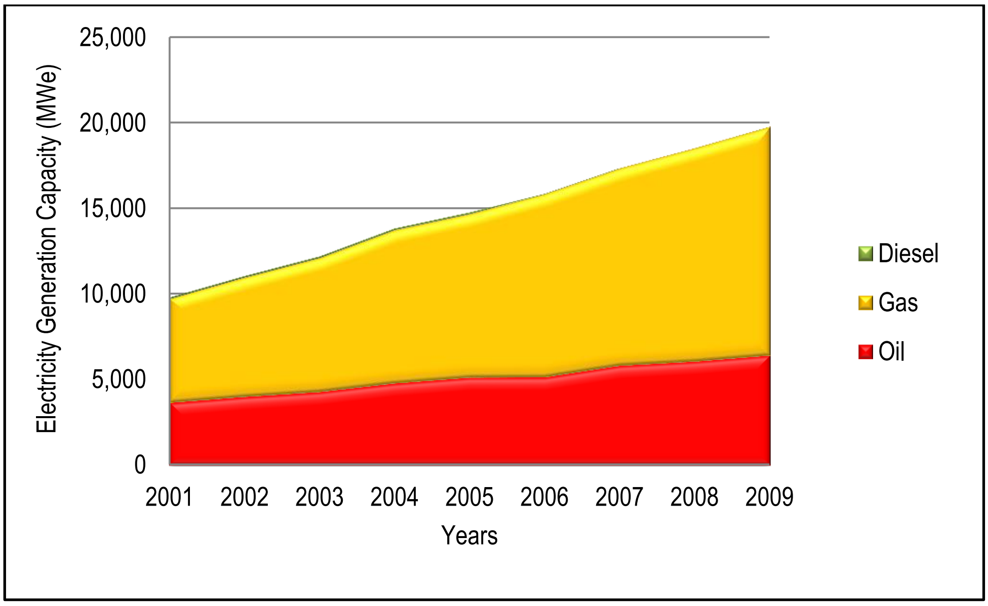


Figure 5-4: The electricity generation capacity per fuel source from 2001 – 2009, (Moenr, 2008)

5.4.1 OIL ENERGY

The UAE has the seventh largest prove oil reserves in the world in 2009 at 97.8 billion barrels with a production of 120.6 Mton. The oil consumption was 23 Mton in 2008 which dropped down to 21.8 Mton in the year 2009 (BP, 2010). These amounts represent the country's overall consumption (electricity, transport, construction, etc). The electricity generated from oil in the UAE was almost 25,075 GWh in the year 2007 (Moenr, 2008). It is predicted that the generated amount of electricity from oil in 2008 was 26,755 GWh according to the evaluations of the expected demand by Ministry of Energy in 2007. This amount will be configured in the simulation software as the base year data.

According to Mongillo (2005), 1 GWh of electricity produced requires almost 253.4 tons of oil. Therefore, the oil used to produce electricity in 2008 is 26,755 x 253.4 which equals 6.78 Mton of oil. Figure 5-5 shows the relation between total oil production and consumption along with the proportion of used oil to produce electricity.

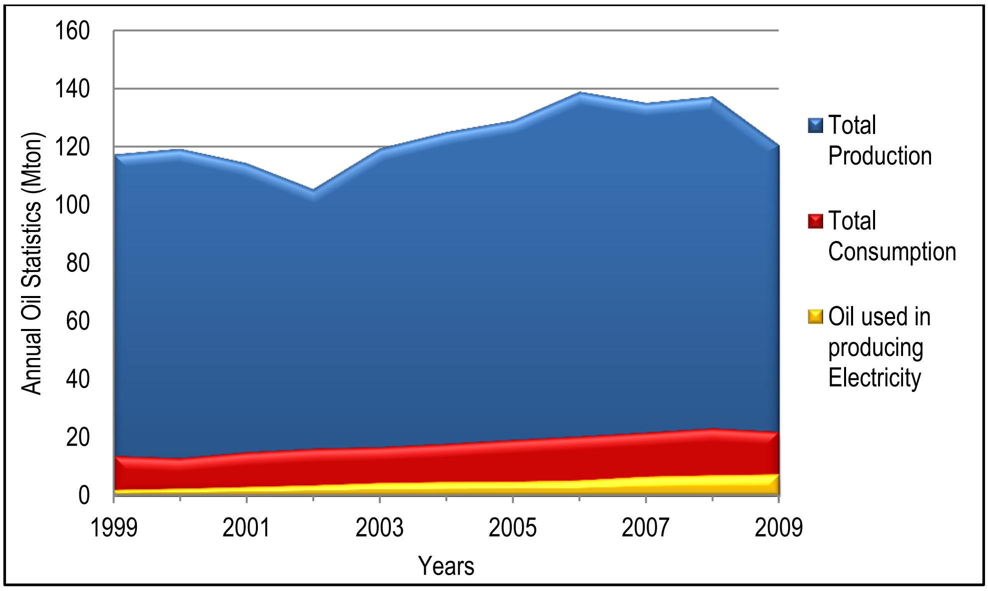


Figure 5-5: Oil Statistics in UAE from 1999 – 2009, (BP, 2010; and Moenr, 2008)

5.4.2 GAS ENERGY

Similar to oil reserves, the UAE has the seventh largest proved natural gas reserves in the world in 2009 at 6.43 trillion cubic meters with an annual production of 44Mton oil equivalents. The natural gas consumption was 53.5Mton of oil equivalent in 2008 which has dropped slightly down to 53.2Mton in the year 2009 (BP, 2010). These amounts, however, represent the country's overall consumption (electricity, cocking, etc).

In recent years, there is a shortage in gas supply for electricity due to increased demand for electricity generated in gas-fired plants, as well as the rapid growth of country's economy. Despite the large reserves of natural gas, it contains impurities and is costly to extract. Therefore, the UAE covers the demand shortage by importing natural gas mainly from Qatar (EIA, 2009). The electricity generated from natural gas was almost 49,574 GWh in the year 2007 Moenr (2008). Mathematically, Natural gas generated around 52,896 GWh of electricity in 2008 as evaluated from the expected demand by Ministry of Energy in 2007. This is the amount which will be used in the simulation software as the base year data. Figure 5-6 shows the relation between natural gas production and consumption in the UAE.

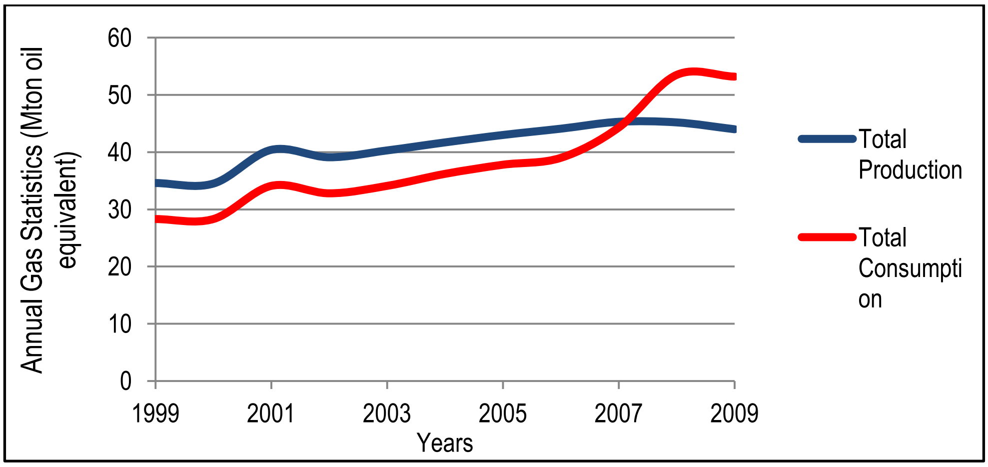


Figure 5-6: Natural gas production and consumption in UAE from 1999 – 2009, (BP, 2010)

5.4.3 NUCLEAR ENERGY

Currently, nuclear energy has no contribution to the electricity grid of the UAE due to the non-yet built NPP. The planned four units APR 1400 NPP have the capacity to supply 1400 MWe each. Hence, and according to ENEC (2010d) operation schedule, the UAE's NPP could supply 1,400 MWe by 2017, 2,800 MWe by 2018, 4,200 MWe by 2019, and a full capacity of supply of 5,600 MWe by 2020. The expected annual consumption of nuclear generated electricity at full operation of the four NPP units by 2020 is estimated using the following equation:

$$\frac{5{,}600\ \text{MWe} \times 365\ \text{days a year} \times 24\ \text{hours a day} \times 90\%\ \text{capacity factor}}{1000} \quad \text{………. (5-1)}$$

The total consumed electricity from nuclear energy equals almost 44,150 GWh. This would account for almost 25% of the total electricity consumption in the UAE by 2020.

5.4.4 RENEWABLE ENERGY

Similar to nuclear energy, renewable energy has not yet scaled to contribute to the electricity grid of the UAE. However, according to ENEC (2008), the renewable energy is targeted to fulfill 6 – 7% of the gross energy demand by 2020. By assuming a 7% of proportional supply as the higher expected rate, this means that almost 1,560 MWe of supply which corresponds to around 12,303 GWh of consumption in 2020. (Figure 6-5) illustrates the expected shares of energy sources in the UAE by 2050.

5.5 CO_2 EMISSIONS

This sub-section highlights the related details of CO_2 emission in the UAE country. The main source for the input data is the IEA (2010) as it has accessible statistics for the UAE. IEA (2010) estimated the CO_2 emissions from fuel combustion by adopting the default techniques and emission factors from the IPCC Guidelines of 1996 (IPCC, 1997). The CO_2 emissions in the UAE have rapidly increased to reach 146.9 Mton in 2008 at 184.7% increase from the year 1990. Figure 5-7 shows the increase in CO_2 emissions in the UAE from 1971 to 2008. The emission rate in recent years is the highest among the past. Figure 5-8 represents CO_2 emissions by sector in 2008 which illustrates the proportional contribution of each sector in emitting CO_2.

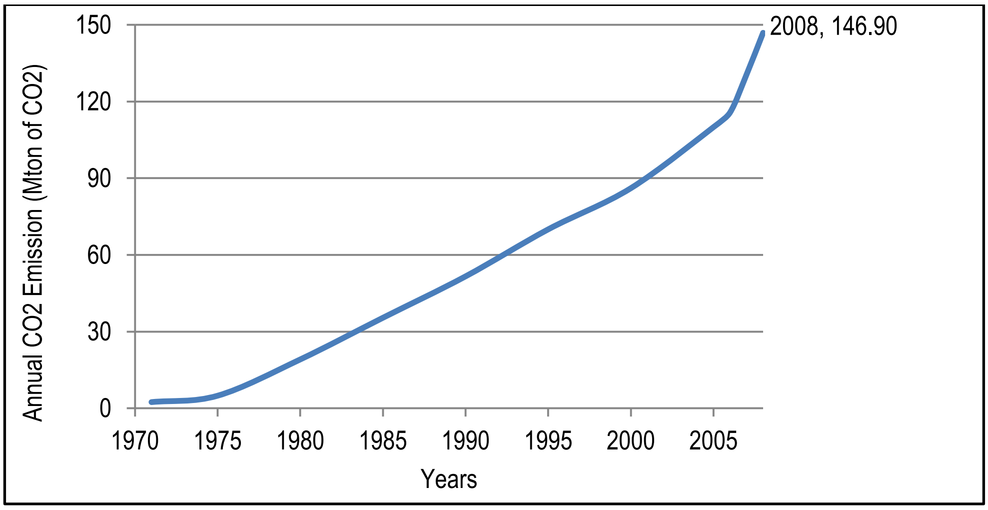


Figure 5-7: CO_2 emissions in the UAE from 1971 to 2008, (IEA, 2010)

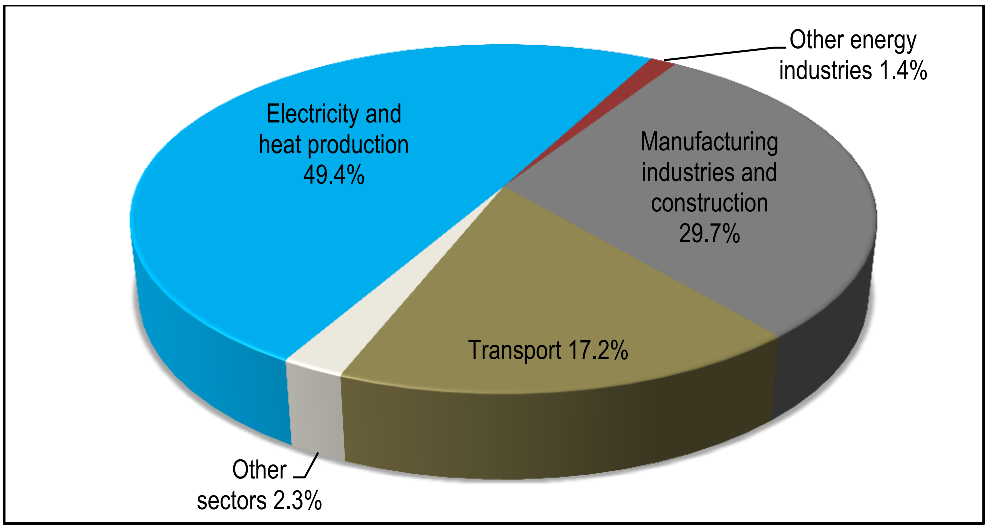


Figure 5-8: CO_2 emissions by sector in 2008, (IEA, 2010)

5.5.1 Electricity

As represented in Fig. 5-8, electricity is the major CO_2 emitter in the UAE. It emitted 72.6 Mton of CO_2 in 2008 which constitutes 49.4% of the total emissions of the same year. The rate of emitting CO_2 from electricity increased slightly in the last years to reach 842g/KWh from 728g/KWh in the year 2000. This could be due to increased demand of combustion and decreased efficiency of power plants. Hence, the average rate of CO_2 emission from electricity till 2008 is 831g/KWh. However, this rate seems inaccurate as it is close to the CO_2 emission from natural gas while gas shares around 66.35% of the total electricity consumption (IAEA, 2010). Therefore, the published rate of CO_2 emission from electricity – from IEA (2010) - will be replaced in the simulation by an estimated rate of 904g/KWh. This new rate is calculated as an average emission of oil and gas use for electricity generation (see Fig. 5-9). Figure 5-10 shows the CO_2 emission from electricity according to the generating fuel source.

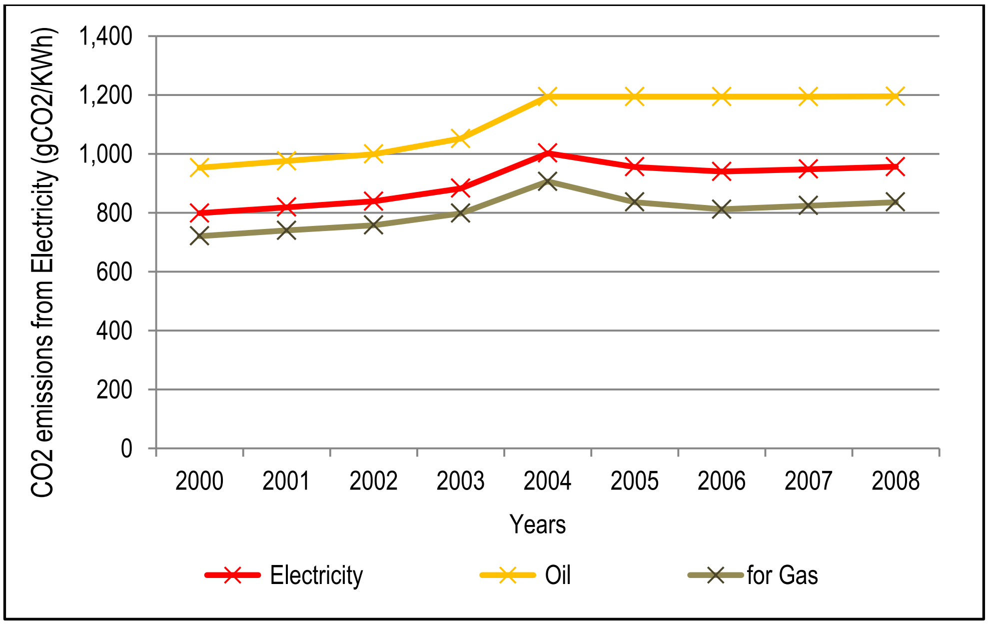


Figure 5-9: CO_2 emissions g/kWh from electricity, and its gas and oil sources, (IEA, 2010)

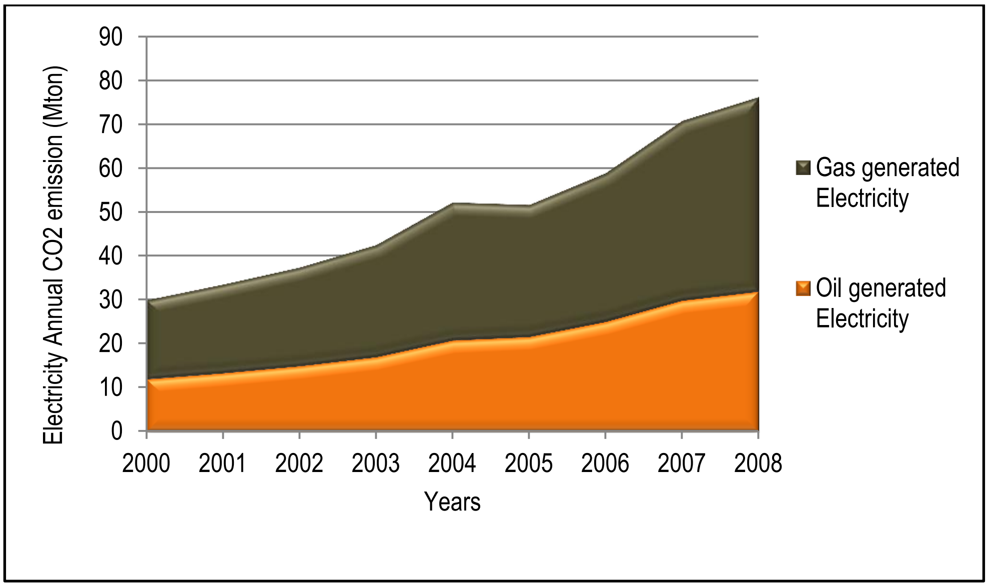


Figure 5-10: CO_2 emission from electricity per fuel consumption according to annual energy consumption and CO_2 rates for oil and gas (Moenr, 2008; and IEA, 2010)

5.5.2 OIL FUEL FOR ELECTRICITY

As mentioned under section 5.4 "Electricity" above, oil produces almost 33.55% of the gross consumed electricity. According to IEA (2010), the total CO_2 emissions from the consumed oil in the UAE increased reaching 34.5 Mton. This increase is higher by 86.6% in the 2008 than the year 1990 (see Fig. 5-11). The emission rate increased between 2001 and 2004 to remain almost constant at 1,194gCO_2/KWh thereafter which constitutes the average CO_2 emission from oil (see Fig. 5-9).

By using the CO_2 emission rates from IEA (2010) and the annual electricity consumption from the Ministry of energy in the UAE (Moenr, 2008), the CO_2 emissions (in million tonnes) from oil used for generating electricity would then be estimated according to the following equation (see figs. 5-10, 5-11). However, the results in the figure is not reasonable, and seems that there is data uncertainty of the total emission rates from the data source IEA (2010):

$$\frac{(\text{Oil Share})0.335 \text{ of total consumed electricity GWh } \times 1{,}194\ (\frac{\text{g}}{\text{KWh}})}{1{,}000{,}000}$$

……………… (5-2)

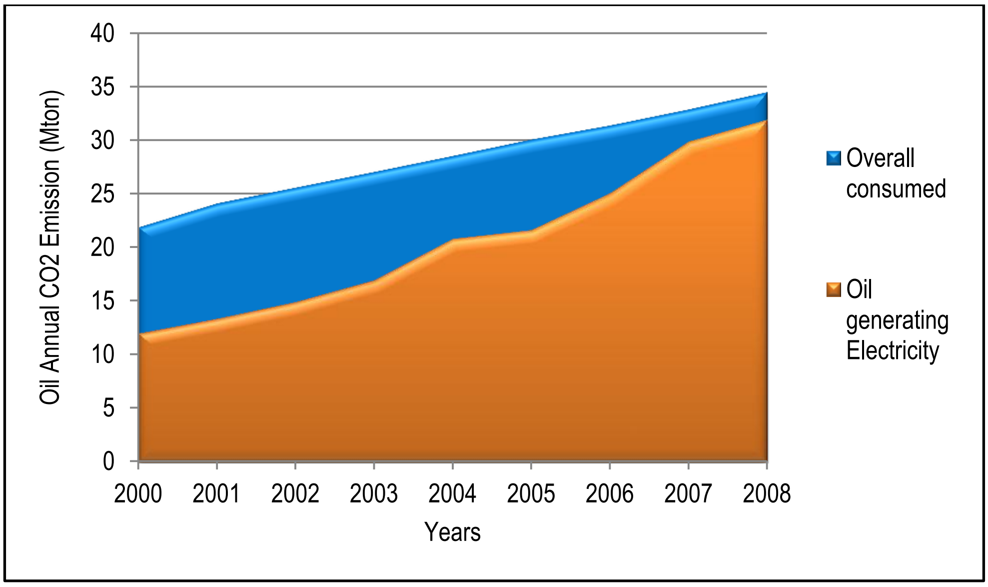


Figure 5-11: CO_2 emission from Oil, total emission is from (IEA, 2010), and emission from oil used to produce electricity is estimated using IEA (2010) rates along with Moenr (2008) annual electricity consumption.

5.5.3 GAS FUEL FOR ELECTRICITY

As mentioned under section 5.4 "Electricity" above, Natural gas produces almost 66.35% (rounded to 66.5%) of the country's consumed electricity. According to IEA (2010), the total CO_2 emissions from consumed gas in the UAE increased in the year 2008 reaching 112.5Mton. This increase is 239.5% higher than the CO_2 emissions in the year 1990 (see Fig. 5-12). The CO_2 emission rate increased slightly in the last years due to natural gas power plants efficiency to have an average of 824gCO_2/KWh (see Fig. 5-9).

Alike to oil emissions, the CO_2 emissions (in million tonnes) from natural gas used for generating electricity would then be estimated according to the following equation (see figs 5-10, 5-12):

$$\frac{\text{(Gas Share)}0.665 \text{ of total consumed electricity (GWh)} \times 824 \left(\frac{\text{g}}{\text{KWh}}\right)}{1{,}000{,}000}$$

……………. (5-3)

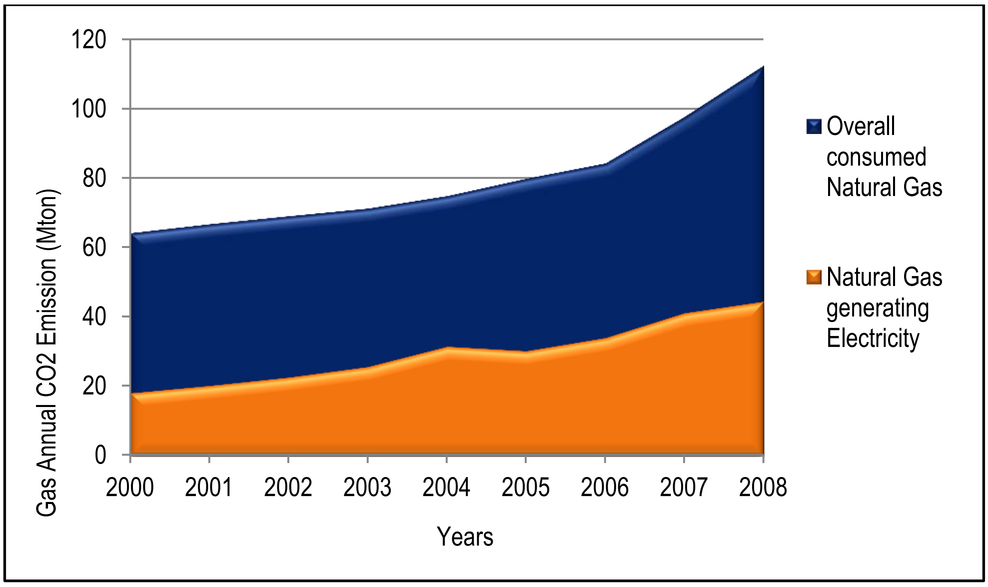


Figure 5-12: CO_2 emission from Natural Gas, total emission is from (IEA, 2010), and emission from oil used to produce electricity is estimated using IEA (2010) rates along with Moenr (2008) annual electricity consumption.

5.5.4 Nuclear - Electricitiy

The estimate of CO_2 emissions from nuclear power plants depends on the energy used through the entire lifecycle of nuclear, starting from mining to disposal of spent fuel, construction, transportation, operation and decommissioning of NPP. CO_2 from all energy inputs should be estimated and compared with saving in fossil fuel emissions when nuclear substitutes conventional energy power plants.

From a review of recent studies of associated GHG emissions with nuclear energy lifecyle, the emissions are estimated between 1 gC/KWh and 80 gC/KWh. the lowest value appears rock-bottom estimates while the highest value is greatly overestimated. the realistic average emission of GHG is about 18 gC/KWh, of which uranium mining and milling emitts 7 gC/KWh (Harvey, 2010 citing Sovacool, 2008 and Lenzen, 2008).

The activities of mining and milling, conversion and reconversion, enrichement, and fuel fabrication for the UAE's NPP will be excluded from the simulated estimates. The geographic limits for this dissertation is the UAE boundaries while these activities will always occure outside the UAE and uranium fuel will be imported to the UAE as fabricated to be used in the NPP. CO_2 emissions from spent fuel waste will also be excluded due to the fact that spent fuel in the UAE will be returned to the fuel seller according to ENEC (2010d). Electricity generation from nuclear has no CO_2 emissions at operation phase but, supportive activities (construction, maintenance, transportation, etc) are the responsible for the emissions. Harvey (2010) presentd that the energy used after construction – excluding spent fuel waste - forms almost 40% of the total energy input for supplying electricity from nuclear energy (see Table B-13, Appendix B). Therefore, the GHG emissions from nuclear energy in the UAE could be around 7 gC/KWh. According to conversion rates of the Department of Trade and Industry (DTI, 2006), the equivalent carbon dioxide emission (gCO_2 /KWh) is equal to 25.62gCO_2/KWh as calculated by the following equation:

$$\text{gCO2/KWh} = 1\ \text{gC/KWh} \times\ 3.66\ (\text{conversion constant}) \qquad (5\text{-}4)$$

Although this rate of emission remains almost three times higher than the Vattenfall study by (Martin, 1999) – mentioned under sub-section 1.7.2 in chapter 1, but it sounds reasonable as it includeds the NPP construction, decommessioning and waste disposal phases. Therefore, 25.6 gCO_2/KWh is the amount of CO_2 emission from nuclear energy which will be adopt in the simulation process.

5.5.5 CO_2 EMISSIONS PER CAPITA

The estimates for CO_2 emission per capita are affected by certain number of sensitive factors. The major factor of these is the correct figures of population from a local accredited source of statistics at the exact same time of estimating the total CO_2 emissions in a country. Further factors include the lifestyle, urbanized area, travel distances, nature of the country, etc.

Figure (5-13) shows the per capita emissions of CO_2 in the UAE from 1971 till 2008. There are two slightly different readings; the first is the published data from IEA (2010) while the other represents an estimate according to the published statistics of population from MoE (2008) by dividing the total CO_2 emission on the population. The trend of per capita emissions has decreased from mid 1990s to 2005 due to certain effective measure such as shifting to natural gas electricity - which confirms the Embassy-of-UAE (2009) under sub section “1.4” of chapter 1 - but, it returned increasing thereafter. This is due to the decreased efficiency of the power plants. However, there might be some intolerance in the published numbers for the period of dropped trend.

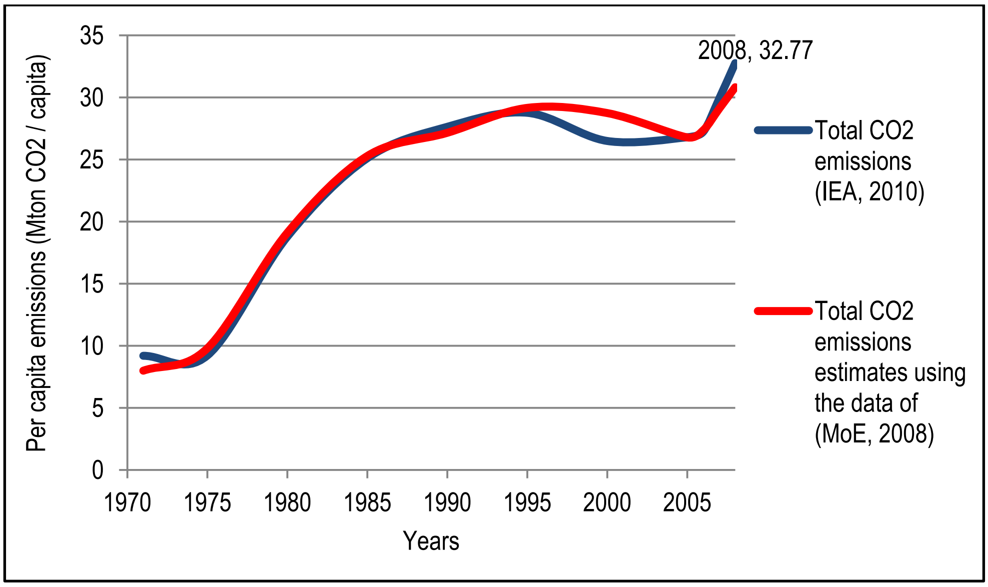


Figure 5-13: The per capita emissions of CO_2 in the UAE from 1971 till 2008, (IEA, 2010; and MoE, 2008)

5.5.6 CO_2 FROM TRANSPORTATION

This sub-section is mentioned in this research to highlight the significant impact of transportation on the CO_2 emission. It is a fast growing sector of energy demand, and is closely associated with oil. Almost 98% of the global transportation fuel is from oil (ExxonMobil, 2009). People in the UAE depend heavily on using transportation in their movements with less dependence on commuting which encouraged the number of private and commercial cars to increase. According to MoE (2007), the number of cars has jumped from 792,000 in 2003 to 1,078,000 in 2006, and the number of buses increased from 17,000 to 40,000 in the same time. This leads to an average rate of 1 car for every 4 persons.

CO_2 emission from transportation sector is the third highest in the UAE after electricity and construction while it is the world's second largest CO_2 emitter of almost 22% of the global CO_2 emissions in 2008. It was responsible of 25.2 Mton of CO_2 emissions in the UAE in the year 2008 which constitutes almost 17.2% of the country's total emissions of that year (see Fig. 5-8). The per capita emission for transportation sector was 5.61 ton CO_2 in 2008 with less than 1% increase from 2007 (IEA, 2010). Figure (5-14) represents the estimated CO_2 emission (in Mton) from transportation sector from 2000 to 2008 using the following equation:

$$\frac{\text{Population} \times 5.61 \left(\text{ton}\frac{\text{CO2}}{\text{capita}}\right)}{1{,}000{,}000} \qquad \text{……….} \ (5\text{-}5)$$

The 25.2 Mton CO_2 emitted in 2008 as published by IEA (2010) will then be adjusted to 26.7 Mton CO_2 in the same year after considering the published population of 4.76 million from MoE (2008) which is slightly higher than the adopted population of 4.4million adopted in IEA (2010) estimates. However, transportation sector must have decisive changes to the used operating fuel. It could move to low carbon fuel sources, hybrid cars, or other effective technologies which can mitigate the CO_2 emissions from transportation sector.

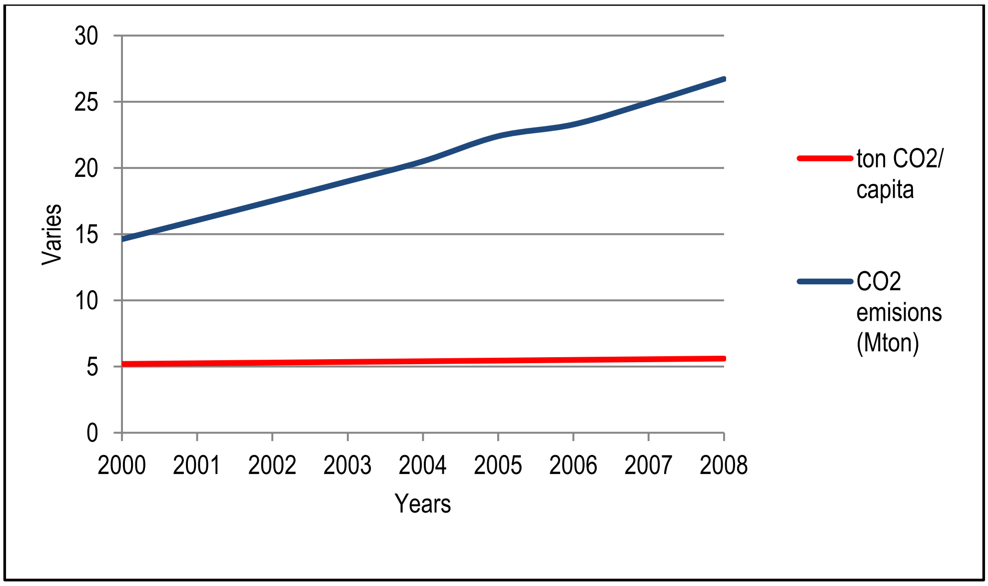


Figure 5-14: CO_2 emission (in Mton) CO_2 per capita (ton / capita) from transportation sector and from 2000 to 2008, (IEA, 2010; and MoE, 2008)

5.5.7 CO_2 PER GROSS DOMISTIC PRODUCT (GDP)

The gross domestic product reflects the economical status of a country, and represents an essential factor of CO_2 emissions. The CO_2 emission per GDP almost always increases in all developing countries due to their increasing demand for industry and development. This development usually consumes conventional fuel which is directly related to the GDP growth. Figure (5-15) shows the CO_2 emissions per GDP in the UAE. It is apparent the emission rate has a drop from mid 1990s to 2005 which might be due to higher trend of economic growth along with certain mitigation measures of CO_2 in the same period as mentioned under sub-section 5.5.5 above.

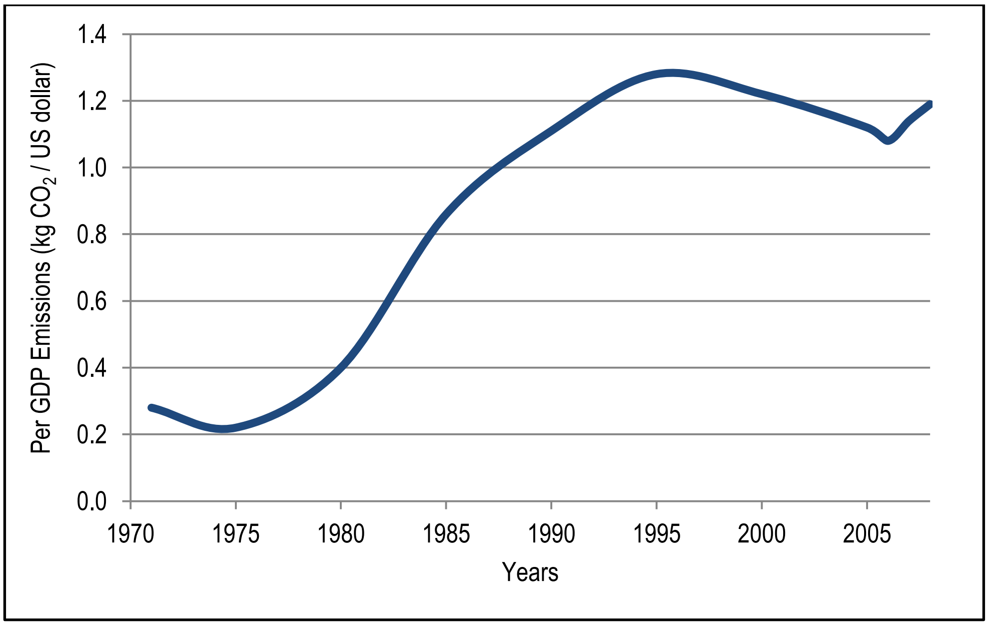


Figure 5-15: CO_2 emissions per GDP rates using 2000 US dollar rates, (IEA, 2010)

5.6 SOFTWARE VALIDATION

A basic validation case was conducted in order to verify the accuracy and the sensitivity of the MESSAGE simulation software. This basic case was compared with a built-in case study in the software. Demo_Case5 is a case with energy components (oil, coal and renewable) as inputs whereas the final chain level is electricity. The base year is 2000 while the simulation period is from 2002 to 2030. Further to estimating the energy contributions to the electricity demand, the demo_case5 computes the SO_2 emission from fossil fuel (coal and oil) at constant emission rates of 0.089 and 0.039 MW/yr respectively. The results are obtainable via selecting a scenario and running the simulation process.

A new case was initiated and given a name of "UAE_Validation" using the same input data of demo_case5 for comparison reason of the results thereafter. The only changes to the built-in case study are replacing the coal energy with natural gas and the SO2 with CO_2 (as it is the focus in the dissertation). All the other parameters remained identical, the base year is 2000 and the target year is 2030, electricity demand is 200 MW/yr at annual growth of 5%, CO_2 emission from oil is 0.039 MW/yr while it is 0.089MW/yr from gas which is the same as coal in the demo_case5, and so on.

Figure (5-16) shows the demo_case5 results for SO_2 emission by energy source, and Fig. (5-17) shows the initiated UAE_validation results for CO_2 emission by energy source. Both results are identical as shown in the figures.

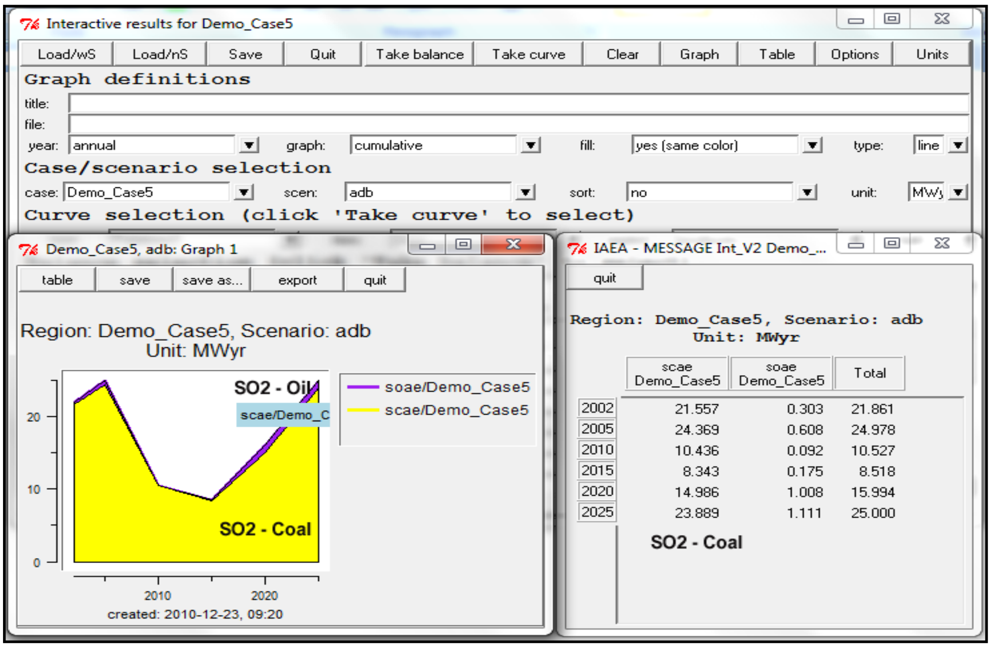


Figure 5-16: Demo_Case5, results for SO_2 emission by energy source

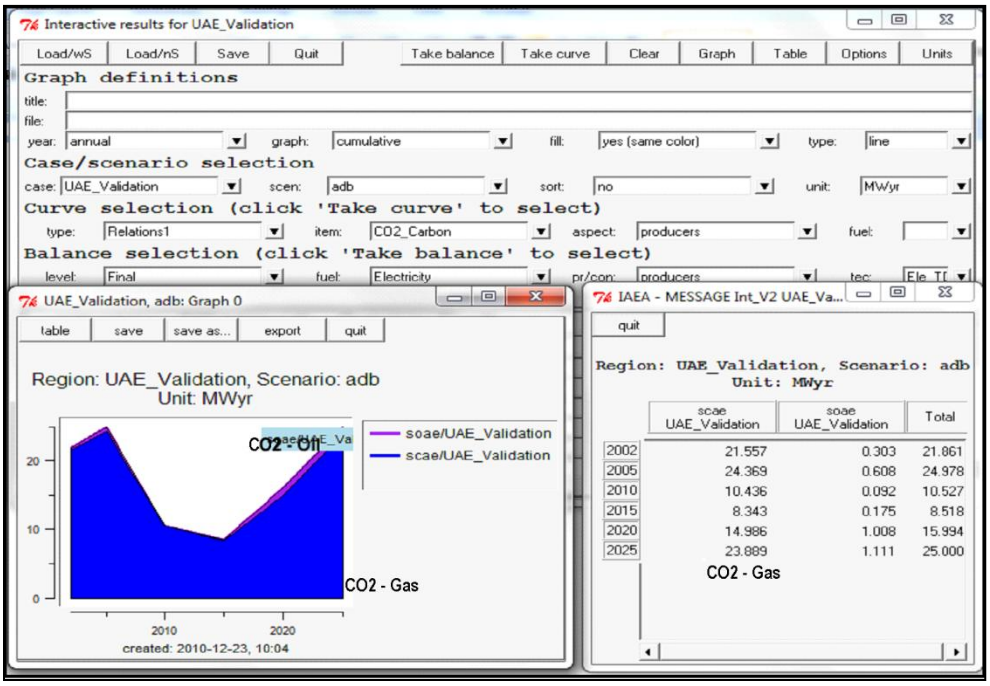


Figure 5-17: UAE_validation, results for CO_2 emission by energy source

5.7 SIMULATION CONFIGURATION

The MESSAGE software is installed under Microsoft Windows 7 as a full version. Simulation parameters (i.e. base year, growth rate, etc) will be configured for each simulation case separately - using the input data which discussed earlier in this chapter. Each case will have an individual file due to different parameters. It has been found appropriate to set three different simulation cases of future CO_2 emissions in the UAE as explained afterward. Upon completion of software installation, new cases will be opened to start the process.

The following three sub-sections discuss the research simulation cases along with the parameters and the assumed scenarios within each case:

5.8 BUSINESS AS USUAL (BAU) SIMULATION CASE

In this case, the same energy rhythm of supply and consumption in 2008 is assumed to remain as is till 2050. The energy demand is estimated to increase at recent growth rate of energy consumption (from 2001 to 2009) which is almost 9% as an average from Moenr (2008) which is mentioned under section “5.4”. The used energy for generating electricity is a combination of 33.5% oil and 66.5% natural gas (0.15% displacing the negligible diesel source to ease the simulation). Population forecast is set-up according to the UN (2008) for this case and the other two cases as well. CO_2 emissions are hence estimated according to the oil and gas emissions rates mentioned under subsections “5.5.2 and 5.5.3” respectively. Thereafter, a new case is initiated at the software from the commands list and given a name and little description (see Fig. 5-18).

From the edit command, configuration starts with setting-up the time period of 2008 as a base year till 2050 the targeted year of the simulation research (see Fig. 5-19). Other configurations such as the energy forms and demand, constraints, resources, etc are follow then (see Appendix C for the step-by-step configuration windows).

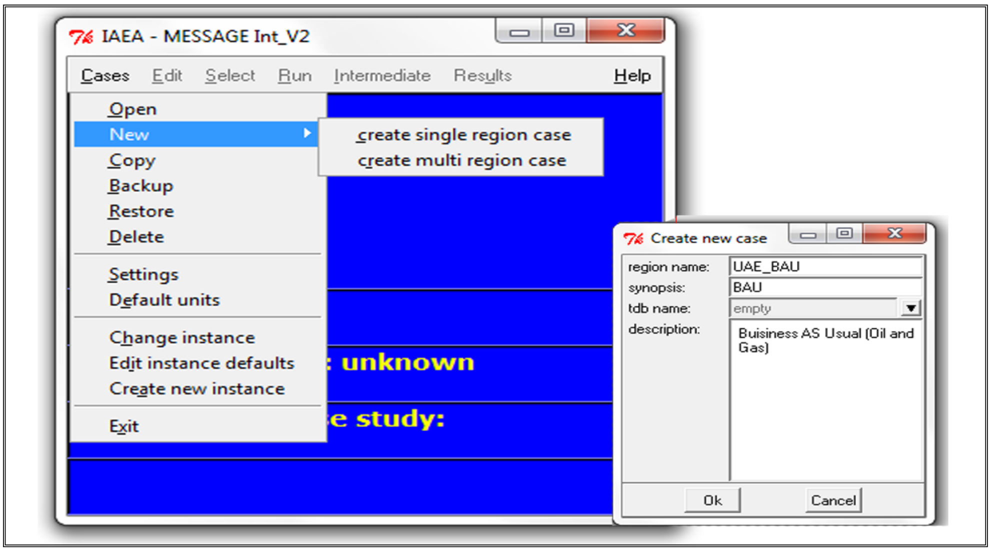


Figure 5-18: Creating new case from new case command

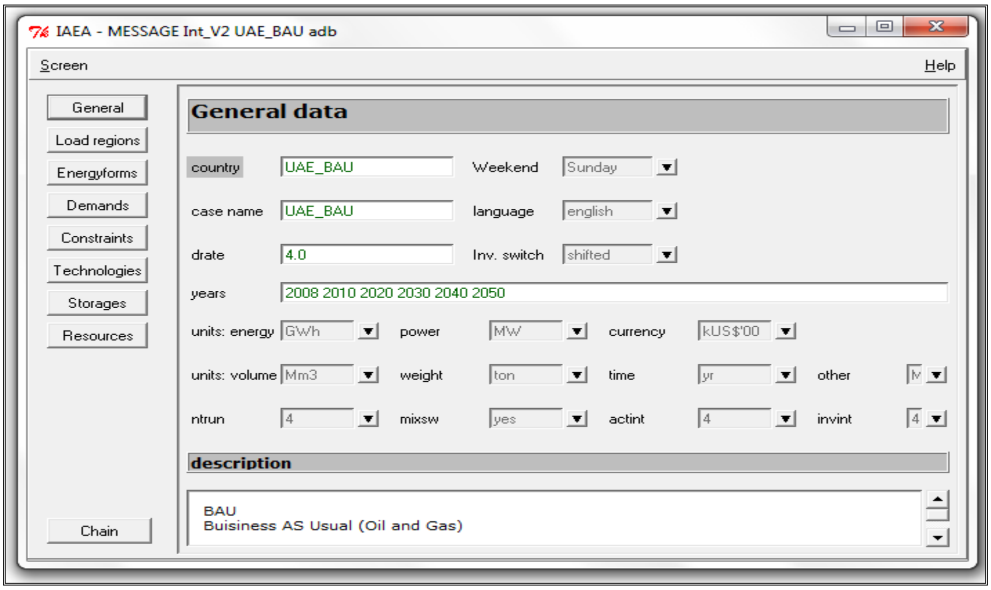


Figure 5-19: Application data base from edit command, general data (simulation period)

5.9 UAE PROPOSED SIMULATION CASE (APR 1400)

This case looks at the actual proposal by the UAE as mentioned under sub-section “3.7.1”. Nuclear energy is introduced to the energy scheme to supply electricity to the national grid. The NPP will start supplying 1,260 MWe (90 % capacity factor) which is equivalent to 11,037.6 GWh of electricity consumption by 2017 with a multiple yearly increase to cover a constant consumption demand of 44,150.4 GWh from 2020 onward. Renewable energy will cover 12,303.25 GWh (7%) of electricity consumption by 2020 and to remain constant till the target year.

Furthermore, CCS is introduced to the case to start cutting 5 Mton of CO_2 emissions by 2014; this feature will be applied after getting the results of total CO_2 emissions. Oil source of generating electricity is more expensive than natural gas and more environmentally harmful according to BP (2010). Therefore, both nuclear and renewable energy are assumed to proportionally displace the oil energy and then natural gas if excess clean energy remains assuming that natural gas is available till the target year. Population remains similar to the BAU case. Figure (5-20) illustrates the integration of the electricity parameters during the simulation period.

Starting working on the simulation case will have similar steps as BAU except for adding nuclear and renewable energy. Different to BAU, energy demand is assumed to grow at lower rate due to the calls for energy saving trends by UAE environmentalists, increased public awareness about the optimal use of energy, and more efficient electricity appliances and devices in future. Therefore, the growth rate of energy demand is assumed to grow constantly at 4% from 2020. This assumption has been influenced by Moenr (2008) prediction for the years 2018 to 2020.

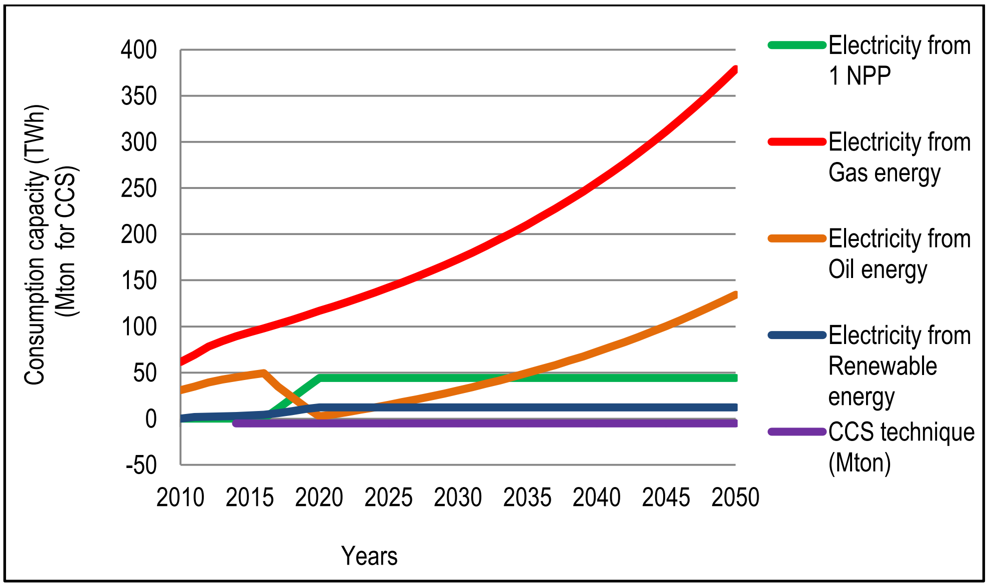


Figure 5-20: The integration of the electricity parameters as proposed in the APR 1400 simulation case.

5.10 The Case of Clean Energy Era (CEE)

In this case, more clean energy acts are integrated into the electricity scheme. Three main scenarios are proposed individually, and each one includes four sub-scenarios. The following sub-sections explain the major parameters of these scenarios which mentioned tentatively in the research matrix in chapter 4:

5.10.1 Nuclear Energy Scenarios (NES)

This scenario includes four sub-scenarios: 1) introducing one NPP of 5,600MWe all over the research period to reach full capacity by 2020 which is the same as the APR 1400 case, 2) two NPPs by 2020 and 2040, 3) four NPPs distributed gradually by 2020, 2030, 2040 and 2050, and 4) eight NPPs at gradual distribution on 2020, 2025, 2030, 2035, 2040, 2045, 2 units by 2050 to reach a total nuclear energy supply of 44,800 MWe from the 8 NPPs. The other parameters for the four NES scenarios will remain identical to the case of APR 1400 (4% energy growth rate, 7% of renewable energy by 2020 and 5Mton CCS unit by 2014). Figure 5-21 illustrates the scheme of introducing NES scenarios during the study period whereas Fig. 5-22 shows the integrated generation percentage of each scenario in the electricity sector. Other parameters are not shown in the figure for ease configuration.

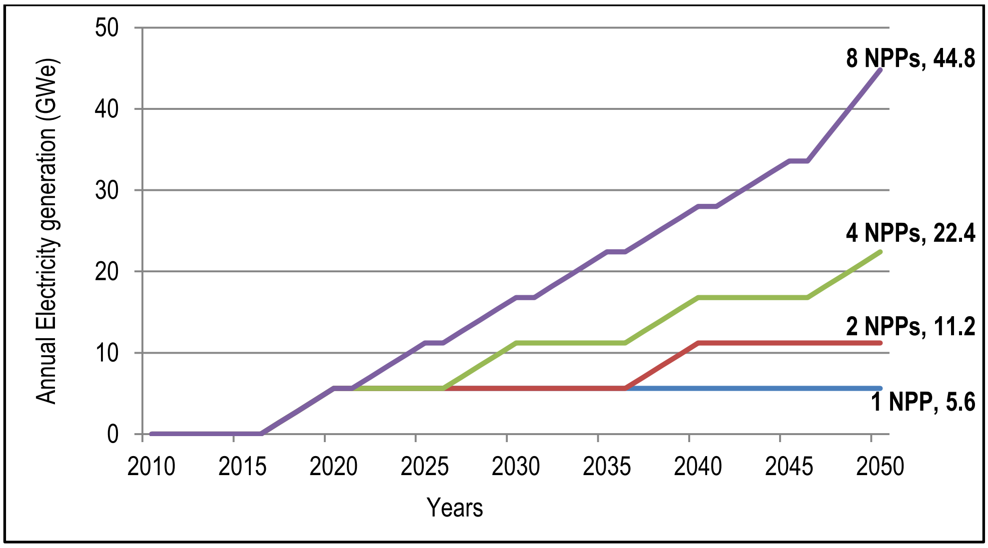


Figure 5-21: the scheme of introducing NES scenarios from 2010 – 2050

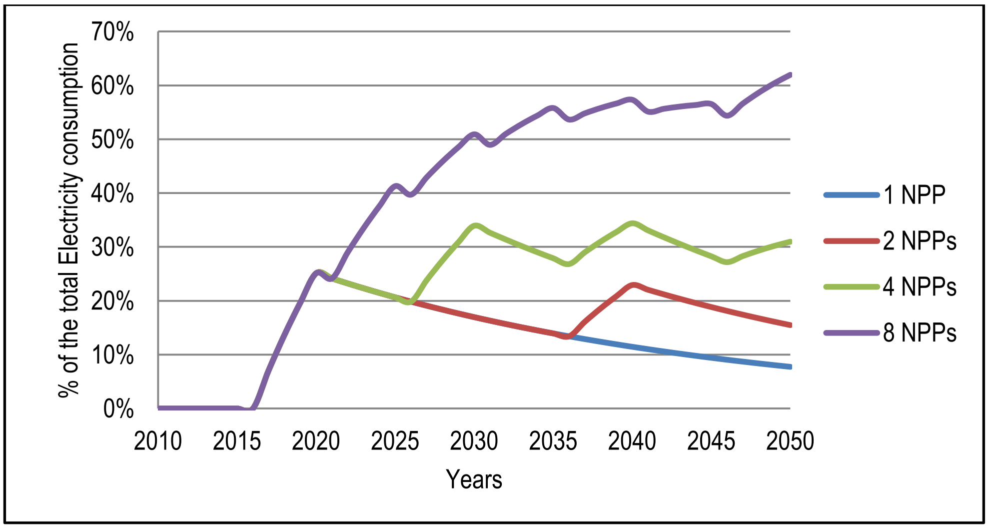


Figure 5-22: the percentage of NES scenario in the total electricity generation

5.10.2 Renewable Energy Scenarios (RES)

Typically, this scenario includes four sub-scenarios: 1) 7% of the 2020 electricity demand will be covered by renewable sources as proposed by the UAE in APR 1400 case, 2) the percentage of renewable energy supply to the electricity grid will reach 15% by 2035 and maintain a constant supply of the same percentage, 3) the percentage of electricity generated from renewable energy will reach 25% by 2040, and 4) 35% of renewable energy will be integrated into supply scheme of the electricity grid by 2050. Further CO_2 mitigation measures are assumed to be identical to the other APR 1400's for the four RES scenarios; these measures are 1NPP by 2020 and 5Mton CCS unit by 2014.

Figure 5-23 shows the introduction of RES scenarios along with their predicted electricity consumptions whereas Fig. 5-24 illustrates the generation percentage of each RES scenario in the electricity sector. The (7%) scenario reaches a 12.3TWh by 2020 and continues supplying a constant amount which is different to the other scenarios where the assume percentage of supply is maintained till 2050.

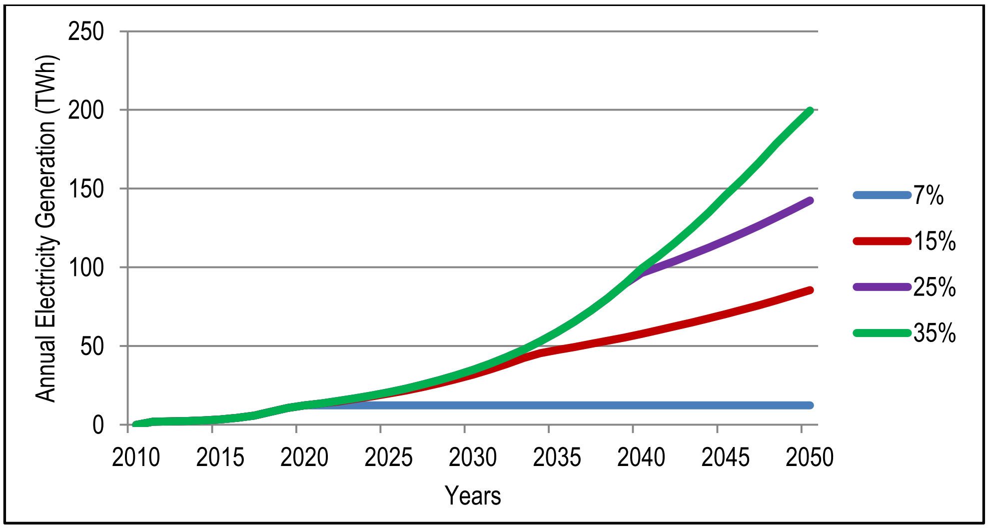


Figure 5-23: the scheme of introducing RES scenarios showing the anticipated electricity consumption value (TWh)

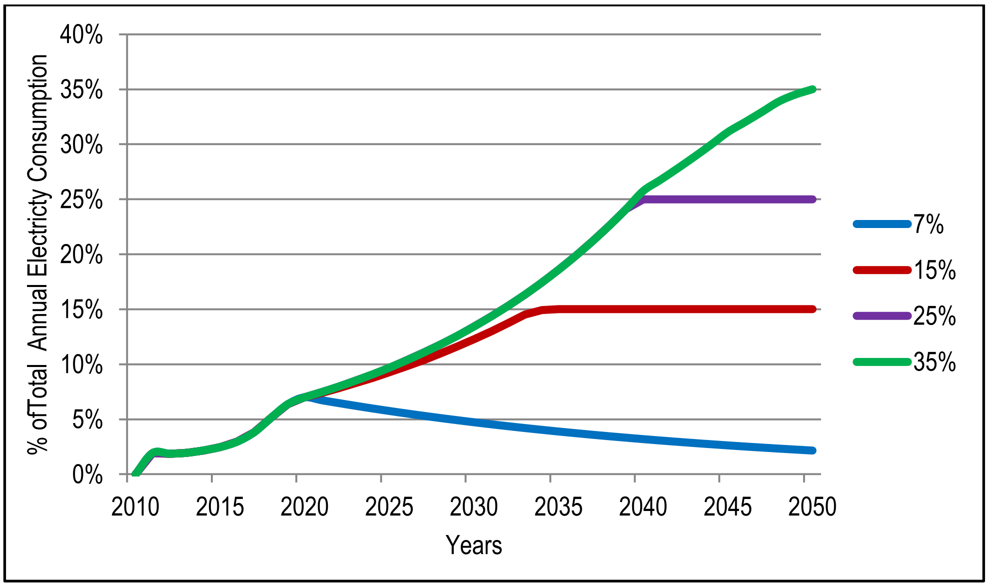


Figure 5-24: the generation percentage of each RES scenario in the electricity sector

5.10.3 Carbon Capture and Sequestration Scenarios (CCSS)

This is the third CEE case scenario which also comprises four sub-scenarios: 1) a unit of 5Mton CO_2 capture by 2014, 2) 5Mton CCS every 6 years to accumulate by 2044 at 30Mton, 3) 5Mton CCS every 3 years to accumulate by 2047 at 60Mton, and 4) 10Mton CCS every 3 years to accumulate by 2047 at 115Mton of CO_2 capture. The other APR 1400's identical constants for the four CCSS scenarios are 1 NPP by 2020 and 5Mton CCS unit by 2014 and 7% of renewable energy by 2020. Figure 5-25 shows the proposed capacities of CCSS scenarios among the study period.

Noteworthy, similar to the second case (APR 1400), the clean energy sources within the CEE case are assumed to proportionally displace the oil energy and then natural gas if extra clean energy remains. Simulation processing steps via the MESSAGE software are almost nearly like the BAU and APR 1400 cases. The results will be compared with the CO_2

emissions of the base year, BAU case, and APR 1400 case. The difference between the APR 1400 case and every CEE scenario will recognized as an achievement to be discussed in details in chapter 6 “Results and Discussion”

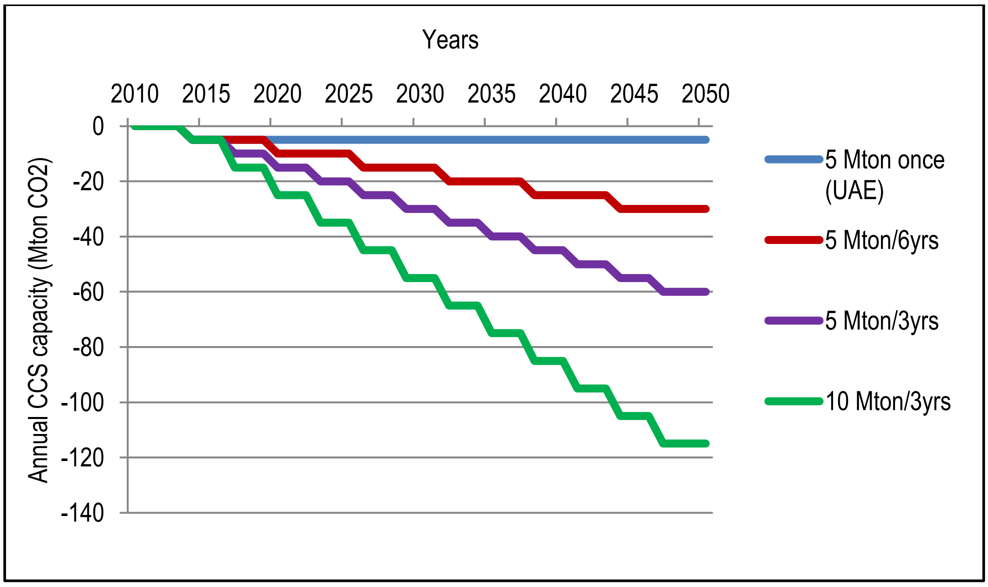


Figure 5-25: the proposed capacities of CCSS scenarios

5.11 RUN THE SIMULATION

Subsequent to completing all the input data – for each case or scenario separately, simulation database application scenario is selected from the “Select” command. The next step is running the simulation process from the “Run” command with selecting all applicable options (see Fig. 5-26). Those steps are repeatedly applicable for all simulation scenarios.

Running the simulation by itself could usually take few minutes (2-4) for each run. Each scenario needs sometimes more than 7 runs due to incompatible inputs or uncertain errors by the software; extra time is needed for the retakes of input data as the scenario configuration and simulation running has to restart again and, frequently, the non-reported cause for an error has to be guessed and manipulated . The inputs intake consume relatively a long time while many parameters and relations have to be configured such as levels of energy chain, energy demand, study period, energy growth rate, rates of CO_2 emission of each energy source, etc. Moreover, in case of missing or incompatible inputs, the software stops running at the middle of the process or sometimes close to the end of running process. This stop due to an error is usually not reported specifically by the software so; it might need to re-initiate a new scenario from scratch.

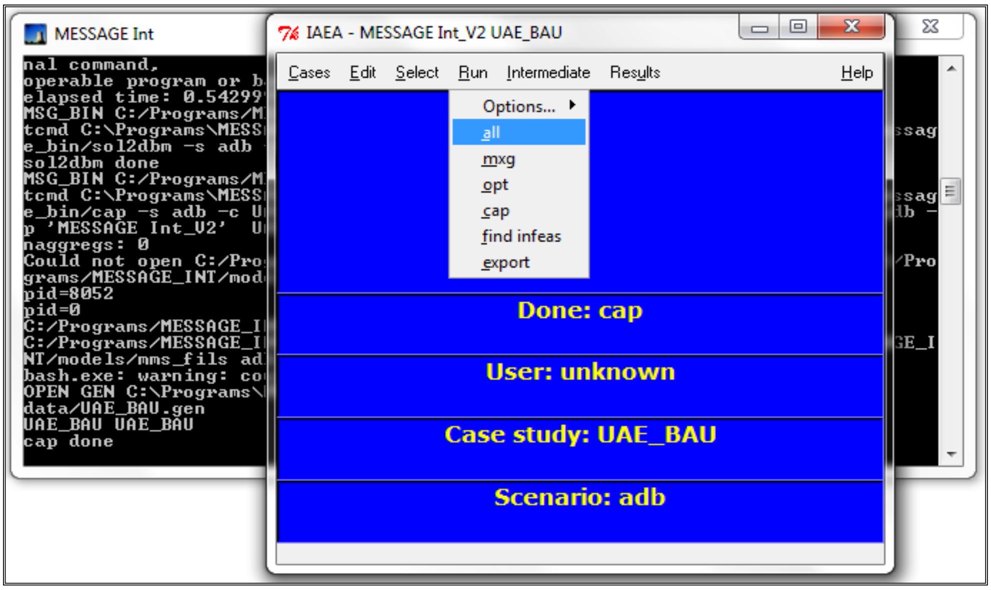


Figure 5-26: BAU, Running the simulation process.

The software, however, has a good level of the outputs whether figures or tables whereas, the tables are much better than the quality of the figures for presentation (see Figs. 5-17 and 5-27). Therefore, it was found better to export the tables to Microsoft Excel to produce the needed charts when applicable. Furthermore, the usage of Excel at the results stage can verify the certainty of the outputs while errors during the inputs intake might happen.

Upon completing all simulation processes, the results are then obtained from "Results" command using various options to select the desired output data from them. Figure (5-27) shows one option of getting results for the electricity produced from oil in the BAU scenario. Similar to the simulation running, this step is repeatedly applicable for each scenario.

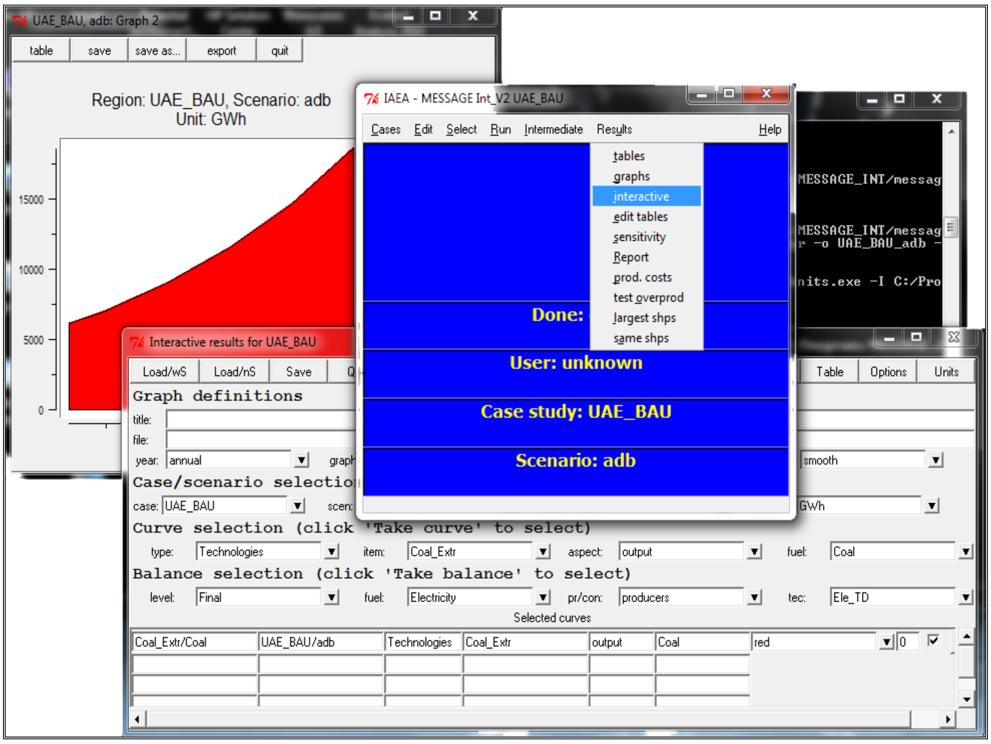


Figure 5-27: BAU, sample of getting results from MESSAGE simulation software

CHAPTER 6: RESULTS AND DISCUSSION

6.1 INTRODUCTION

The results from the simulation processes are presented in this chapter and discussed under each simulation case individually. Illustration charts are provided wherever meaningful to support the discussion and to present the outputs for each case and scenario. The sub-scenarios are often integrated in one figure under a main scenario to ease the comparison among them. The results are also compared with the base year data and the other cases and scenarios whenever useful. Detailed tables and data of the results can be found in Appendix “D”.

6.2 BUSINESS AS USUAL (BAU) CASE

This simulation case is a scenario by itself. The results are divided into two separate sub-sections: the first discusses the energy demand while the second sub-section focuses on the CO_2 emissions under the BAU case from 2010 to 2050.

6.2.1 ENERGY DEMAND

The simulation results for future energy demand represent an exponential increase till 2050. The predicted electricity consumption in 2050 is almost 2,975TWh which is nearly 40 times the consumption of the base year (see Fig. 6-1). The UAE was facing inability problems in fulfilling the electricity demand in 2008 and started looking for alternative energy sources as mentioned in sub-section “3.7.1”. Due to the large forecasted demand of electricity by 2050, it is a priority to find alternative energy sources and other energy saving techniques to avoid a probable catastrophe in the next four decades.

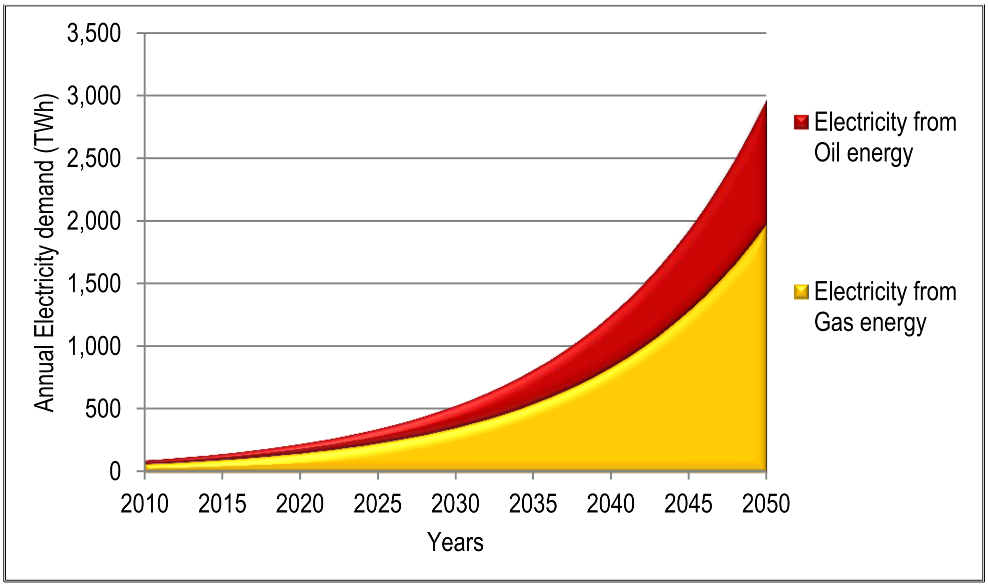


Figure 6-1: BAU, Expected energy demand till 2050 per energy fuel source

The capacity of production in 2050 is almost 691.5 GWe at 49% generation efficiency from power plants. The oil energy and gas energy remain supplies 33.5% and 66.5% of the overall generated electricity. UAE is currently importing natural gas according to BP (2010) as the locally available amounts are insufficient to fulfill the increasing demand. This trend is expected to continue and more imported natural gas will steadily be demanded. There are certain factors to be considered when importing gas such as political stabilization, the availability of the assets, the availability of gas from its source, and the price of imported fuel which have to be considered during energy planning techniques.

6.2.2 Carbon Dioxide Emission

The large increase of consuming conventional energy in the electricity sector is associated with the unprecedented increase in emitting CO_2 into the atmosphere. CO_2 emission from electricity is increasing almost 40 times the 2008 levels at an annual increase of 9% which reflects the same energy growth rate. By 2050, the CO_2 emission from electricity could reach 2,820 Mton. The oil energy of 33.5% electricity supply is responsible for almost 42% of the electricity emissions (see Fig. 6-3).

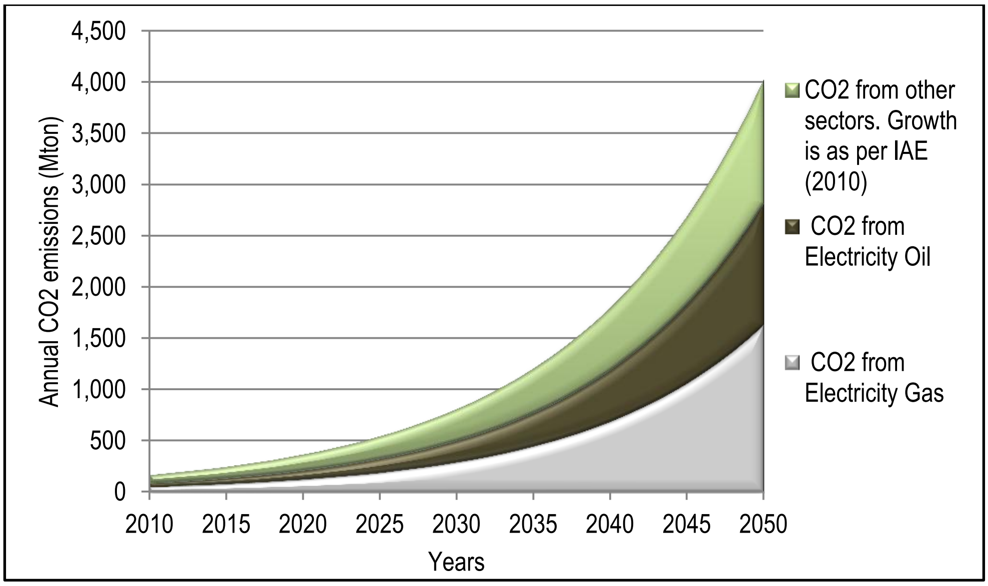


Figure 6-2: BAU, Total CO_2 emission per source till 2050

The emission from other sectors is added to the electricity emissions using an estimated average of 7% annual increase for other sectors according to IEA (2010) average growth rate. This rate is 2% less than the electrical energy growth rate in the BAU. The country's total CO_2 emission could reach 4,027Mton by 2050 (see Fig. 6-2). This amount of emission exceeds the total emitted CO_2 from the entire European continent of 3,991.2 Mton in 2008. It also represents more than two and half times the 2008 emission from the entire Middle East countries as influenced from the IEA (2010) statistics. UAE has been recognized by Kyoto Protocol as a Non-annex I region thus, limitations on CO_2 emission has not been put yet to constitute a guide for the country emissions. However, from the comparison with the European continent as an Annex I region, the projected emission in this scenario is threatening to the national and international environment.

In the year 2050, the per capita emission is increasing by more than 13-fold, as an overall emission, than the current CO_2 levels (see Fig. 6-3). This is due to higher growth rate of per capita emissions than it for population. The UAE is currently the World's second highest per capita emitter after Qatar according to IEA (2010); however, UAE might become the highest per capita emitter of CO_2 by 2050 if the BAU continued. The emission rate of 488 ton CO_2/capita by 2050 is a terrifying value which requires necessary preventive actions and techniques in place to lessen the emitted amounts of CO_2 .

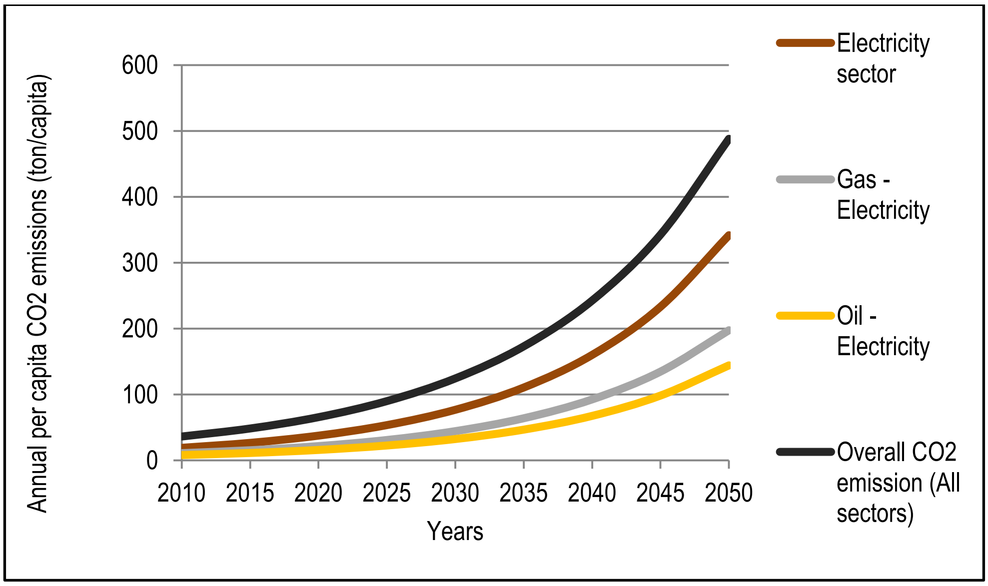


Figure 6-3: BAU, per capita emission of CO_2 (ton / capita)

6.3 APR 1400 SCENARIO

This scenario is an actual proposal which is planned to be implemented by the UAE government. The results are therefore, reflecting the expected status of UAE future plans for energy and its environmental impacts of CO_2.

6.3.1 ENERGY DEMAND

Due to the assumed mitigation measures to the future energy demand under the APR 1400 scenario, the simulation results represent reasonable increase till 2050. The total predicted consumption of electricity in 2050 is expected to be almost 570 TWh (see Fig. 6-4) which constitutes 7-fold the base year demand, and less than 20% of the BAU scenario. The fuel components in 2050 are expected to be 66.5% natural gas, 23.6% oil, 2.2% renewables, and 7.7% nuclear energy (see Fig. 6-5). Under this scenario, clean energy has more influence – as a percentage – into the electricity grid once introduced by 2020 (refer to Appendix D).

The capacity of production is found to be 132.5GWe in 2050 at almost 62.5% generation efficiency from power plants. The key achievement of alternative energy sources is that they are displacing oil energy which is responsible for the majority of CO_2 emission. Natural gas is still expected to be imported but at lower amounts if compared with the BAU scenario as the needed natural gas in this scenario is for 397.09 TWh which is less than 20% of (1,978.4 KWh) the needed in BAU scenario.

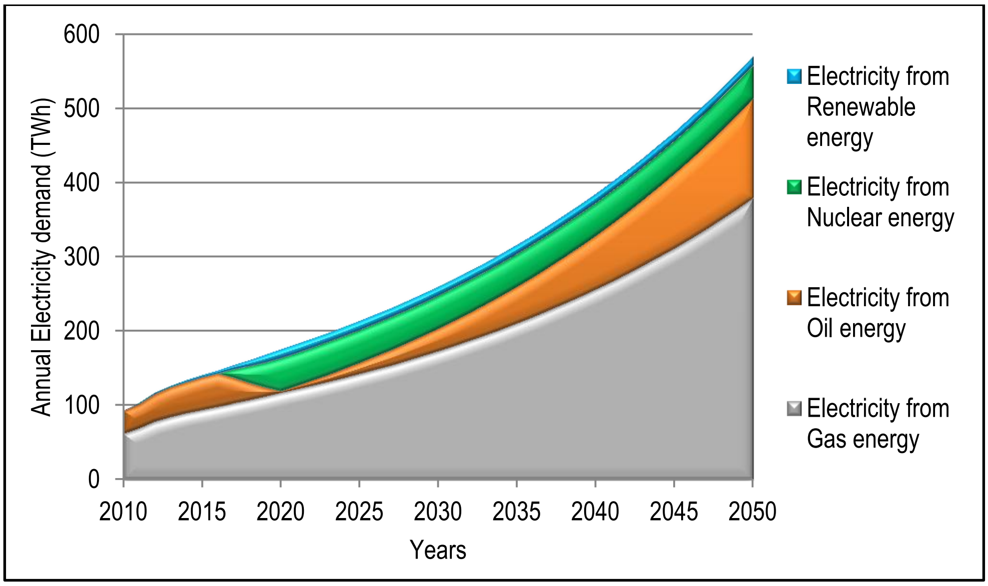


Figure 6-4: APR 1400 scenario, Expected energy demand till 2050 per energy fuel source

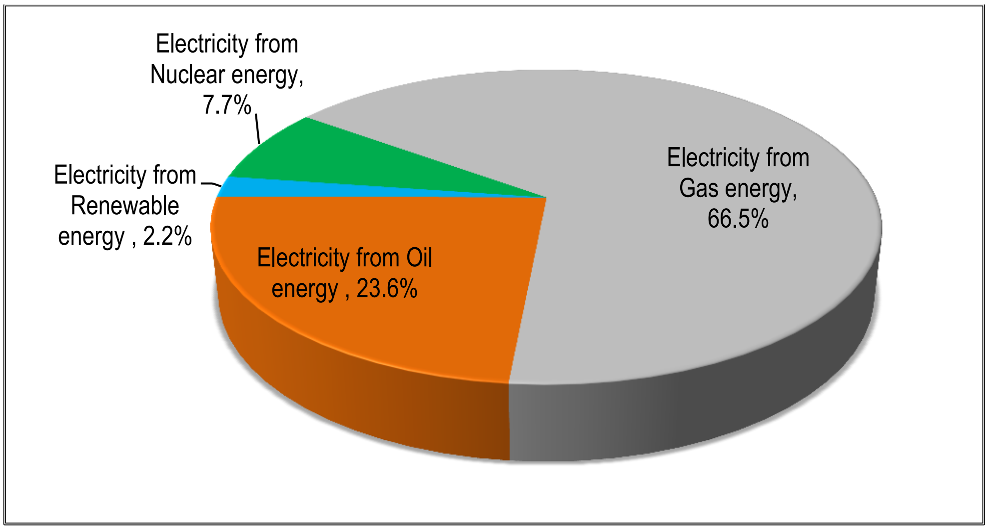


Figure 6-5: APR 1400 scenario, Percentage of the expected fuel shares by 2050

6.3.2 CARBON DIOXIDE EMISSION

The comparatively less future demand of electricity has – by itself - a constructive mitigation tool of CO_2 emissions. Alternative energy sources, mainly nuclear energy of 25% of the total electricity generation by 2020, contributed positively to the mitigation measures of CO_2 emission as well. Electricity sector, by the 2050, found emitting 6-folds the base year but, it is almost 16.6% of the emitted amounts in the BAU scenario.

The CO_2 emission from electricity, in the target year 2050, could reach 474Mton. This amount is adjusted to 469 Mton due to the effective measure of 5 Mton CCS. Nuclear energy which supplies 7.7% of the total electricity emit less than 0.25% of the total CO_2 emission from electricity in 2050 (see Fig. 6-6). The per capita emissions have a drop-down between 2014 and 2020 due to introducing CCS technique in 2014 and then, nuclear and energy by 2017 till 2020, and renewable energy also resulted a lower per capita rate of CO_2 emission (see Fig. 6-7).

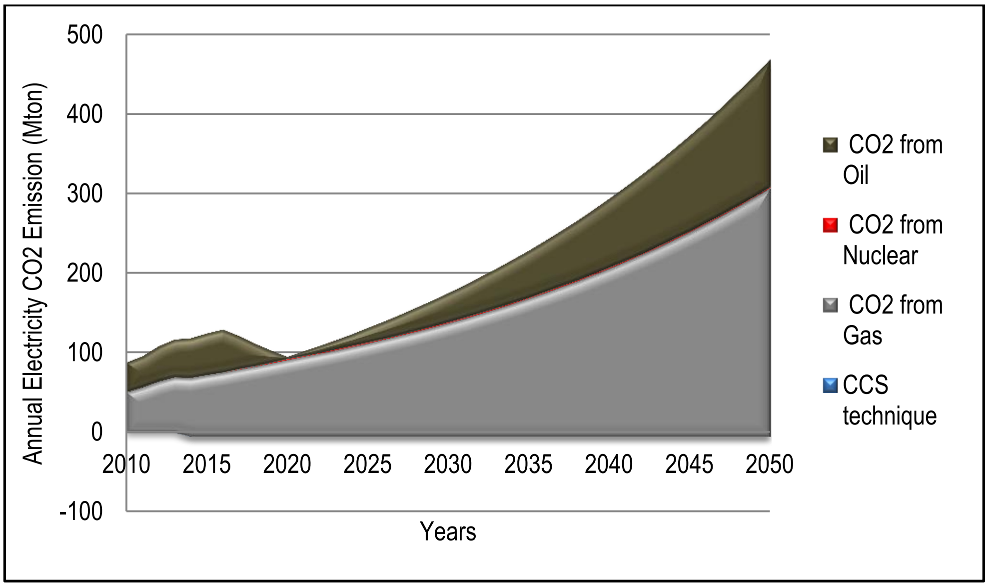


Figure 6-6: APR 1400 scenario, CO2 emission from electricity per fuel source till 2050 including the CCS technique * (CCS is not shown as it is below the X axis and filled in with CO2)

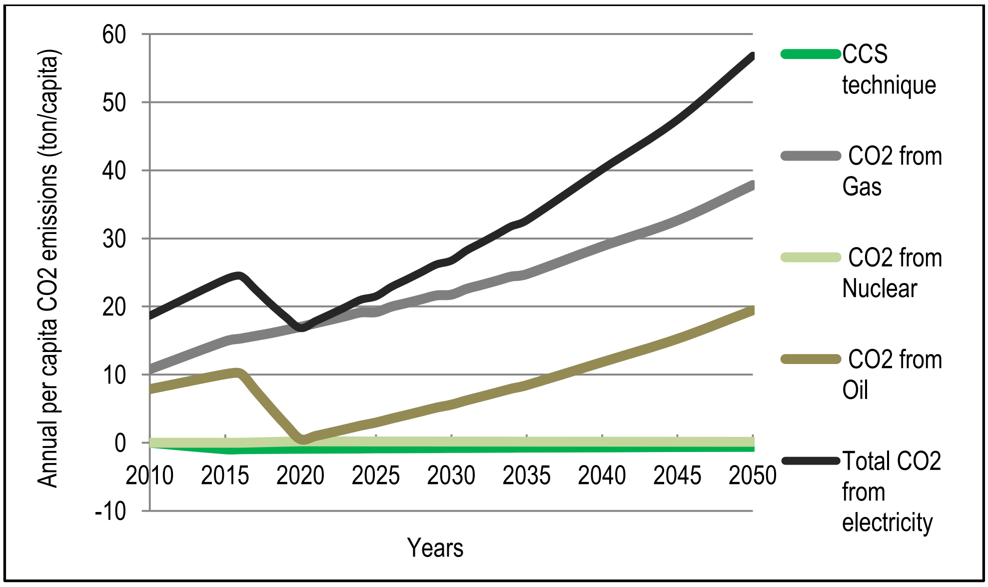


Figure 6-7: APR 1400 scenario, per capita emission of CO_2 (ton / capita) from electricity and its components including the CCS technique.

The total per capita trend returned increasing after 2020 at an annual average of 20% as the CO_2 growing rate returned overbeating the population growth rates. The per capita rate of emission is expected to reach 56.8ton CO_2/capita by 2050 which is significantly high in comparison to 2008 rate.

6.4 THE CASE OF CLEAN ENERGY ERA (CEE)

This scenario is proposed in this study to promote a clean environment level to a high viable extent in the UAE. Due to the relatively wide range of scenarios within the CEE as shown in the research matrix "chapter 4", the results for some scenarios – almost the moderate scenarios - will be presented tentatively while the extreme scenarios will be more detailed. The results are reflecting optimistic scenarios in order to assist the decision makers to easily choose among them for implementation in the country. Similar to APR 1400 scenario, future energy demand represents reasonable trend of 4% annual growth rate between 2020 and 2050. Population projections are also identical to both BAU and APR 1400 scenarios.

6.4.1 NUCLEAR ENERGY SCENARIOS (NES)

Nuclear energy starts displacing the conventional energy (oil and then gas) at its first operation in 2020 to generate electricity. The four scenarios (1NPP, 2NPPs, 4NPPs, and 8NPPs) are step-by-step integrated into the electricity scheme at different degrees. As shown in Fig. (5-22), the nuclear energy in 1NPP and 2 NPPs scenarios has a peak supply of 25% in 2020. In the 4NPPs scenario, it has a peak supply of 34.4% in 2040 while the 8NPPs scenario records the highest peak supply of 62% electricity from nuclear energy by 2050. Figure (6-8) shows the shares of energy sources in generating electricity for NES scenarios in the target year 2050. It is apparent that the conventional energy sources become less when more nuclear energy is integrated into the electricity scheme. This means cleaner environment in the future as discussed later in this sub-section in the CO_2 emission.

Figure (6-9) shows the trends of energy components from 2010 to 2050 for the extreme scenario (8NPPs). This is thought to be an optimum choice to achieve the future energy demand and maintain cleaner environment alike. Oil energy, as the most CO_2 emitter in the UAE, is expected to be barred by the year 2022. Under this NES scenario, clean energy has significant influence into the electricity grid which encourages cleaner and healthier environment (refer to Appendix D).

However, natural gas is still demandable but, at low levels if compared with BAU and APR 1400 scenarios. The natural gas required in this scenario is almost half the quantity in the NES (1NPP) and APR 1400 scenarios. It also accounts for almost one ninths the needed natural gas for BAU scenario by the year 2050. This is a great contribution to lessen the dependence on fossil fuel energy in order to mitigate CO_2 emissions.

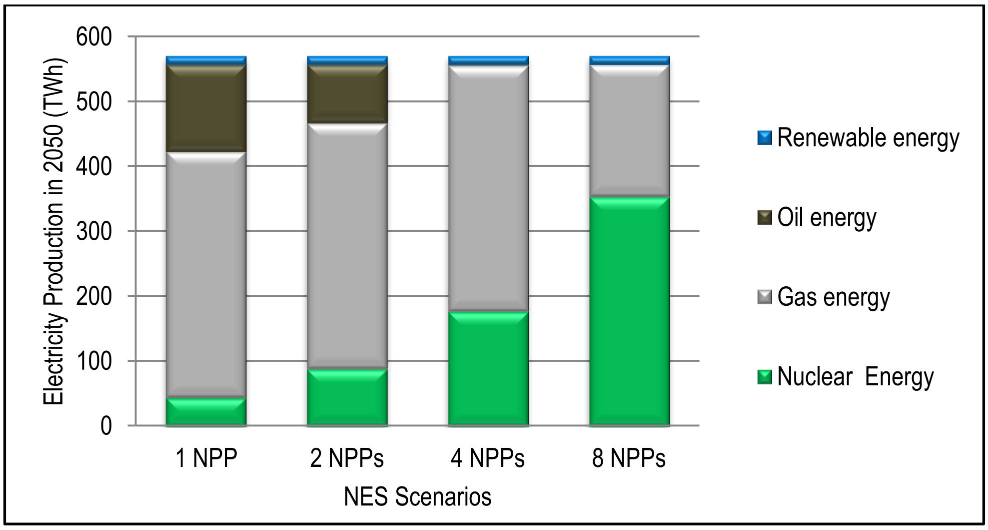


Figure 6-8: Energy shares in generating electricity for each NES scenario in 2050

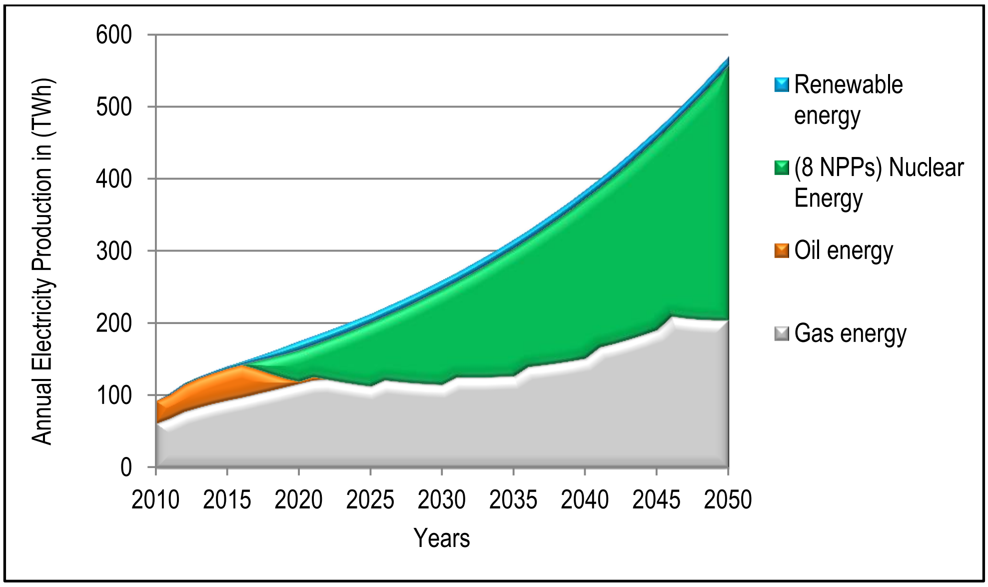


Figure 6-9: NES (8NPPs) scenario, the trend of electricity supply per fuel source till 2050

CARBON DIOXIDE EMISSION:

Further clean energy to the electricity grid, the application of eco-friendly building codes by local authorities, and energy saving approaches; all these and more are usually important factors which play significant role in adapting and mitigating the CO_2 emissions. Although the other factors rather than energy are assumed as part of adaptation mechanism (refer to sub-section 1.6.2) and not estimated along with the CO_2 emission in this study, they still can be recognized by the decision makers at the measurements of CO_2 emissions from electricity. This is in line with Psomopoulos et al. (2009) which discussed in chapter 2 “Literature Review”.

Each one of the four NES scenarios mitigated variant levels of CO_2 from the electricity sector during the study period. The more goes extreme in generating electricity by nuclear, the more CO_2 mitigation is achieved (see Fig. 6-10). The overall emitted CO_2 from electricity at the 8NPPs scenario in 2050 is almost 172.6Mton (from nuclear and gas energy only). This emitted amount forms almost one third the emissions at the 1NPP scenario and 6% of the CO_2 emission at BAU. Therefore, the 8NPPs scenario saves almost two thirds of the emitted CO_2 from 1NPP which is the same as APR 1400. The saving goes significantly at 94% is compared to the BAU. Noteworthy, in this extreme NES scenario nuclear energy supplies around 62% of the total electricity while it emits less than 5.25% of the total CO_2 from electricity. The moderate scenarios, 2NPPs and 4NPPs save around one ninth and one third CO_2 emissions from the APR 1400 respectively.

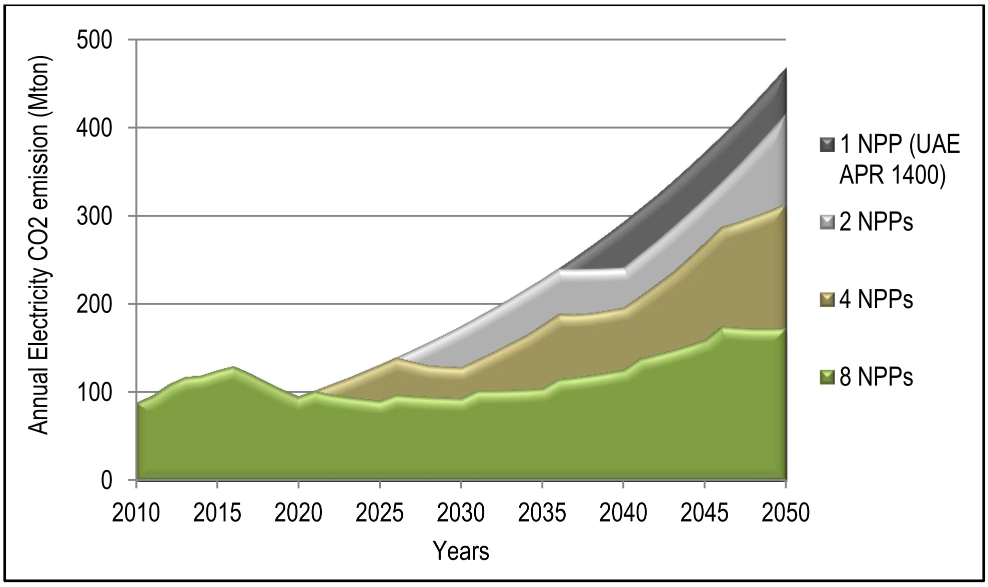


Figure 6-10: NES scenarios, total CO_2 emission from electricity till 2050 including the CCS technique.

The overall emitted CO_2 from the 8NPPs by 2050 is relatively twice the base year amount of CO_2 from electricity. It is also 4-fold higher for 4NPPs, 5.5 times more for 2NPPs, and 6-fold higher than the base year for the 1NPP scenario in the same target year. The emitted amounts from 4NPPs and 8 NPPs scenarios in 2050 are less than the CO_2 emission from France in 2008 while the later is the world second leading country in using nuclear energy to generate electricity, according to IEA (2010). Figure (6-11) show the CO_2 emission per fuel source along with the CCS technique in the 2050 for the four NES scenarios. It is obvious that more nuclear energy integration leads to more mitigation measures of CO_2 by the target year.

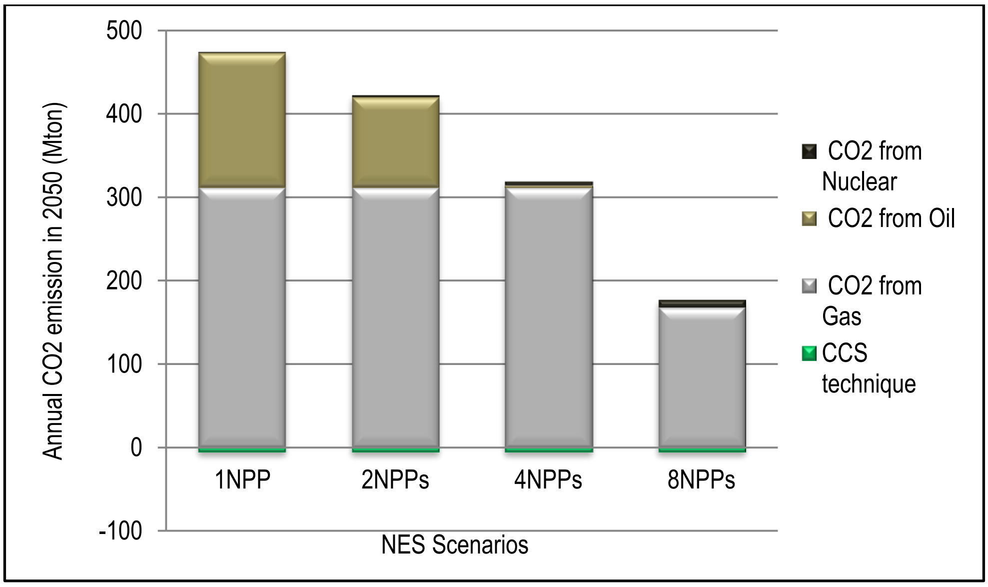


Figure 6-11: CO_2 emission per fuel source including the CCs technique in the 2050 for the NES scenarios.

The results prove the potential capability of nuclear energy to mitigate CO_2 from electricity sector in the built environment. This conforms the researches of Matsui et al. (2008), Mourogov (2000) and Kanoh (2006) which were studied in chapter 2 "Literature Review". The researchers confirmed the vital role of nuclear energy in mitigating the CO_2 emissions. Therefore, it is apparent now that the nuclear energy could be integrated into the electricity generation scheme as a tool of lessening the carbon dioxide emission which ultimately improves the built environment.

The per capita emissions from electricity fluctuated during the study period with the peak emission rate of 56.84 ton CO_2/capita in 2050 from the 1NPP scenario. The lowest achieved per capita rate of 14.26 ton CO_2/capita in 2030 was by the 8NPPs scenario (see Fig. 6-12). This rate is less than the base year emission rate per capita for electricity.

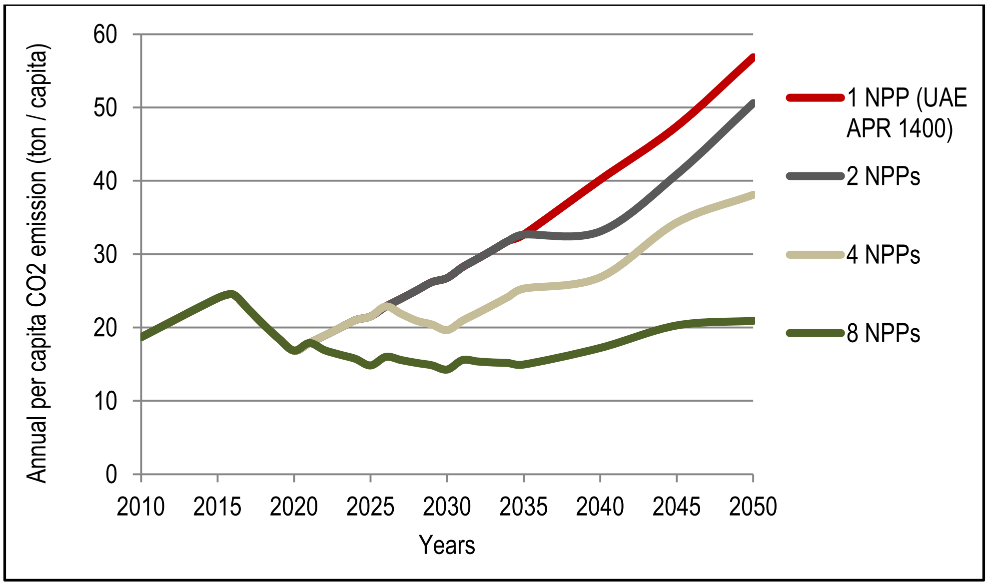


Figure 6-12: NES scenarios, per capita emission of CO_2 (ton / capita) till 2050

6.4.2 RENEWABLE ENERGY SCENARIOS (RES)

Each scenario of the four RES scenarios is gradually introduced into the scheme of electricity to replace fossil fuel stating from 2010 as shown in Fig. (5-23). The renewable energy in the (7%) scenario, which is proposed by the UAE in the APR 1400 case, reaches a constant peak supply of 12.3TWh by 2020 so, its percentage share of the total electricity starts decreasing till 2050. In the (35%) scenario, renewable energy supply maintains gradual increase till the 2050. The two intermediate scenarios maintain gradual supply of renewable electricity at stable percentages which has the peak in 2035 and 2040 for the (15%) and (25%) scenarios respectively.

Figure (6-13) shows the shares of energy sources in generating electricity for each RES scenario in 2050. The gas energy in the (35%) scenario has slightly reduced in comparison with the 8NPPs scenario while the oil energy is significantly reduced in the (15%) scenario if compared by the 2NPPs scenario. It then presents a bit more influence of RES scenarios to restraint the gas energy from electricity sector.

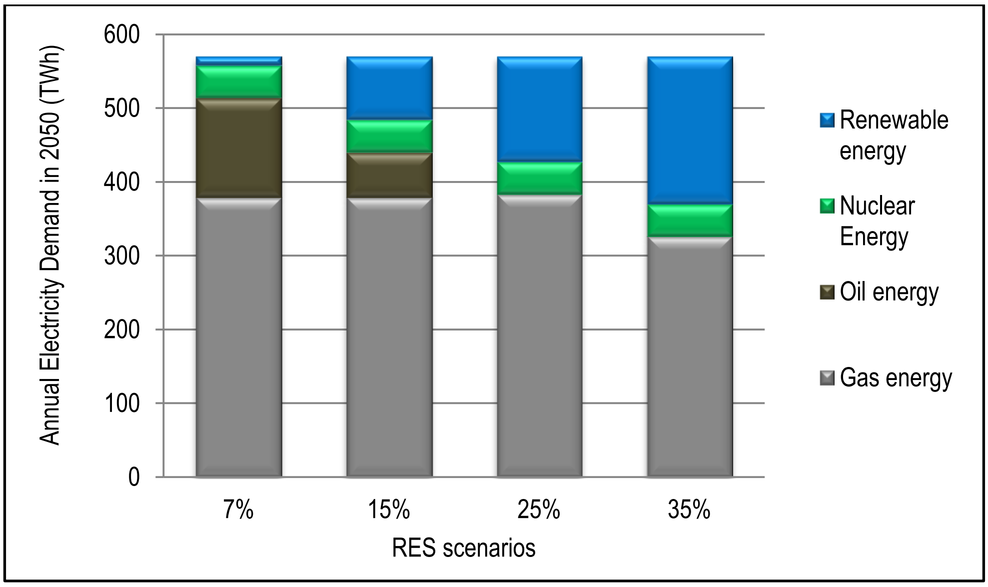


Figure 6-13: Energy shares in generating electricity for each RES scenario in 2050

Figure (6-14) shows the trends of energy components from 2010 to 2050 for the extreme scenario (35%). This is thought to be a better choice, within the RES scenarios, to displace oil energy totally by the year 2035. The gas energy at the (35%) scenario becomes slightly less than the APR 1400 scenario by 2050. The renewable energy sources in this scenario supplies almost 199.5 TWh which is more than two and half time the total electricity demand in the base year. This amount of supply constitutes one third the renewable-sourced electricity in China, the current world's leading producer of renewable energy, in 2008. The growth rate of renewable energy is almost 13% which is equal to the renewable growth in Germany from 1998 to 2008 according to Liebard et al. (2009). This growth is however less than what Romeo et al. (2009) expected regarding 31% growth of renewable energy in 2050 as mentioned in section "2.3" in chapter 2.

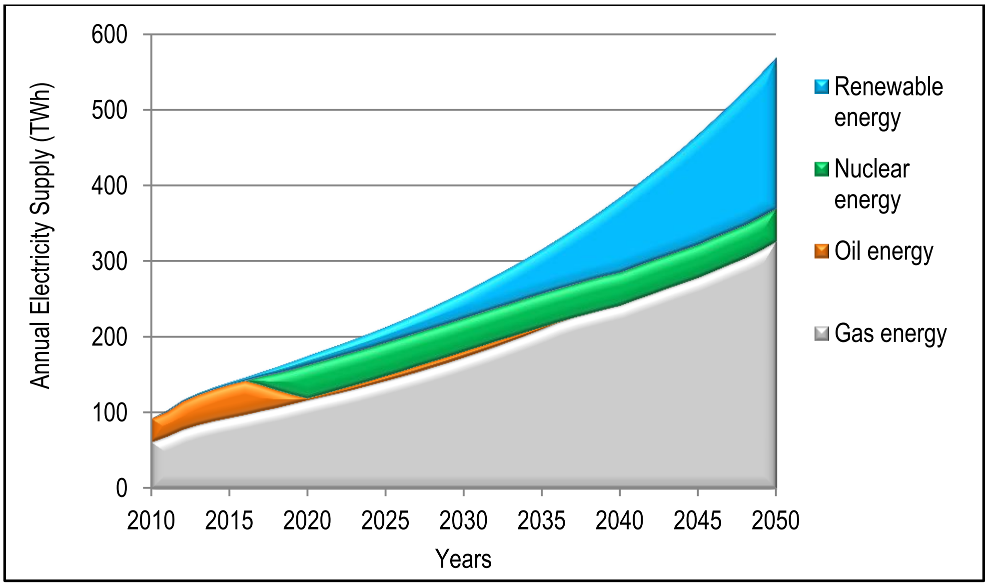


Figure 6-14: RES (35%) scenario, the trend of electricity supply per fuel source till 2050

Carbon Dioxide Emission

The four NES scenarios are individually contribute to the CO_2 mitigation from the electricity sector in the UAE at variant levels for each scenario. Figure (6-15) shows the different CO_2 emission schemes from electricity for each scenario between 2010 and 2050. Noteworthy, the renewable energy is a free carbon emission source as mentioned in the research parameters in chapter 4.

The total CO_2 emission at the (35%) scenario in 2050 could be about 265Mton which is almost one and half the emitted amount from the 8NPPs scenario. However, this scenario is saving almost 40% of the CO_2 from the (7%) and APR 1400 scenarios. It is, furthermore, saving about 90% of the CO_2 emitted at the BAU scenario. The moderate scenarios, (15%) and (25%) save around one fifth and one third CO_2 emissions from the APR 1400 respectively.

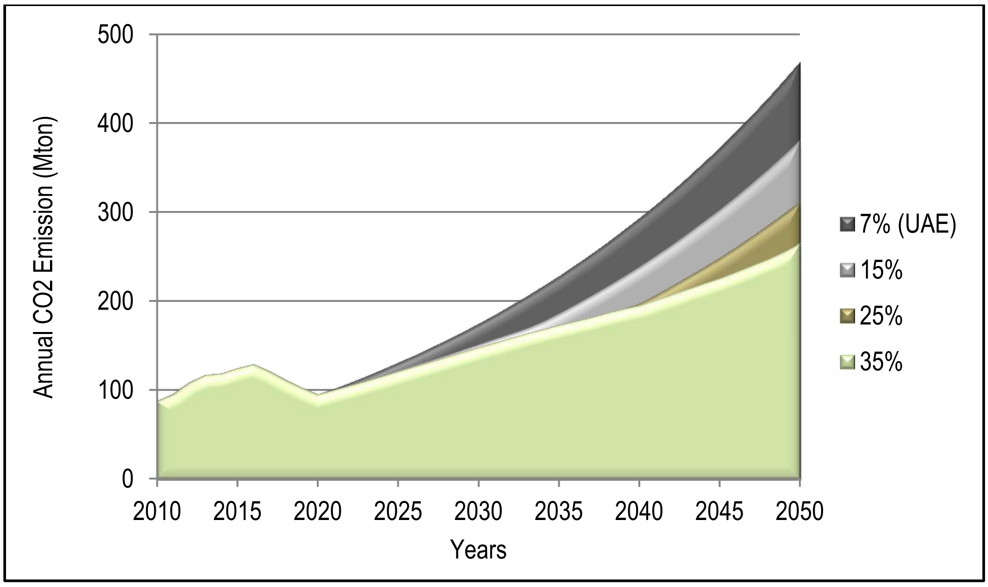


Figure 6-15: RES scenarios, total CO_2 emission from electricity till 2050 including the CCS technique.

The overall emitted CO_2 from the (35%) by 2050 is around three and half times the base year amount of CO_2 from electricity. It is also 4-fold higher than the base year at the (25%) scenario, five times more at the (15%), and 6-fold higher than the base year for the (7%) scenario in the same target year. The emitted amounts at the (25%) and (35%) scenarios in 2050 are less than the CO_2 emission from Franc in 2008 which is similar to the 4NPPs and 8NPPS scenarios as aforementioned. Figure (6-16) presents the CO_2 emission per fuel source including the technique of CCS in the 2050 for the four RES scenarios. It is apparent that increasing the shares of renewable energy to generate electricity mitigates further CO_2 emissions by the target year.

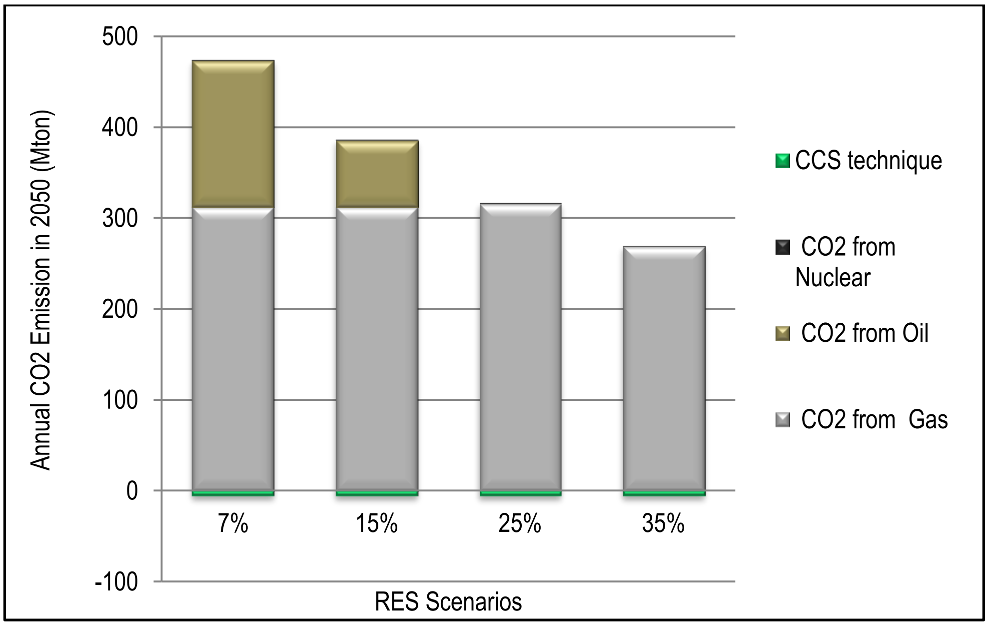


Figure 6-16: CO2 emission per fuel source including the CCS technique in the 2050 for the RES scenarios.

The per capita emissions from electricity started decreasing from the year 2014 due to the application of CCS technique. This decrease continued due to the introduction of nuclear energy and increasing renewable supply of electricity till 2020 to be 16.8ton CO_2 /capita. Thereafter, the per capita emissions returned to steady increase for the four RES scenarios at different individual levels (see Fig. 6-17). This might be interpreted due to more growth of CO_2 emissions than the population growth. After the 2020 increase, the lease achieved rate in 2050 was 32.12 ton CO_2 /capita at the RES (35%) scenario which is almost double the base year.

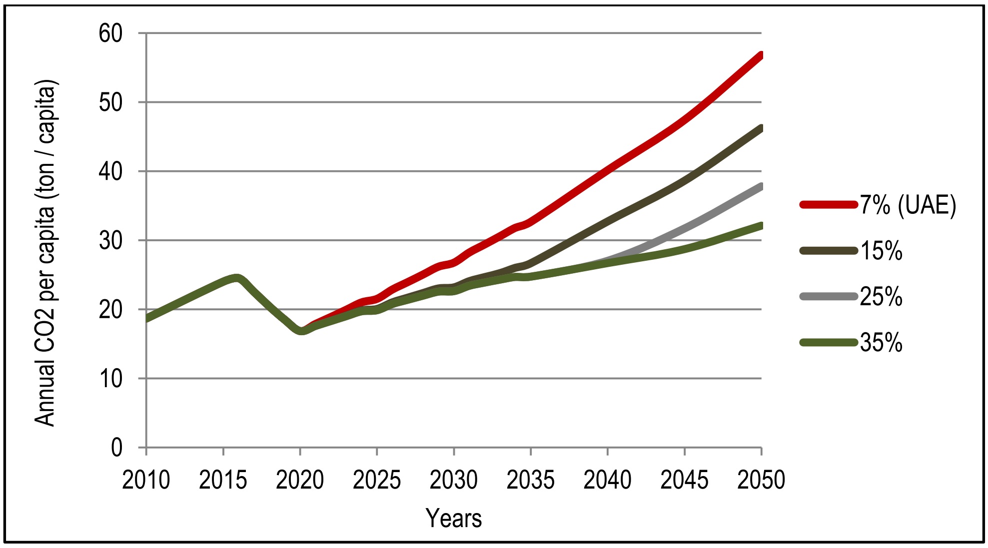


Figure 6-17: RES scenarios, per capita emission of CO_2 (ton / capita) till 2050

6.4.3 Carbon Capture and Sequestration Scenarios (CCSS)

As shown in Fig. (5-25) of chapter 5, the four CCSS scenarios have different effective schemes of integration for each scenario. Figure (6-18) shows the different levels of CO_2 emission from electricity after applying each CCSS scenario individually between 2010 and 2050. The overall CO_2 emission form electricity at the (10 Mton/3yrs) scenario in 2050 could be about 359Mton which is almost two times the emitted amount from the 8NPPs scenario. However, this scenario is saving almost one fourth of the CO_2 emissions from the (5 Mton once) and APR 1400 scenarios. The moderate scenarios, (5 Mton/6yrs) and (5 Mton/3yrs), have a CO_2 saving of 25Mton and 55Mton respectively when compared by the APR 1400 scenario by the 2050.

Figure (6-19) shows the CO_2 emission per fuel source including the CCS technique by 2050 for the four CCSS scenarios. It is obvious that the emission levels of CO_2 from Gas, oil and nuclear energies remain identical for each CCSS scenario whereas, the overall level of CO_2 is changing due to different CCS reservoirs capacity for each scenario.

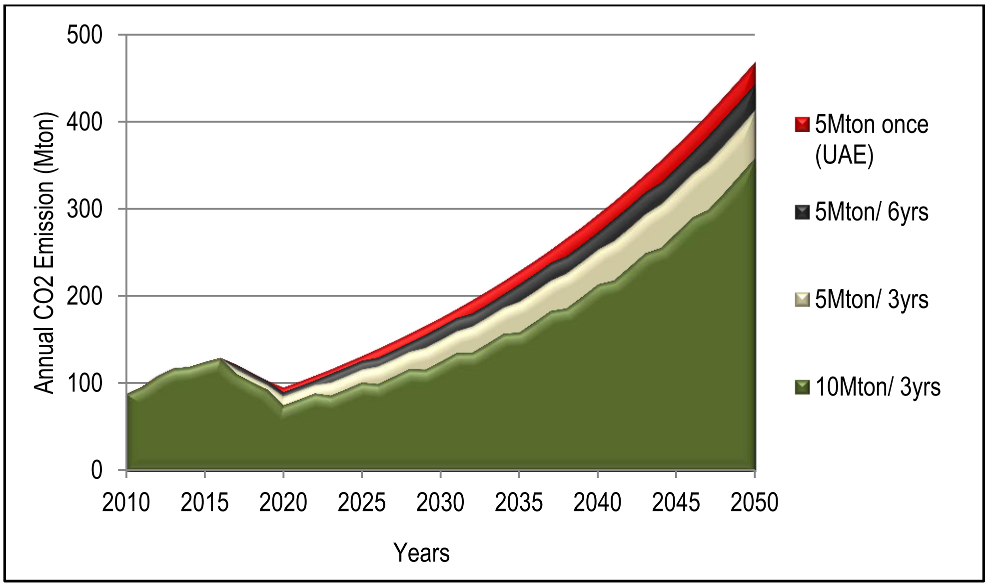


Figure 6-18: CCSS scenarios, total CO_2 emission from electricity till 2050 after applying the CCS techniques.

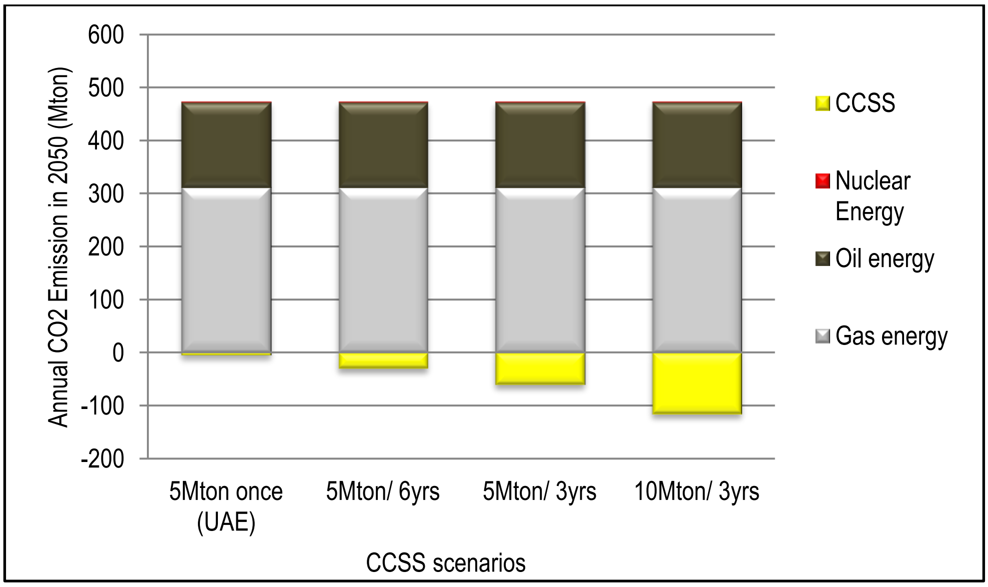


Figure 6-19: CO_2 emission per fuel source in the 2050 for the CCSS scenarios.

The per capita emissions from electricity have the least value by 2020 due to the introduction of nuclear energy and renewable energy. Thereafter, the per capita emissions returned to steady increase for the four CCSS scenarios at different individual levels due to the less population growth than CO_2 emission (see Fig. 6-20). After the least per capita emission of 13.3 ton/capita from the extreme scenario (10 Mton/3yrs) in 2020, the least achieved rate in 2050 was 43.5 ton CO_2 /capita which is almost two and half times the base year. The per capita emissions from (5 Mton/6yrs) and (5 Mton/3yrs) scenarios were above three times higher than the base year per capita emissions.

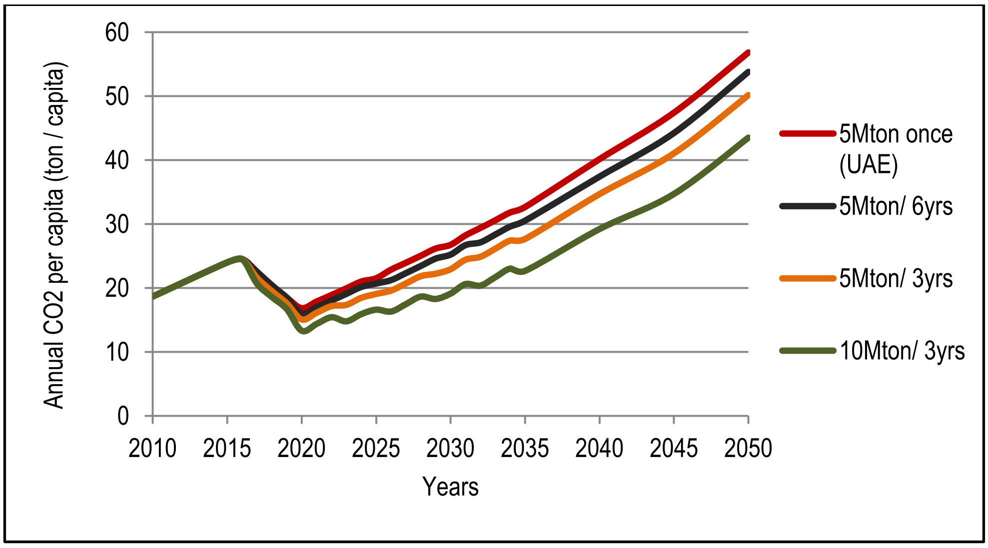


Figure 6-20: CCSS scenarios, per capita emission of CO_2 (ton / capita) till 2050

6.5 Comparative Analysis of the Scenarios

Comparative analysis was found needful in order to determine the suitable scenario for a desirable target. Among the extreme scenarios of CEE case, the CCSS (10Mton/3yrs) achieved the least CO_2 emission between the years 2017 and 2024 thereafter, returned increasing to rank the highest among the three extreme scenarios. The RES (35%) scenario achieved a comparatively less CO_2 emission from the 2039 to 2050 than the CCSS (10Mton/3yrs) to rank in the middle status among the three extreme scenarios. The 8NNPs scenario noticed to be achieving the minimum CO_2 emission from the 2024 till the target years (see Fig. 6-21). This is a proof that nuclear energy is the best option to mitigate the CO_2 emissions of the built environment as pointed-out under sub-section "6.4.1"

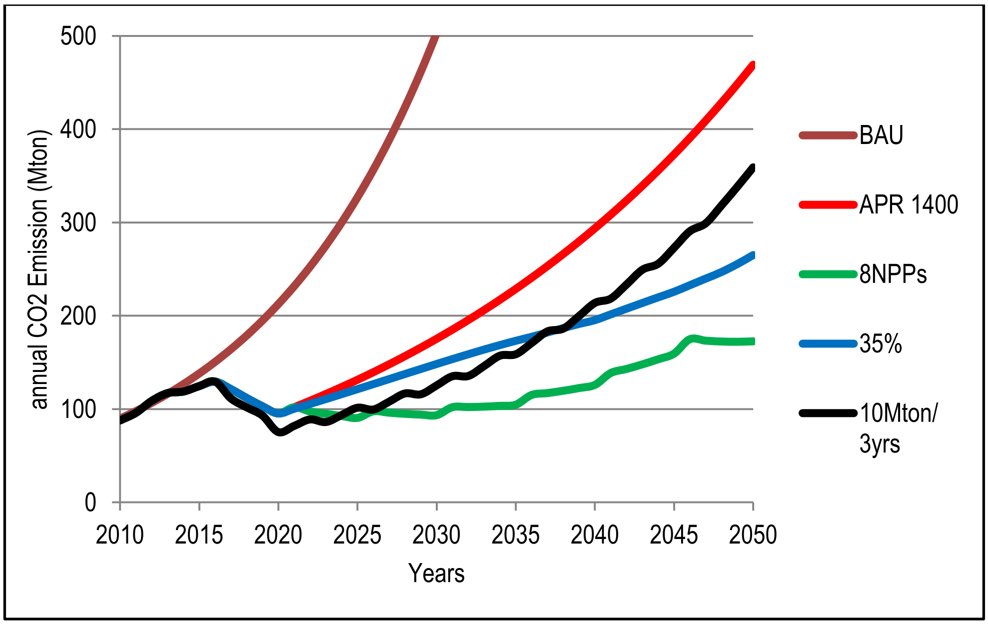


Figure 6-21: Comparison between the CEE extreme scenarios, APR 1400 and BAU of CO2 emission from 2010-2050

Figure (6-22) compares of the CEE moderate scenarios, APR 1400 and the BAU in terms of CO_2 emission values from 2010 to 2050. The trends of CO_2 emission are fluctuated and varied among all the scenarios. The CCSS (5Mton/3yrs) found to be properly mitigating CO_2 emission between 2017 and 2027. The NES (4NPPs) achieved, relatively, better mitigation level between the 2028 and 2034. The RES (25%) was the best scenario among the CEE moderate in mitigating the CO_2 from 2035 to 2050. By the target year, both RES (25%) and NES (4NPPs) were very close, they furthermore, achieved better mitigation options than the extreme CCSS (10Mton/3yrs) scenario.

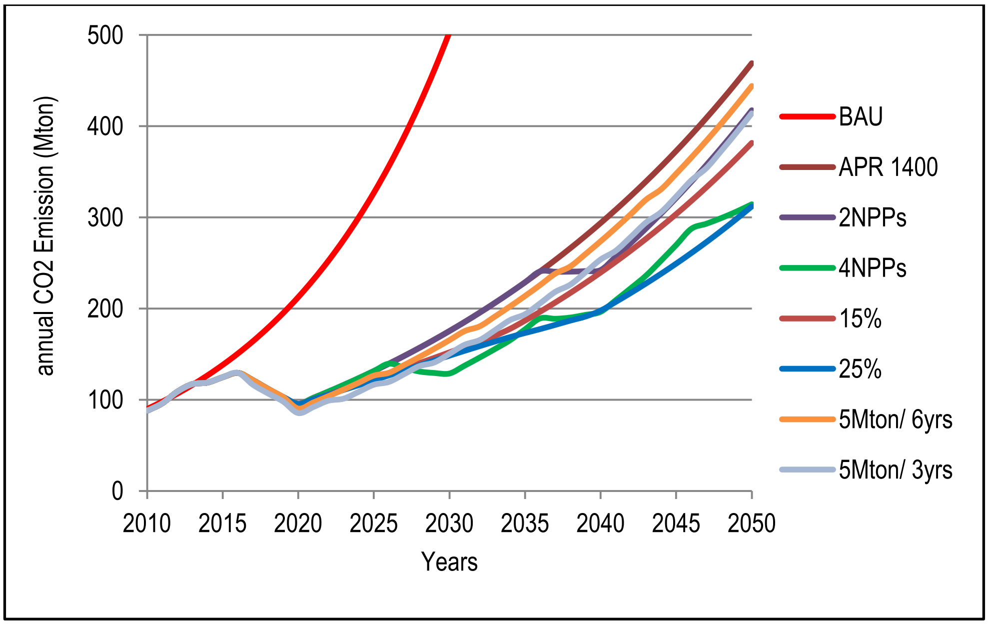


Figure 6-22: Comparison between the CEE moderate scenarios, APR 1400 and BAU of CO_2 emission from 2010-2050

Similar to the CO_2 emission values, the CCSS (10Mton/3yrs) of the CEE extreme scenarios recorded the least per capita emission between the years 2017 and 2024 afterward, it returned increasing. The RES (35%) scenario achieved less CO_2 emission from the 2039 to 2050 than the CCSS (10Mton/3yrs). The 8NNPs scenario was achieving the minimum per capita emissions from the 2024 till the target years. It has a per capita emission value of 20.9 ton CO_2 / capita in the 2050 which is slightly higher than the base year value (see Fig. 6-23). This is again confirms that nuclear energy is the superlative option to mitigate the CO_2 emissions from the built environment in the UAE.

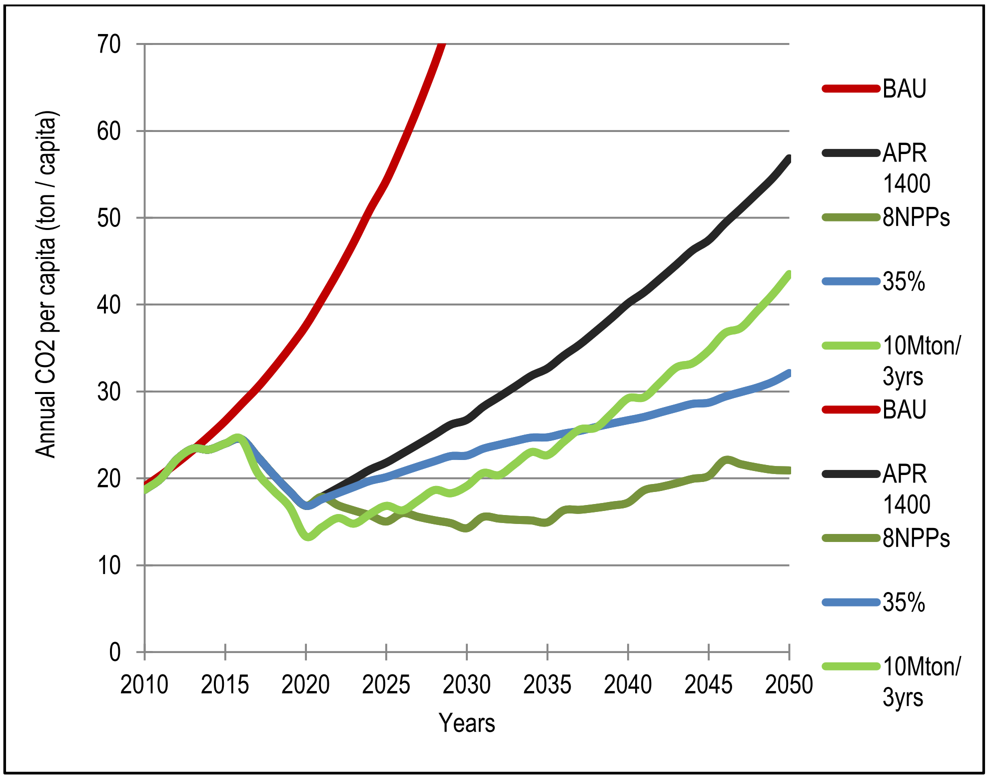


Figure 6-23: Comparison between the CEE extreme scenarios, APR 1400 and BAU of per capita emission of CO2 from 2010-2050

Figure (6-24) compares between the CEE moderate scenarios, APR 1400 and the BAU in terms of CO_2 per capita emission values from 2010 to 2050. The CCSS (5Mton/3yrs) found to be the superlative scenario in mitigating CO_2 emission as a proportion of population between 2017 and 2027. By the target year, both RES (25%) and NES (4NPPs) were very close at 37.8 ton CO_2 /capita and 38.1 ton CO_2 /capita respectively. They furthermore, achieved better mitigation option than the extreme CCSS (10Mton/3yrs) scenario by the 2050. Both CCSS (5Mton/3yrs) and NES (2NPPs) were also very close at 50.18 ton CO_2 /capita and 50.59 ton CO_2 /capita respectively while the RES (15%) was lower than both of them at 46.25 ton CO_2 /capita.

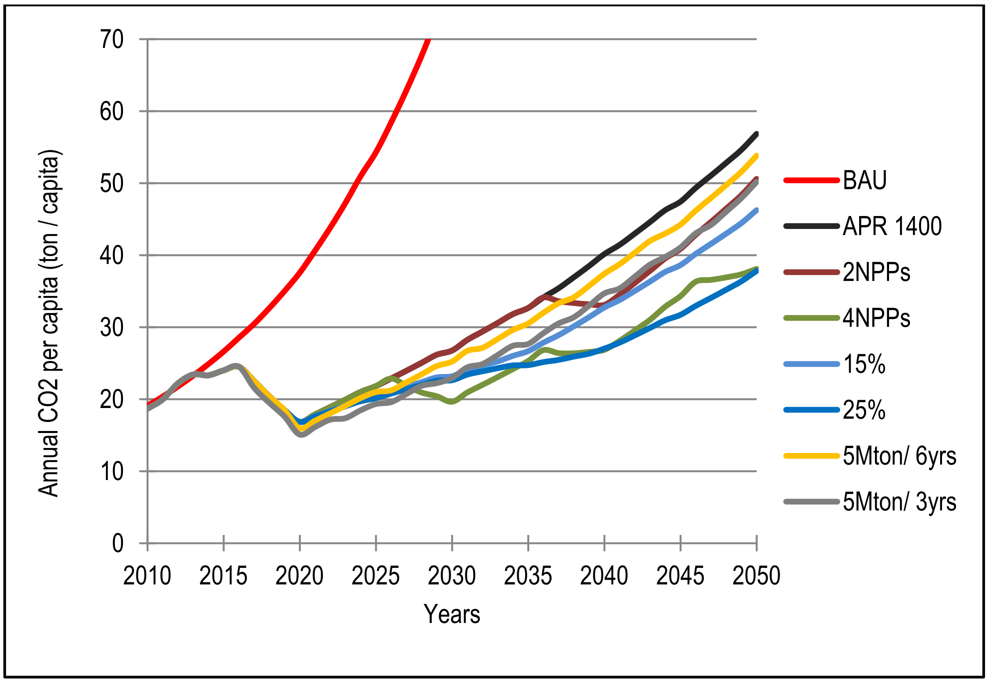


Figure 6-24: Comparison between the CEE moderate scenarios, APR 1400 and BAU of per capita emission of CO_2 from 2010-2050

As a summary, the nuclear energy in the extreme scenarios (NES, 8NPPs) found to be the most appropriate option to mitigate the CO_2 emission and consequently lessening the global warming and climate change from the built environment of the UAE. In the upper moderate scenarios (NES 4NPPs, RES 25%, and CCSS 5Mton/3yrs), nuclear energy noticed to be playing a very close role to the renewable energy in CO_2 mitigation which also confirms the potential role of nuclear energy in mitigating the CO_2 emission. In the lower moderate scenarios (NES 4NPPs, RES 25%, and CCSS 5Mton/6yrs), the renewable energy achieved a better mitigation option than nuclear energy and CCS by 8% and 14% respectively which still confirms that nuclear energy is a competitive option for future mitigations of CO_2 emissions from electricity sector in the UAE's built environment. Slight enhancement, hence, might be required for the nuclear energy at the lower moderate scenario.

6.6 OPTIMUM SCENARIO

As influenced from the comparison between the scenarios, it has found interesting to gather the CEE extreme scenarios in an optimum scenario. This scenario has further effective power of contribution to diminish CO_2 emissions of the built environment. The three inputs are (8NPPs), (35%) renewable energy, and (10Mton/3yrs). The energy growth demand is 4% after 2020, population growth is according to the UN (2008). Figure 6-25 shows the electricity supply up to 2050 per fuel source. The natural gas energy is decreasing from 2021 to supply merely 17.34 TWh (3% of the total grid electricity) by the 2050 which is almost 38% of the UAE's gas production in the base year. The UAE can thence export gas rather than importing it from Qatar. Nuclear energy supplies 62% of the total grid electricity by the 2050 which is same as CEE RES (8NPPs) scenario.

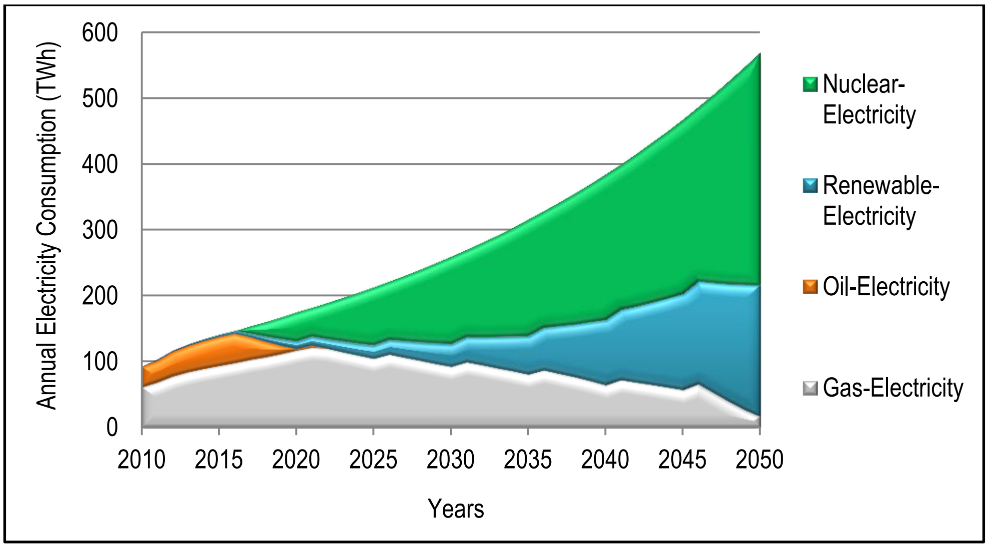


Figure 6-25: The optimum scenario, the trend of electricity supply per fuel source till 2050

It is almost 97% clean energy sources to the electricity grid which significantly diminishes the CO_2 emissions by 2050 to almost 23.33 Mton. The carbon capture and sequestration of 115 Mton capacities by 2050 gets rid of CO_2 emission totally from the UAE's atmosphere with empty reservoirs to accommodate around 91.67 Mton. In this scenario achieved CO_2 saving of 162.4% of the target year (see Fig. 6-26).

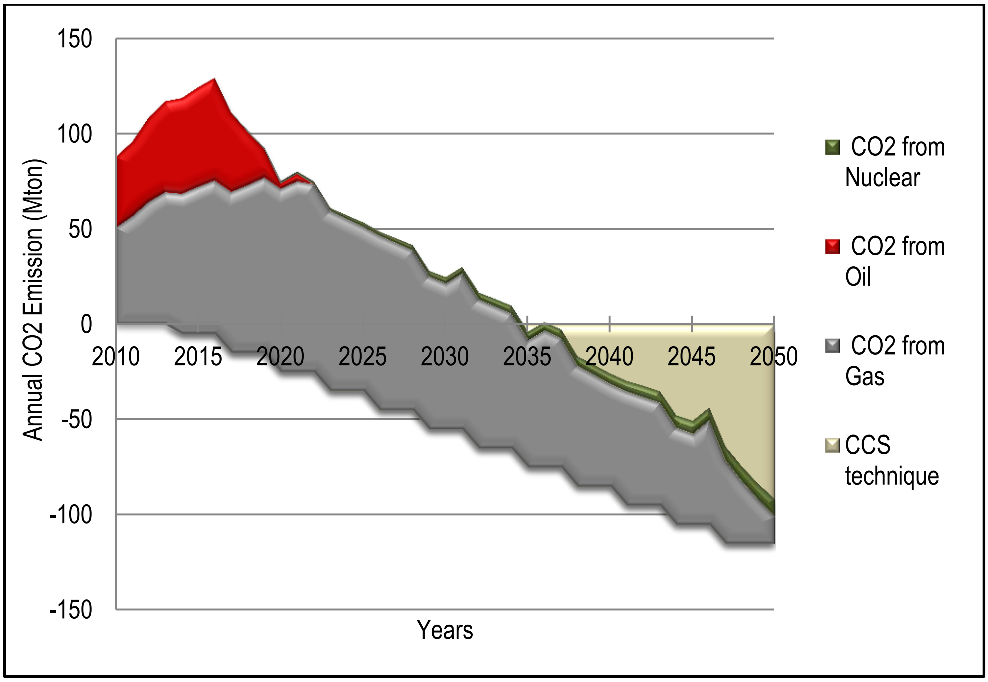


Figure 6-26: The optimum scenario, total CO_2 emissions from electricity till 2050 including the CCS technique.

*(CCS has started appearing beyond 2035 as it is empty)

At the first glance, this achievement looks over targeted and this scenario might be the optimum beyond the year 2050. In fact, this accomplishment is from electricity sector only which was responsible for 49.4% in 2008 as discussed in Chapter 5 under section "5.5". The other sectors (Construction, transportation and others) may perhaps not accomplish similar level of mitigation by the target year so, the empty reservoirs will be eager to receive captured CO_2 from these other sectors. On the other hand, the CCS can be advanced and improved to be a business sector. This new type of investment can be used similar to carbon trading and cap-and-trade system. CO_2 can be captured from other countries, especially neighbors and sequestered in these empty CCS reservoirs. Unlike the carbon trading, CCS business diminishes the overall CO_2 emission rather than redistribute it which will definitely be favoured by Kyoto Protocol. However, it might be a competitor sector to the carbon trading so; feasibility study is mandatory prior launching this kind of business. In the event of non effective feasibility study then, almost quarter of the proposed CCS capacities would be enough if there is no further CO_2 emission from other sectors than electricity. Accordingly, the (10Mton/3yrs) could be replaced by (5Mton/6yrs) which will end up of only (-6.67) Mton by the 2050

CHAPTER 7: ECONOMIC ANALYSIS

7.1 Introduction

Economic analysis is a vital factor to evaluate the effectiveness of nuclear power plants in terms of commercial feasibility and integration. Integrating NPPs into the electricity grid should positively contribute to the economic growth, and the outcome benefits are to outweigh the induced costs in addition to the environmental contribution. This chapter highlights the costs associated with nuclear energy from capital cost till electricity supply to the grid along with the CO_2 emission cost. It, mainly, draws on the data from the recently built or about to be built nuclear reactors. Cost competitiveness is also explained as an important tool for the future of nuclear energy.

7.2 Capital Cost

The capital cost of building an NPP can be estimated in various methods; however, the accurate method should set-up for the cumulative expenses during the construction period (5 – 10 years) along with the inflation cost and interest rate costs. One assessment method is called "overnight" cost which is quoted using the prices at the start of construction as everything is supplied at once without interest rate; this includes the engineering, procurement, and construction (EPC). Additional costs include: overhead and profit, inflation and interest rate, and changes to upgrade the grid to absorb the additional loads of power. The final capital cost could jump to twice the overnight EPC cost, and is often found to be 50 -75% higher (Harvey, 2010).

Figure 7-1 shows cost variation of completed NPPs between 1971 and 1997 and projected NPPs from 2001 to 2009. The projected overnight EPC costs were in range of $1,400 to 2,350 / KWe from 2001 to 2009. The EPC costs increased from $2,500 to 5,500/KWe between 2007 and 2008.

Further increases of $5,000 to 10,000/KWe are projected between 2008 and 2009 (Harvey, 2010 citing Cooper, 2009).

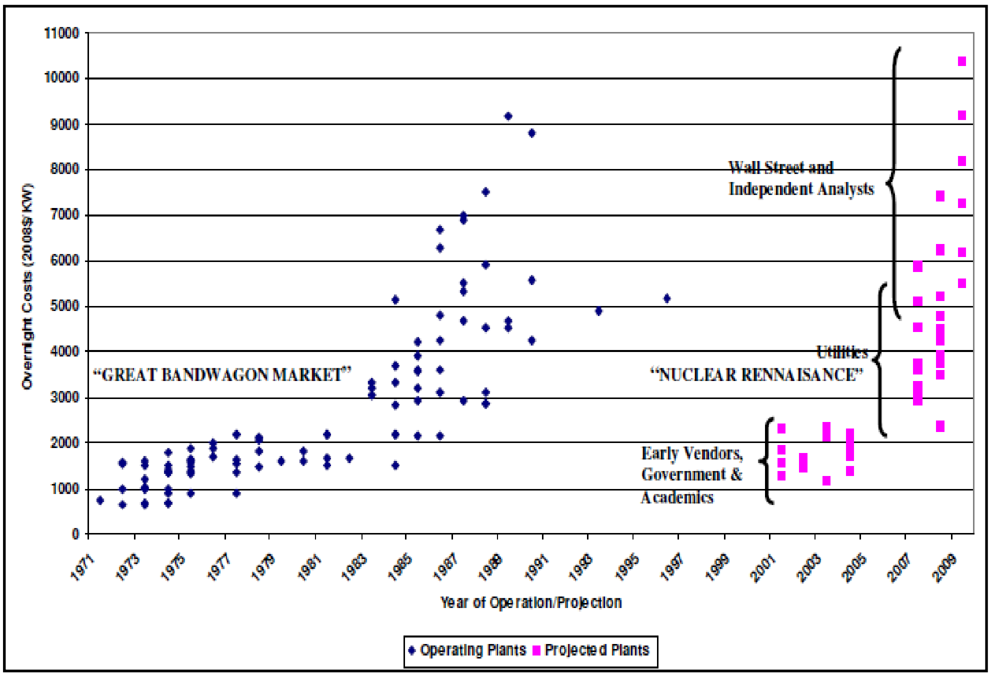


Figure 7-1: Overnight Cost of Completed Nuclear Reactors Compared to Projected Costs of Future Reactors (Cooper, 2009)

An under construction NPP at Olkiluoto site in Finland was contracted in 2004 for 1,600MW unit at a cost of around $2,800/KWe. On March 2009, the progress recorded three years delay of construction program, and the projected cost jumped to $4,400/KWe (Harvey, 2010 citing Schneider, et al. 2009) the reasonable range of capita; cost ranges from $4,000/KWe to $6,000/KWe (Kok, 2009; and Harvey, 2010).

According to Carlisle (2010), the initial cost of the UAE's NPP is $20 billion. By dividing this capital cost on the capacity of 5,600Mwe, it results an overnight EPC cost of almost $3,571/KWe. However, this cost is less than the final Olkiluoto NPP in Finland and it is within the cost range of Harvey (2010) between the years 2007 and 2008. Therefore, this is a constructive indication that the UAE proposed NPP have a reasonable initial cost which keeps the nuclear energy in the UAE in line with the other nuclear country in terms of supplying electricity from nuclear energy.

7.3 OPERATING COSTS

The costs of operating NPPs include all fixed and variable costs of operation and maintenance (O&M), employees, fuel (which comprises the mining, enrichment, conversion, and manufacturing), waste and decommissioning strategies and insurance. However, the minimum annual fixed cost is about $50 million (Kok, 2009; and Harvey, 2010). The fixed O&M costs $56/KWe/yr while variables without fuel cost 0.042cents/KWh (Harvey, 2010 citing Du and Parsons, 2009). The fuel cost ($/kg) is estimated from the following equation:

$$C_f = \sum_i M_i C_i + \sum_i M_i C_i \emptyset \Delta T \qquad (7\text{-}1)$$

Where M_i is the mass of material used in stage(i), C_i is the cost per unit mass, $\emptyset$ is the annual carrying charge as a fraction of initial investment, and ΔT is the duration (years) from the start of cost till halfway point in 9the use of fuel. The first part of equation (7-1) deals with the yearly cost whereas, the second part happens only once prior electricity generation (Harvey, 2010).

There is almost 4.5 million tons of uranium worldwide can be mined at $80/Kg which maintain almost 50 – 70 years of usage at the current consumption rate of 65,000 tons per year. The recent increasing demand and escalating uranium prices encouraged the investment in uranium mining industry. The uranium price is, therefore, escalating to more than $130/kg in recent years (Adamantiades and Kessides, 2009).

Table (7-1) present the inputs of equation (7-1), the total cost of fuel is \$2,040/Kg for uranium ore of \$30/Kg. When uranium ore cost increases to \$150/Kg (which is 5-fold expensive than \$30/Kg), the fuel costs becomes almost \$3,788/Kg (which is less than double). The cost of fuel per KWh of electricity is estimated via the following equation (Harvey, 2010):

$$\frac{\$}{\mathrm{KWh}} = \frac{C_f(\$/\mathrm{kg})}{B(\mathrm{MWd/kg})\mu} \times \frac{1\ \mathrm{MW}}{1000\ \mathrm{KW}} \times \frac{1\ \mathrm{day}}{24\ \mathrm{hours}} \qquad (7\text{-}2)$$

Where B is the burn-up, and μ is the thermal efficiency. If B=40MWd/kg (Mega Watt day per kilogram) and μ=0.33, fuel – according to equation (7-2) will cost 0.64 cents/KWh and 1.2cents/KWh for C_f =\$2,040/kg and \$3,788/kg respectively.

Table 7-1: Inputs to equation (7-1) for computing the cost of 1kg of uranium fuel, and final fuel cost, (Harvey, 2010 citing MIT, 2003)

Item	Input			**Direct cost** $\mathbf{M_i\ C_i}$ **(\$)**	**Carrying charge** $\mathbf{M_i\ C_i \emptyset \Delta T}$ **(\$)**
	M_i	C_i	ΔT (yr)		
Ore purchase	10.2 kg/kg	\$30/kg	4.25	307	130
Conversion	10.2 kg/kg	\$8/kg	4.25	82	35
Enrichment	6.23 kg SWU/kg	\$100/kg SWU	3.25	623	202
Fabrication	1 kg/kg	\$275/kg	2.75	275	76
Storage and isolation	1 kg/kg	\$400/kg	-2.75	400	-90
Total				1686	353
Grand total				\$2040/kg	

7.4 Decommissioning Cost

At the first instance, decommissioning cost could be equal to the construction cost if not more expensive. However, the already decommissioned NPPs constitute a learning example such as 28 shutdown reactors in the USA, and the land is reused. Figure (7-2) shows estimated costs of decommissioned power plants in UK. It is obvious that there is an inverse relationship between decommissioning cost and NPP size. According to Harvey (2010), similar to the down estimation of capital cost which usually increases during the construction, the actual costs of decommissioning initial estimates are likely to be higher during or after decommissioning. Nevertheless, the average cost of decommissioning per KWh is around 0.15 cents/KWh.

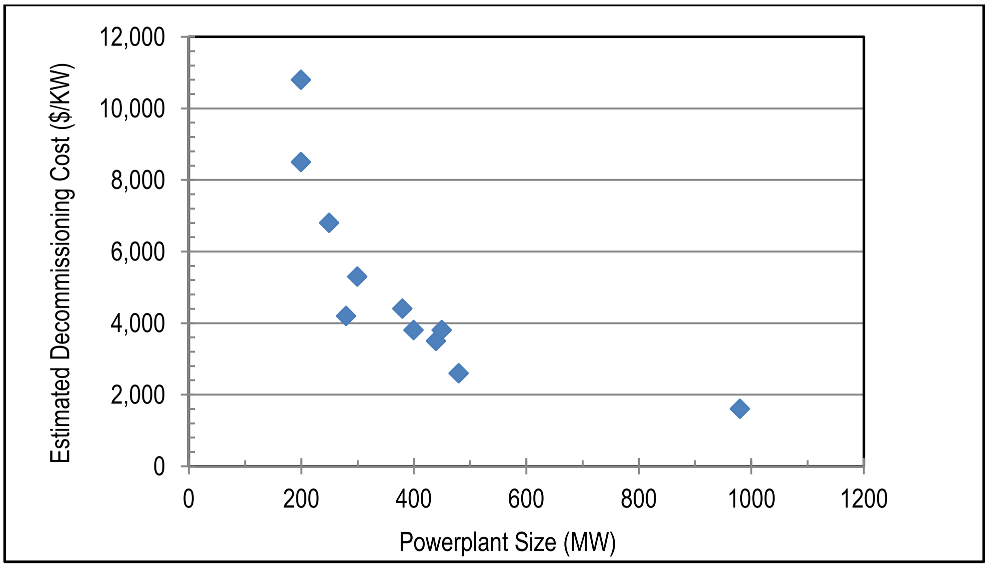


Figure 7-2: Estimated cost of decommissioning graphite-moderated nuclear power plants in UK, (Harvey, 2010)

7.5 Financing Costs

There are several methods of financing nuclear power plants or manufacturing facilities. Among these are (Kok, 2009; and Harvey, 2010):

- Debt (borrowing from lending institutes and paying interest ranges between 5-6%).
- Equity (selling additional stocks or bonds in the power plant). The expected return of equity by stockholders is almost 16% annually.

Due to the high risk of investment in nuclear plants and the long construction time which accumulate the interest rate, the private investors will demand a comparatively higher return rate.

7.6 COST OF NUCLEAR ELECTRICITY (UAE AND GLOBAL)

As accumulated from the precedent factors, the electricity cost for the UAE NPP (5,600 MW) operating at 90% capacity factor could be as follow as it will produce 44.15×10^9 KWh:

Simple annual pay-back capital cost according to Kok (2009) is calculated by the following equation:

$$\text{Annual Payment} = \text{Principle payment} \times \frac{\mathrm{i}}{1-(1-\mathrm{i})^{\mathrm{n}}} \quad (7\text{-}3)$$

Where i is the interest rate which will be assumes as 5% as mentioned in section "7.5". And n is the project life cycle which is 60years. Noteworthy, the commercial NPPs are usually licensed to operate for 40 years which can be extended to extra 20 years as what happened on 52 NPPs in USA in 2009, this is discussed in sub-section "3.5.2". According to ENEC (2010b), the UAE have designed the NPP for a continuous 60years of operation.

So, annual payment of the UAE NPP by using the equation (7-3) is almost $ 1,048,294,727

Therefore, the amortized capital cost per KWh is:

$\$1{,}048{,}294{,}727/44.15 \times 10^9$ kwh = 2.37 cents / KWh

The fixed operation cost (not including fuel) will be (assumed $85 million a year) as a range according to Kok (2009): $\$85{,}000{,}000/ 44.15 \times 10^9$ kwh which equals to 0.19 cents / KWh

Fuel cost is assumed to be 0.64 cents / KWh as per Harvey (2010)

Disposal waste in excluded as it will not be disposed within the UAE but, will be returned back to fuel supplier.

The total cost could then be 3.2 cents/KWh which equals to almost Fills 11.8 (Emirati currency) on currency conversion rate of Dhs 3.68 for $1. This estimated cost is also confirmed by the ENEC (2010b) as the mentioned that the KWh electricity from nuclear power will cost almost one third the current cost of electricity from conventional energy sources which is around Fills 30 according to ADWEC (2009).

Per KWh cost is also called "the levelized cost of electricity" which has to be charged to the consumer to pay back the investment expenditures. This can be also calculated via the following equation (Harvey, 2010):

$$C_{elec} = \frac{(CRF+I)\ C_{cap} + OM_{fixed}}{8760CF} + OM_{variable} + C_{fuel} \qquad (7\text{-}4)$$

Where CRF is the factor of cost recovery, I is the annual insurance payment (proportion of capital cost), C_{cap} is the capital cost of NPP, OM_{fixed} is the annual fixed O&M ($/kw/yr), $OM_{variable}$ is variable O&M cost ($/kwh), CF is the capacity factor, and C_{fuel} is the cost of fuel to generate electricity.

Table (7-3) represents cost estimates of electricity using equations (7-1, 7-2, and 7-4), subject to assumptions in Table (7-2). The construction period is assumed to be 5 years. It appears that nuclear electricity costs almost 5 to 34 cents/KWh depending on the capital cost and investment's rate of return. However, the estimated costs vary from 4 cents/KWh to 24 cents/KWh for more recent estimates which are tending to be at higher cost (Harvey, 2010). This cost increase is due to such factors of increasing initial cost of construction, increasing fuel price, and cost of uncertainty.

Table 7-2: Assumptions for computing the future nuclear electricity cost, (Harvey, 2010)

Parameters	Assumed Value
Construction period	5 years, distributed as 10%, 20%, 30%, 25% and 15% of the total cost over years 1 to 5 respectively.
Owner's cost	20% of EPC cost
Decommissioning cost	Equal to construction cost, discounted at 3%/yr
Plant lifespan	40 years
Capacity factor	0.85*
Fixed O&M	$60/KW/yr
Variable O&M	0.05 cents/KWh
Insurance and Liability	0
Fuel Cost	$2000/kg
Burn-up	40MWd/kg
Thermal efficiency	0.328

* The capacity factor of the UAE NPP is 90% rather than 85% of Harvey (2010) which means more efficient energy supply.

Table 7-3: Illustrative costs of nuclear electricity for various capital costs subject to assumptions in Table (7-3), (Harvey, 2010)

Overnight EPC cost ($/kw)	EPC + financing + owner's costs ($/kw)	Discounted decommissioning cost ($/kw)	Cost of Electricity (cents/kwh)	
			Without decommissioning	With decommissioning
		5%/yr cost of capital		
2,000	2696	591	4	4.5
4,000	5393	1183	6.1	7
6,000	8088	1774	8.2	9.6
8,000	10785	2366	10.3	12.2
		10%/yr cost of capital		
2,000	3022	591	6.1	6.9
4,000	6044	1183	10.2	11.8
6,000	9066	1774	14.4	16.8
8,000	12088	2366	18.5	21.8
		15%/yr cost of capital		
2,000	3380	591	8.7	9.9
4,000	6760	1183	15.6	18
6,000	10140	1774	22.4	26
8,000	13520	2366	29.2	34

7.7 CARBON EMISSION TRADING AND COST OF CO_2 EMISSION

Cap-and-trade (also as emission trading) is a market-based approach which provides economic incentives to control CO_2 emission or pollution by reducing and limiting further emissions and pollutions from the pollutant. Usually a limit or “cap” is set-up by government or international firm like Kyoto protocol on the allowed amount of CO_2 emission. This cap is sold to certain specialized firms in a form of emission permits which determine the specific allowed volume of emissions – usually per year. However, these specialized firms have to hold specific number of permits (or carbon credits) which is equal to their emissions. This number is equal or less than the cap. From here, firms the demand an increasing emission permits must buy them from other firms that consumed less permits than allocated for them (Stavins, 2001).Trade is thus referred to as the transfer of permits while the buyer pays a charge for CO_2 emissions and the seller gets rewards for reducing emission. Therefore, theoretically, reducing CO_2 emission will be favourable at the lowest cost to nations and societies (Montgomery, 1972).

The CO_2 emission from conventional energy sources can be limited in two ways (and thus limit oil and gas use): via applying carbon taxes or quotas “i.e. a cap-and-trade system”, and the preferred option which depends upon particular economic conditions where these ways are implemented. The quota system was calculated by economists like Weitzman (1974). Recently, taxes are being favoured as superior to quotas, mostly in dynamic economic climates, in order to allow more flexibility in the existence of uncertainty. Cap-and-trade systems would be an appropriate approach to mitigate climate change. These systems are currently preferred by the Canadian Federal Government as well as the United States, as reflected in the Act of American Clean Energy and Security in 2010 (Davidson, 2010).

The price of electricity from conventional energy sources can, therefore, be raised by $30 per tonne of carbon emitted for example as a carbon tax according to Davidson (2010) and Houston (2010). Alike, MacCracken et al. (2010) mentioned that the CO_2 marginal cost could be $26 per tonne of carbon in 2010 if a global system of mitigating CO_2 emissions could be implemented quickly and effectively. Since oil and gas burning emit CO_2, such a tax would increase the cost of producing electricity by conventional energy sources. According to Houston (2010), this such a mechanism will probably be a useful tool to limit CO_2 emissions. This tax will furthermore favour the option of nuclear energy.

7.8 COST COMPARISON OF POWER SOURCES

The current pricing forecasts indicates that oil and gas generated electricity might be more economically viable in the absence of fiscal mechanisms like carbon tax or quota system. The future implementation of such fiscal mechanisms would be encouraging for an eventual carbon market to mitigate climate change. Therefore, applying a carbon tax in cap and trade system depends on the average amount of CO_2 emitted from conventional power plants. As influenced by Chapter 5 in sub-sections "5.5.2" and "5.5.3", 1 KWh of oil generated electricity produces an average of 1,194 g CO_2 , and 1 KWh of natural gas generated electricity produces an average of 824 g CO_2 .

According to BP (2010), 1 barrel of oil costs, internationally, $61.39. The 1 barrel of oil is equivalent to 0.1364 metric tonne meanwhile; the cost of 1 tonne of oil is $\$61.39/0.1364\ \text{ton}$ which equals $450.07 / tonne of oil. Since the 1 tonne of oil produces 4,400 KWh of electricity then, the cost of oil generated electricity per KWh is $\$450.07/4{,}400\ \text{KWh}$ which equals around 10.23 cents / KWh electricity from oil. Alike, 1 million BTU of natural gas costs $9.06. Since the 1 KWh is equivalent to 3,412 BTU then, the cost of KWh electricity from gas is $3{,}412\ \mathrm{BTU} \times \$9.06/\ 1000{,}000$ which equals 3.1 cents / KWh electricity from gas. As these are international prices they will be used as a ratio to estimate the exact costs of local oil and gas generated electricity in the UAE as follow:

The total cost of electricity (oil and gas) in UAE is 30 Fills which equals to 8.15 cents as influenced from section “7.6”. This cost is a total of 66.5% of gas and 33.5% of oil so; the following two equations will be used to estimate the local costs of oil and gas:

$$33.5\%\ \mathrm{oil} + 66.5\%\ \mathrm{gas} = 8.15\ \mathrm{cents} \qquad (7\text{-}5)$$

$$\binom{\mathrm{oil}}{10.23} \times \binom{\mathrm{gas}}{3.1} \rightarrow 10.23\mathrm{gas} = 3.1\mathrm{oil}\ \rightarrow \mathrm{gas} = 3.1\mathrm{oil}/10.23 \qquad (7\text{-}6)$$

By applying the equations (7-5) and (7-6), the estimated costs of electricity generation from oil is 15.2 cents per kwh and 4.6 cents per kwh whereas it is 3.2 cents/KWh for nuclear – as calculated in section “7.6”. By applying a \$30 per tonne of CO_2 emission as discussed in seb-section “7.7” and from the known rates of CO_2 emission from oil and gas in generating electricity, the cost of conventional energy sources in the UAE would increase as follow: The CO_2 tax for 1 KWh of oil generated electricity is:

$$(\$30\mathrm{tax\ \ for\ tonne\ CO2}\ \times 1194\ \mathrm{gCO2/KWh} \times 100\mathrm{cents})/(1000{,}000\ \mathrm{tonne}) \qquad \cong 3.6\ \mathrm{cents/KWh} \qquad (7\text{-}7)$$

Therefore, the oil generated electricity should cost 15.2 cents plus 3.6 cents which equals to 18.8 cents/KWh. Similarly, but by changing the CO_2 emission rate in equation (7-7) to 824 gCO_2 /KWh, gas generated electricity would cost 7.1 cents/KWh.

Accordingly, by applying a simple mathematical process, the proposed nuclear plant of 5,600 MWe in the APR 1400 scenario in Chapter “6” is displacing 44.15 TWh of oil from 2020 onward which means a saving of (18.8 cents of oil – 3.2 cents of nuclear) X 44.15TWh = $ 6.88 billion annually while $(1\,\mathrm{TWh} = 10^9\mathrm{KWh})$. There is a cost of inflation and interest rate should also be added to this saving in addition to the predicted increase in the future oil prices. Moreover, the saving of 51.58 million tone of CO_2 as illustrated in Fig. (6-6) can be traded as an investment for extra income to the local economy.

Another example for instance, the proposed scenario of CEE NES (8NPPs) starts supplying an 11.04 TWh of oil by 2017 to revoke the oil energy from electricity generating scheme by 2021 and thereafter starts displacing gas energy from 2022. The saving in displacing gas energy is (7.1 cents of gas – 3.2 cents of nuclear) which equals 3.9 cents / KWh. similar to the precedent estimation or the APR 1400 scenario. Figure 7-3 and Table 7-4 represent the yearly saving of nuclear energy in generating electricity between the years 2017 and 2050. This estimation excludes the cost of inflation, interest rate, and future increase in oil and gas prices.

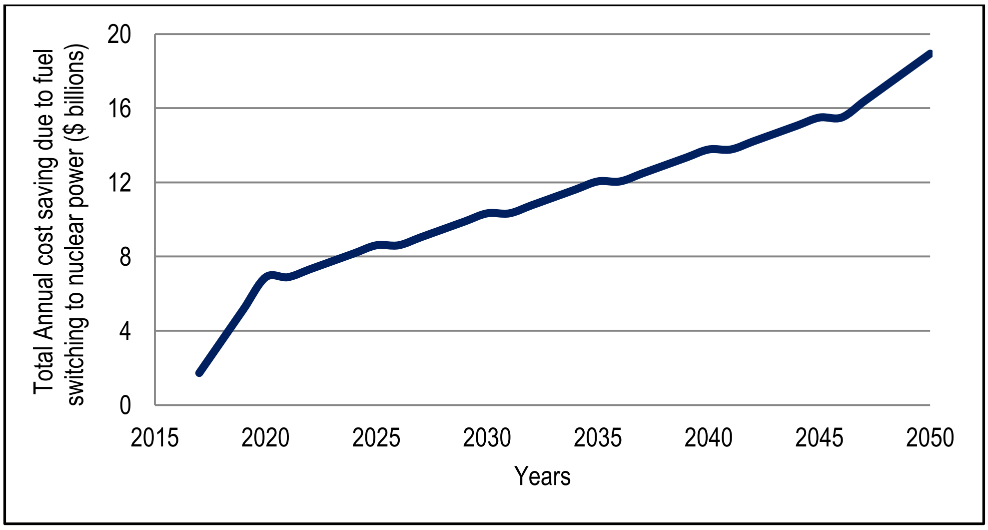


Figure 7-3: Annual cost saving by nuclear energy in 8NPPs scenario as it displaces oil and gas energy.

Table 7-4: Annual cost saving by nuclear energy in 8NPPs scenario as it displaces oil and gas energy according to the shown ammounts along with the amount of CO_2 which can be traded.

Year	Displaced Oil energy (TWh)	Displaced Gas energy (TWh)	Annual cost Saving by nuclear ($ billion)*	CO_2 saving which can be traded (Mton CO_2)
2017	11.04	0.00	1.72	12.90
2018	22.08	0.00	3.44	25.79
2019	33.11	0.00	5.165	38.69
2020	44.15	0.00	6.88	51.59
2022	44.15	11.04	7.31	63.07
2025	44.15	44.15	8.60	92.45
2030	44.15	88.30	10.33	133.44
2035	44.15	132.45	12.05	175.68
2040	44.15	176.60	13.77	219.43
2045	44.15	220.75	15.49	265.02
2050	44.15	309.05	18.94	348.10

* Cost saving due to fuel switching (i.e. using nuclear energy instead of oil and gas)

Table (7-5) shows comparison of energy sources along with the factors involved in the total cost to generate electricity. Construction cost is the most ambiguous due to the inflation rate of used material in recent years. For fuel cost, natural gas costs for gas turbine-combined cycle (GTCC) plants are the most volatile (Kok, 2009).

Table 7-5: Comparative costs of generating electricity in cents/KWh, (Kok, 2009)

Plant Type	Capacity factor (%)	Capital cost (Cents)	Operating cost (Non fuel) (Cents)	Fuel costs (Cents)	Total (Cents)	Carbon tax (Cents)
Nuclear	90	2.9	1.1	0.8	4.8	-
Coal (pulverized)	95	1.9	0.7	1.5	4.1	-
GT/CC natural gas	95	1.5	0.7	4	6.2	-
Solar (photovoltaic)	45	9	0.5	0	9.5	-
Wind	30	6	0.5	0.5	7	-
UAE NPP *	90	2.37	0.19	0.64	3.2	-
UAE Oil energy *	35%	-	-	-	15.2	3.6
UAE Gas energy*	-	-	-	-	4.6	2.5

* These cases are estimated by the researcher in this chapter under sections "7.6" and "7.8"

Alike to APR 1400 and 8NPPs scenarios, the annual cost savings and traded CO_2 amounts can be estimated for the other (NES) nuclear scenarios, the (RES) renewable energy scenarios as well as the optimum scenario estimates. The amounts of CO_2 which can be traded from the (CCSS) carbon capture scenarios can also be estimated in the same way. However, the presented example of the 8NPPs adds significant value to encourage the choice of nuclear energy integration in the electricity scheme in the UAE. Hence, the nuclear energy is economically favourable alongside to its environmental complimentary feature in mitigating CO_2 emission from the built environment in the UAE.

CHAPTER 8: CONCLUSION AND RECOMMENDATIONS

8.1 CONCLUSION

Global warming and climate change have increased to threatening levels in recent years. Carbon dioxide is a foremost GHG contributor to global warming while the current concentration of CO_2 exceeds the natural fluctuation over the past 650,000 years. The CO_2 emission in the UAE has jumped around two and half times from 1990 to 2008. Electricity sector in the UAE depends solely on fossil fuel (oil and gas) which is the primary responsible source of CO_2 emission. Although, the UAE is classified by the Kyoto protocol as a non-Annex I country which means a permit to emit further CO_2 in the following few years, the UAE has willingly decided to commit to the Kyoto protocol which they signed in 2005 and reduce the country's CO_2 emissions. Therefore, the UAE has decided to approach nuclear energy of 5,600MWe NPP as a feasible low-carbon energy source to displace conventional energy, meet the increasing energy demand, and to mitigate CO_2 emissions. Hence, this founded an encouraging motivation to evaluate the effectiveness of the proposed nuclear energy and its role in mitigating CO_2 emissions from the built environment of the UAE by the UAE, further aggressive scenarios of switching to nuclear energy proposed in the research to verify its scalable effects in mitigating the emissions. This goal was the main engine of the dissertation which achieved thereafter in the due course Chapters.

Simulation research methodology is used in the dissertation as found appropriate to serve the goal of the dissertation the next forty years. MESSAGE software from the international atomic energy agency was used to run the simulation process. Simulation research parameters such as Carbon Dioxide Emission Rates, Nuclear Energy, Renewable Energy, Carbon Capture and Storage, were explained and configured in the simulation. The research simulates three main cases (Business As Usual, the UAE proposed APR 1400, and Clean Energy Era of three main scenarios and twelve sub-scenarios from 2010 to 2050.

The results were interpreted for each scenario individually. Electricity demand in the BAU scenario was estimated at an annual growth of 9% after 2020 versus 4% for the other scenarios. The APR 1400 scenario could emit 16.6% of the CO_2 at the BAU case. The CEE (8NPPs) scenario found to be the least CO_2 emitting option of almost 6.1% of the CO_2 emission at the BAU and 36.7% of the CO_2 emission at the UAE proposed scenario (APR 1400). CCS significantly mitigated CO_2 emissions between the years 2017 and 2024 and RES (35%) relatively mitigated CO_2 emission from 2035 to 2050. However, both of them did not compete with 8NPPs scenario till the 2050. The nuclear energy at the four CEE nuclear scenarios found an appropriate option to mitigate CO_2 emissions from electricity sector which ultimately lessening the global warming and climate change impacts of the built environment in the UAE. Therefore, this indicates that the nuclear energy is more competitive source of energy than other sources of energy. For an optimum option, a collection of the three CEE extreme scenarios would nearly diminish the CO_2 emission from the UAE built environment by 2050.

Finally, economic analysis was conducted in the study to examine the economic feasibility of nuclear energy. The cost of KWh nuclear-electricity found 3.2 cents/KWh versus 18.8 cents/KWh for oil-electricity and 7.1 cents/KWh for gas-electricity after applying a carbon tax system. The cost saving by (8 NPPs) scenario in 2050, due to fuel switching to nuclear energy, is almost $18.94 billion. Furthermore, the amounts of CO_2 emission that saved by using nuclear energy can be traded as an investment asset for the country. Hence, nuclear energy is economically viable in addition to its environmental viability in mitigating CO_2 emissions so; it should be extensively used as an integrated source to generate electricity and to displace conventional energy sources which are environmentally harmful and not economically competitive.

8.2 RECOMMENDATIONS

At this stage, the research has achieved its intended purpose to verify the potential role of nuclear energy in mitigating CO_2 emissions of the built environment in the United Arab Emirates. The results were represented, discussed and compared with other relative works and data. Therefore, the following recommendation should be a vital tool to constitute guide lines to future researches:

- Deregulations of electricity industry can be studied as a vital tool to introduce commercial and private investors which could encourage alternative energy sources at variant scales such as nuclear Privatization (i.e. competitive market for expertise nuclear companies), renewable energy at individual self-sufficiency (i.e. wind mills for factories and farms and solar cells for housing).
- Carbon capture and storage found a functional measure to decrease the overall CO_2 emission from power plants therefore, a study is recommended to investigate the economic viability of increasing CCS reservoirs. Furthermore, Can these reservoirs be upgraded to form an independent business by capturing CO_2 from other countries at certain charges as an additional system to carbon taxes, Carbon taxes or quota (i.e. cap-and-trade system) and carbon trading?
- An integration of advanced nuclear reactors such as the IV generation and Fusion technology could be researched to investigate its mitigation to eco-environment and diminishing CO_2 emissions.
- Transparency is one of the UAE nuclear policies. This policy can be surveyed within a study of the nuclear social impacts therefore, the interaction with the public can be measured clarified in terms of involvement in decision making, site selection, design criteria, nuclear satisfaction and awareness, and so forth.

- The cultural impacts of nuclear energy can be researched to examine its influence on the religion, customs and traditions, national enthusiasm, etc

- The actual capital cost should be known precisely as the signed fixed price contract with the prime contractor (Korea Electric Power Corporation Team as Prime Contractor) might be higher by 2020 similar to Olkiluoto site in Finland which is discussed in section "7.2" of Chapter 7. Furthermore, the currently contracted price includes fuel filling for the first and a half year and other operational related items as mentioned by AlQahtani (2010) which could lead to an estimation conflict.

- Locally measured CO_2 emissions by special instruments would lead to more accredited results as almost the entire available data are estimated according to Kyoto Protocol and IEA (2010). Therefore, a case study could be reformed, at a comparatively longer time, by using real measurements of CO_2.

- Certain upper limit of CO_2 emission for the UAE has to be determined by Kyoto Protocol for referenced comparisons which also assist in selecting the right strategy accordingly in the right time.

- Further extensive integration scenarios that using higher capacities of nuclear power could be researched of its economical viability for longer targeted periods of simulation (i.e. the year 2100). It has to discuss the decommissioning of the first current plant by 2077, waste disposal, transportation, inflation cost and interest rate cost, and other relative economic issues.

- Mitigating CO_2 emissions from UAE transportation could be studied as transportation is responsible for almost 17.2% of the total CO_2 emission. Fuel switching options can investigated (i.e. Hybrid engines, nuclear-electrical operating vehicles).

References and Bibliographies

Abdul-Salam, R. (2009). *Nuclear Energy and sustainable goals in the Gulf Council countries.* Abu Dhabi: The Emirates Center for Strategic Studies and Research. [Arabic]. pp25-36.

Abu-Khader, M. (2009). *Recent advances in nuclear power: A review.* Progress in Nuclear Energy 51 (2009) 225–235, Elsevier Ltd.

Adamantiades, A., and Kessides, I. (2009). *Nuclear power for sustainable development: Current status and future prospects.* Energy Policy 37 (2009) 5149–5166, Elsevier Ltd. [pdf].

ADWEC. (2010). *ADWEC Winter 2009 / 2010 Demand Forecast.*, from Abu Dhabi Water & Electricity Company (ADWEC) [online]: [accessed 31 October 2010]. Available at: http://www.adwec.ae/documents/ppt/2074005133_adwec%20meed%20march%202010%20arabian%20power%20water%20summit%20final%20submitted%20to%20meed.pdf

AlQahtani, F. (2010). Capital cost of the UAE NPP. (T. researcher, Interviewer)

Andersen, M. (2009). *A Copenhagen Accord it is* [online]. Denmark. [accessed 20 December 2010]. Available at: http://www.denmark.dk/en/menu/Climate-Energy/COP15-Copenhagen-2009/Selected-COP15-news/A+Copenhagen-Accord-it-is.htm

ANS. (n.d). *Nuclear Power: A Sustainable Source of Energy.* American Nuclear Society. [pdf].

Apt, J., Keith, D. W., and Morgan, M. G. (2006). *Promoting Low-Carbon Electricity Production* [online]. Issued in Science and Technology: [accessed 02 November 2010]. Available at: http://www.issues.org/23.3/apt.html

Atieno, O. (2009). *An Analysis of the Strengths and Limitations of Qualitative and Quantitative Research Paradigms. Problems of Education in the 21st century. Vol. 13, p13-18, 6p.*, EBSCOHost database.

Barnaby, F., and Kemp, J. (2007). *Secure Energy? Civil Nuclear Power, Security and Global Warming.* London: Oxford Research Group.

Bates, B., Kundzewicz, Z. W., Wu, S., and Palutikof, J. (2008). Climate Change and Water. Technical Paper of the Intergovernmental Panel on Climate Change, IPCC Secretariat, Geneva.

BBC. (n.d). *Climate change glossary.* [online]. [accessed 28 October 2010]. Available at: http://news.bbc.co.uk/2/hi/science/nature/8314501.stm

BEE. (n.d). *Energy Scenario .* from The National Certification Examination for Energy Managers and Energy Auditors, Bureau of Energy Efficiency [online]. [accessed 30 October 2010]. Available at: http://www.em-ea.org/Guide%20Books/Book-1/1.1%20Energy%20Scenario.pdf

Bennet, R. (2007). *The Generation IV International Forum. A Partnership for Sustainable Nuclear Energy Systems.* Idaho National Laboratory, US. [pdf].

Bob, W. (2009). *Lise Meitner (1878–1968): Protactinium, Fission, and Meitnerium* [online]. [accessed 05 May 2010]. Available at: http://www.weizmann.ac.il/ICS/booklet/21/pdf/bob_weintraub.pdf

BP. (2010). *BP Statistical Review of World Energy.* British Petrolium. [pdf]

Brain, M., and Robert, L. (2000). *How Nuclear Power Works. [online].* [accessed 11 May 2010]. Available at: http://science.howstuffworks.com/nuclear-power3.htm#

Bruhn-Tysk, S., and Eklund, M. (2001). *Environmental impact assessment - a tool for sustainable development? A case study of biofuelled energy plants in Sweden.* Sweden: Elsevier Science Inc. 22 (2002) 129–144.[pdf]

Carlisle, T. (2010). *Abu Dhabi may use debt to finance nuclear plant.* [online]. [accessed 21 December 2010]. Available at: http://www.thenational.ae/business/energy/abu-dhabi-may-use-debt-to-finance-nuclear-plant

CCC. (2009). *The Road to Copenhagen* [online]. Copenhagen Climate Council. [accessed 20 December 2010]. Available at: http://www.copenhagenclimatecouncil.com/get-informed/climate-negotiations-updates.html

CHF. (2005). *Otto Hahn, Fritz Strassmann, and Lise Meitner.* Chemical Heritage Foundation [online]. [accessed 05 May 2010]. Available at: http://www.chemheritage.org/classroom/chemach/atomic/hahn-meitner.html

CNSC. (2007). *Site Evaluation for New Nuclear Power Plants.* Canada: The Canadian Nuclear Safety Commission. [pdf]

Cooper, M. (2009). *The Economic of Nuclear Reactors: Renaissance or Relapse?* [online]. Vermont Law School. [accessed 21 December 2010]. Available at: http://www.vermontlaw.edu/Documents/Cooper%20Report%20on%20Nuclear%20Economics%20FINAL%5B1%5D.pdf

Davidson, D. (2010). *Nuclear Energy In Alberta: What you Need to Know.* Alberta: University of Alberta.[pdf]

DIE-G. (2010). *Population predictions of Wadi Elhelow and adjacent villages for 2010.* Sharjah: Department of Information and E-Government.

DOE. (1996). *The Changing Structure of the Electric Power Industry.* Washington, DC. : Department Of Energy. DOE/EIA-0562(96). pp110.

DOE/NE. (n.d). *Science and Technology.* Washington, P4-12: Department Of Energy / Office of Nuclear Energy.

Doosan. (2009). *Nuclear Power Plants* [online]. Doosan Heavy Industries and Construction. [accessed 09 December 2010]. Available at: http://www.oecd-nea.org/science/smins2/documents/DoosanHeavyIndu-NUCLEARPOWERPLANT.pdf

DTI. (2006). *Policy Framework for New Nuclear Build* [online]. Department of Trade and Industry: [accessed 15 December 2010]. Available at: http://webarchive.nationalarchives.gov.uk/+/http://www.berr.gov.uk/files/file31931.pdf

ECSSR. (2009). *Nuclear Energy in the Gulf. .* Abu Dhabi. pp24-63: the Emirates Center for Strategic Studies and Research (ECSSR).

EIA. (2006). *World marketed energy consumption by region*[online]. [accessed 02 November 2010]. Available at: http://www.eia.doe.gov/neic/press/images/06-03-1.gif

EIA. (2009). *Country Analysis Briefs, United Arab Emirates*[online]. U.S Energy Information Adminstration: [accessed 13 December 2010]. Available at: http://www.eia.doe.gov/cabs/UAE/pdf.pdf

Embassy-of-UAE. (2009). *The UAE Energy and Climate Change* [online]. Embassy of The United Arab Emirated in Washington DC. [accessed 31 October 2010]. Available at: http://www.uae-embassy.org/uae/energy/climate-change

ENEC. (2008). *Policy of the United Arab Emirates on the Evaluation and Potential Development of Peaceful Nuclear Energy.* Abu Dhabi: Emirates Nuclear Energy Corporation.

ENEC. (2010a). *Subject: Request for a limited construction licence for manufacturing and assembling Nuclear safety related equipments, UAE Nuclear Power Plants Units 1, 2, 3 and 4* [online]. Emirates Nuclear Energy Corporation. [accessed 10 December 2010]. Available at: http://www.enec.gov.ae/images/pdfs/en/limited-construction-license-for-manufacturing-and-assemblin.pdf

ENEC. (2010b). *Emirates Nuclear Energy Corporation Files License application and environmental assessment for UAE civil Nuclear Power Program* [online]. Emirates Nuclear Energy Corporation. [accessed 10 December 2010]. Available at: http://www.enec.gov.ae/images/pdfs/en/enec-preferred-site-application-en.pdf

ENEC. (2010c). *ENEC Receives License Approvals for Work at Braka, Preferred Site for UAE Nuclear Power Plants* [online]. Emirates Nuclear Energy Corporation. [accessed 10 December 2010]. Available at: http://www.enec.gov.ae/news/enec-receives-license-approvals-for-work-at-braka-preferred-site/

ENEC. (2010d). Emirates Nuclear Energy Corporation Forum. Abu Dhabi: Emirates Nuclear Energy Corporation.

ENEC. (n.d). *Timelime* [online]. Emirates Nuclear Energy Corporation. [accessed 10 December 2010]. Available at: http://www.enec.gov.ae/timeline/

EPA. (2007). *Recent Climate Change: Atmosphere Changes.* Retrieved 10 29, 2010, Climate Change Science Program [online]. United States Environmental Protection Agency. [accessed 29 october 2010]. Available at: http://www.epa.gov/climatechange/science/recentac.html

ExxonMobil. (2009). *Outlook for Energy, A View to 2030. SP-124.* Texas.[pdf]

Finn, P. (2005). *Chernobyl's Harm Was Far Less Than Predicted, U.N. Report Says. Washington Post Foreign Service* [online]. [accessed 06 May 2010]. Available at: http://www.washingtonpost.com/wp-dyn/content/article/2005/09/05/AR2005090501144.html

Fishbone, L., and Abilock, H. (1981). *MARKAL, a linear-programming model for energy systems analysis: technical description of the BNL version.* Energy Research 5, 353–375.[pdf]

Flavin, C. (2008). *Low-Carbon Energy: A Roadmap.* Danvers, USA: Worldwatch Institute, 2008. ISBN 978-1-878071-87-3 [pdf].

GIF. (2001). *Charter of the Generation IV International Forum.* Generation IV International Forum. [pdf].

Griffith, C., and Rossenfeld, C. (2008). *Controlled Nuclear Fission.* Atomic Archive [online]. [accessed 10 May 2010]. Available at: http://www.atomicarchive.com/Fission/Fission4.shtml

Groat, L., and Wang, D. (2002). *Architectural Research Methods.* United States of America. (346). John Wiley & Sons.

Gürpinar, A. (2010). *An Overview of Site Survey, Site Selection and Site Evaluation for Nuclear Installations.* Vienna: International Atomic Energy Agency.

Hardly, J. (2001). *Climate change: causes, effects, and solutions.* England: John Wiley and Sons Ltd. Pp 3 - 20.

Harvey, L. D. (2010). *Energy and the New Reality 2, Carbon-Free Energy Supply.* London: Earthscan Ltd.

Houghton, J. (2004). Global Warming. Camridge: 3rd ed., The Press syndicateof the university of Cambridge, UK.

Houston. (2010). *Researchers calculate the cost of CO2 emissions, call for carbon tax* [online]. Rice University. [accessed 29 December 2010]. Available at: http://www.rice.edu/nationalmedia/news2010-07-07-natgas.shtml

IAEA. (1995). *Electricity, health, and the environment: The DECADES project.* Vienna: International Atomic Energy Agency, IAEA BULLETIN, 2/1995. [pdf]

IAEA. (1997). *History of the International Atomic Energy Agency.* International Atomic Energy Agency [online]. [accessed 05 May 2010].

Available at: http://www-pub.iaea.org/MTCD/publications/PDF/Pub1032_web.pdf

IAEA. (1999). *Evaluating and Improving Nuclear Power Plant Operating Performance* [online]. [accessed 31 December 2010]. Available at: http://www-pub.iaea.org/MTCD/publications/PDF/te_1098_prn.pdf

IAEA. (2002a). *Time-line of Nuclear Power in The World. Unpublished work* [online]. [accessed 06 May 2010]. Available at: International Atomic Energy Agency: http://www.iaea.org/About/Policy/GC/GC48/Documents/gc48inf-4_ftn3.pdf

IAEA. (2002b). *Workshop on Advanced Nuclear Reactor Safety Issues and Research Needs* [online]. International Atomic Energy Agency. [accessed 01 January 2011]. Available at: http://books.google.ae/books?id=UndUTe_nAmAC&pg=PA132&lpg=PA132&dq=APR1400+Nuclear+Island&source=bl&ots=_wWMGvDPCB&sig=_lbfNdMbZWH5WCWA2zDk46q2U00&hl=en&ei=tzIeTeSaCYPtrAexuaTLCw&sa=X&oi=book_result&ct=result&resnum=1&ved=0CBQQ6AEwAA#v=snippet&q=MCR&f=fal

IAEA. (2004a). *From Obninsk Beyond: Nuclear Power Conference Looks to Future* [online]. International Atomic Energy Agency. [accessed 05 May 2010]. Available at: http://www.iaea.org/NewsCenter/News/2004/obninsk.html

IAEA. (2004b). *Energy supply options for Lithuania, A detailed multi-sector integrated energy demand, supply and environmental analysis.* Vienna: International Atomic Energy Agency. IAEA-TECDOC-1408.

IAEA. (2007a). *Managing the first nuclear power plant project* [online]. International Atomic Energy Agency. [accessed 01 December 2010]. Available at: http://www-pub.iaea.org/MTCD/publications/PDF/te_1555_web.pdf

IAEA. (2007b). *MESSAGE, Model for Energy Supply Strategy Alternatives and their General Environmental Impacts, User Manual.* International Atomic Energy Agency. [pdf]

IAEA. (2008). *Guidance for the Application of an Assessment Methodology for Innovative Nuclear Energy Systems, INPRO Manual — Overview of the Methodology.* Vienna: International Atomic Energy Agency, IAEA-TECDOC-1575 Rev. 1. [pdf]

IAEA. (2010). *Power Reactor Information System* [online]. International Atomic Energy Agency. [accessed 18 May 2010]. Available at: http://www.iaea.org/pris/

IAEA. (n.d). *Sustainable Development, Nuclear power advantages* [online]. International Atomic Energy Agency. [accessed 16 May 2010]. Available at:
http://www.iaea.org/Publications/Booklets/Development/develeven.html

IEA. (2006). World energy outlook 2006. . International Energy Agency, OECD Publication Service, OECD, Paris. [pdf]

IEA. (2010). *IEA Statistics. CO2 emissions from fuel consumption Highlights.* France: International Energy Agency, 2010 edition. [pdf]

IME. (2009). *Mitigation, Adaptation and Geoengineering* [online]. Institution of Mechanical Engineers. [accessed 13 December 2010]. Available at: http://www.imeche.org/about/keythemes/environment/Climate+Change/MAG

IPCC. (1997). *The Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories.* Paris: Intergovernmental Panel on Climate Change, IPCC/OECD/IEA.

IPCC. (2007a). *Chapter 1: Historical Overview of Climate Change Science.* Retrieved 10 29, 2010, from http://www.ipcc.ch/pdf/assessment-report/ar4/wg1/ar4-wg1-chapter1.pdf

IPCC. (2007b). *Summary for Policymakers. In: Climate Change 2007: The Physical Science Basis. Contribution of Working.* Cambridge University Press, Cambridge, United Kingdom.

IPCC. (2007c). *Climate Change 2007: Synthesis Report, 4. Adaptation and mitigation options* [online]. IPCC Fourth Assessment Report. [accessed 31 October 2010]. Available at: http://www.ipcc.ch/publications_and_data/ar4/syr/en/spms4.html

Ismail, M. (2005). *Quantitative Research Methodology* [online]. [accessed 22 March 2010]. Available at: http://www.scribd.com/doc/98295/Quantitative-Research-Methodology

IWS. (2010). *Internet Usage in the Middle East* [online]. Internet World Stats, usage and population statistics: [accessed 18 December 2010]. Available at: http://www.internetworldstats.com/stats5.htm

Jacobs, R., and Haber, S. (2003). *Organizational processes and nuclear power plant safety* [online]. Science Direct. [accessed 28 December 2010]. Available at: http://www.sciencedirect.com/science?_ob=ArticleURL&_udi=B6V4T-481DTF1-3R&_user=10&_coverDate=12%2F31%2F1994&_rdoc=1&_fmt=high&_orig=search&_origin=search&_sort=d&_docanchor=&view=c&_searchStrId=1590662286&_rerunOrigin=scholar.google&_acct=C000050221&_ver

Jenkins, L. (2009). *Fundamentals of Quantitative Research. Suite101,* [online]. [accessed 22 Mar 2010]. Available at: http://academicwriting.suite101.com/article.cfm/fundamentals_of_quantitative_research

Jun, E., WonJoonKim, YongHoonJeong, and SoonHeungChang. (2009). *Measuring thesocialvalueofnuclearenergyusingcontingent valuation methodology.* Energy Policy38(2010)1470–1476, ElsevierLtd.

Kanoh, T. (2006). *Nuclear energy–An essential option for sustainable development of global economy Keynote Speech at Opening Session of ICONE-13.* Nuclear Engineering and Design 236 (2006) 1455–1459, Elsevier, Science Direct. [pdf]

Kaya, Y. (1990). Impact of Carbon Dioxide Emission Control on GNP. *Interpretation of Proposed Scenarios. Paper presented to the IPCC Energy and Industry Subgroup, Response Strategies Working Group, Paris.*

Kok, K. D. (2009). *Nuclear Engineering Handbook.* Boca Raton, USA: Tylor & Francis Group, LLC, pp 727 - 749.

Kurosawa, A. (2000). *Long term Nuclear power Role under CO2 Emissions.* Vol. 37, No. 1-4. pp. 101-106, 2000. Elsevier Science Ltd. [pdf]

Kurosawa, A., Yagita, H., Zhou, W., Tokimatsu, K., & Yanagisawa, Y. (1999). *Analysis of carbon emission stabilization targets and adaptation by integrated assessment model.* The Energy Journal Kyoto Special Issue, 157-175. [pdf]

Laura, W. (2008). *Power and Water in the GCC Provides a Comprehensive Overview of Recent Developments.* Dublin, Ireland: Research and Markets.

Lenzen, M. (2008). Life Cycle Energy and greenhouse gas emissions of nuclear energy: A review. *Energy Conversion and Management. Vol 49,* , 2178 - 2199.

Levine, M., Ürge-Vorsatz, D., Blok, K., Geng, L., Harvey, D., and Lang, S. (2007). *Residential and commercial buildings. In Climate Change 2007: Mitigation. Contribution of Working Group III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change* [online]. [accessed 30 October 2010]. Available at: http://www.ipcc.ch/pdf/assessment-report/ar4/wg3/ar4-wg3-chapter6.pdf

Li, Z. (2009). *Quantitative analysis of sustainable energy strategies in China.* ElsevierLtd, Energy Policy38(2010)2149–2160.

Lidstone, D. (2010). *Demand for electricity soars in Abu Dhabi* [online]. Middle East Buisiness Intelligence. [accessed 31 October 2010]. Available at: http://www.meed.com/supplements/2010/gcc-power-market-report-2010/demand-for-electricity-soars-in-abu-dhabi/3005256.article

LIÉBARD, A., Nahon, C., and Bal, J.-L. (2009). *Worldwide electricity production from renewable energy sources, Eleventh Inventory - Edition 2009* [online]. [accessed 24 December 2010]. Available at:http://www.energies-renouvelables.org/observ-er/html/inventaire/Eng/conclusion.asp

Lillington, J. (2004). *The Furture of Nuclear Power.* Amesterdam: Elsevier Ltd. Google books.

Loa, M. (2010). *Earth's CO2 Home Page* [online]. Mauna Loa Observatory: NOAA-ESRL, powered by Joomla. [accessed 29 October 2010]. Available at: http://co2now.org/

MacCracken, C. N., Edmonds, J. A., and Sands, S. H. (2010). *The Economics of the Kyoto Protocol* [online]. International Association for energy Economics: [accessed 29 December 2010]. Available at: http://www.iaee.org/cn/publications/kyoto.aspx

Martin, A. (1999). *Greenhouse Emissions of Nuclear Power* [online]. [accessed 02 November 2010]. Available at: http://nuclearinfo.net/Nuclearpower/WebHomeGreenhouseEmissionsOfNuclearPower

Masdar. (2010). *Press Release, Masdar signs MOU with the Province of Alberta* [online]. [accessed 01 November 2010]. Available at: http://www.masdar.ae/en/mediaCenter/newsDesc.aspx?News_ID=139&fst=mc&nws=1&MenuID=55&CatID=44

Matsui, K., Ujita, H., and Tashimo, M. (2008). *Role of Nuclear Energy in Environment, Economy and Energy Issues of the 21st century Green House Gas Emission Constraint Effects.* Progress in Nuclear Energy 50 (2008) 97-102, Elsevier Ltd. Science Direct.[pdf]

McCracken, M. (2005). *explain Capacity factor* [online]. TeachMeFinance. [accessed 20 December 2010]. Available at: http://www.teachmefinance.com/Scientific_Terms/Capacity_factor.html

Metz, B., Davidson, O., Coninck, H., Loos, M., and Meyer, L. (2005). *IPCC Special Report on Carbon Dioxide Capture and Storage.* Canada: Intergovernmental Panel on Climate Change.

MMdMA. (2006). *Perfil Ambiental de Espan˜a , Informe basado en indicadores 2006.* Spain: MMA Ministerio de Medio Ambiente.

MoE. (2007). *U.A.E In Figures 2007* [online]. Ministry of Economy. [accessed 15 December 2010]. Available at: http://www.economy.gov.ae/Arabic/EconomicAndStatisticReports/StatisticReports/Documents/Statistic%20Reports/UAE%20in%20Numbers/UAE%20Figures2007.pdf

MoE. (2008a). *Statistic Abstract 2008, ch2-Population and Vital Statics 2008* [online].Ministry of Economy - Central Statistic Department. [accessed 12 December 2010]. Available at: http://www.economy.gov.ae/English/EconomicAndStatisticReports/StatisticReports/StatisticAbstract/Pages/sa2008.aspx

MoE. (2008b). Economic Reports, National Abstract [online]. Ministry of Economy: [accessed 12 December 2010]. Available at: http://www.economy.gov.ae/Arabic/EconomicAndStatisticReports/EconomicReports/Documents/National%20Abstract-Ar/National%20Abstract%202008.pdf

Moenr. (2008). *Final Yearly Statistics Report for electricity and water in UAE, 2003 - 2007.* Abu Dhabi: Ministry of energy.

Molina, M., Zaelke, D., Sarma, K. M., Andersen, S. O., Ramanathan, V., and Kaniaru, D. (2009). *Reducing abrupt climate change risk using the Montreal Protocol and other regulatory actions to complement cuts in CO2 emissions* [online]. Department of Chemistry and Biochemistry, University of California: [accessed 31 October 2010]. Available at: http://www.pnas.org/content/early/2009/10/19/0902568106.full.pdf

Mongillo, M. (2005). *Saving Factors for Geothermal Energ Utilization* [online]. [accessed 12 December 2010]. Available at: http://www.iea-gia.org/documents/SavingsFactorsforGeoEnergyUseMongillo14Jan0523Dec08.pdf

Montgomery, W. (1972). *Markets in Licenses and Efficient Pollution Control Programs, published in 2004* [online]. [accessed 29 December 2010]. Available at: http://www.sciencedirect.com/science/article/B6WJ3-4CYGBY2-PD/2/8497b83217afcb9dd9197f22fb18ac5b

Mourogov, V. M. (2000). *Role of Nuclear energy for Sustainable Development.* Progress in Nuclear Energy, Vol. 37, No. 1-4, pp. 19-24, 2000, Elsevier Science Ltd.

NAP. (1992). *Policy Implications of Greenhouse Warming: Mitigation, Adaptation, and the Science Base* [online]. The National Academy Press. [accessed 20 December 2010]. Available at: http://books.nap.edu/openbook.php?record_id=1605&page=433

NEAC. (2008). *Nuclear Energy: Policies and Technology for the 21st Century.* Nuclear Energy Advisory Committee. [pdf].

NEI. (2009). *World Statistics* [online]. Nuclear Energy Institute. [accessed 19 May 2010]. Available at: http://www.nei.org/resourcesandstats/nuclear_statistics/

NEI. (2010). *No reason why NPPs cannot live beyond 60* [online]. Nuclear Engineering International: [accessed 31 December 2010]. Available at:

http://www.neimagazine.com/story.asp?sectionCode=132&storyCode=2057693

NEImagazine. (2010). *KEPCO wins UAE civil nuclear bid* [online]. Nuclear Engineering International. [accessed 23 December 2010]. Available at: http://www.neimagazine.com/story.asp?storyCode=2055052

Newsroom, I. (2010). *British Energy to extend the life of two nuclear power plants* [online]. Industrial fuel and power. [accessed 31 December 2010]. Available at: http://www.ifandp.com/article/008705.html

Nikitin, A., & Kudrik, I. (2006). *Life Extension of Russian Nuclear Power Plants* [online]. Bellona: [accessed 31 December 2010]. Available at: http://www.bellona.org/filearchive/fil_Bellona_Position_Paper-reactors-Oktober-06.pdf

Nishioka, S., Fujino, J., Kainuma, M., Kanie, N., Hanaki, K., and Fujimoto, J. (2008). *Japan Low Carbon Society Scenarion towards 2050* [online]. National Institute for Environmental Studies. [accessed 02 November 2010]. Available at: http://2050.nies.go.jp/project_e.html

NOAA. (2009). *State of the Climate* [online]. National Oceanic and Atmospheric Administration, National Climatic Data Center. [accessed 28 October 2010]. Available at: http://www.ncdc.noaa.gov/sotc/?report=global&year=2009&month=13

NOAA. (2010). *Trends in Atmospheric Carbon Dioxide* [online]. NOAA Earth System Research Laboratory. [accessed 29 October 2010]. Available at: http://www.esrl.noaa.gov/gmd/ccgg/trends/

Ohnishi, T. (2003). *A method to forecast quantitative variables relating to nuclear public acceptance* [online]. ScienceDirect. [accessed 28 December 2010]. Available at: http://www.sciencedirect.com/science?_ob=ArticleURL&_udi=B6V1R-498W1P1-19W&_user=7381840&_coverDate=07%2F31%2F1992&_alid=159071363

1&_rdoc=3&_fmt=high&_orig=search&_origin=search&_zone=rslt_list_item&_cdi=5681&_sort=r&_st=13&_docanchor=&view=c&_ct=18559&_a

Olivier, J. (2005). Recent trends in global greenhouse gas emissions: regional trends 1970-2000 and spatial distribution of key sources in 2000. *Environmental Science, DOI: 10.1080/15693430500400345.* , 2(2-3), pp. 81-99.

Omoto, A. (2005). *Nuclear Power for Sustainable Development and relevant IAEA activities for the Future.* Great Britain: Progress in Nuclear Energy; gol. 47, No. 1-4, pp. 16-26, 2005, Elsevier Ltd.[pdf]

Othman, I., and Mashfej, H. (2010). *Site Selection in Syria.* Vienna: Syrian Atomic Energy Commission. [pdf]

Otway, H. J., Maurer, D., and Thomas, K. (1978). *Nuclear Power The question of public acceptance.* FUTURES, IPC Business Press.

Pidgeon, N., Henwood, K., Parkhill, K., Venables, D., and Simmons, P. (2008). *Living with Nuclear Power in Britain: A Mixed-methods Study.* Cardiff University and the University of East Anglia.[pdf]

Pomeroy, G., Bari, R., Wonder, E., Zentner, M., Haas, E., Killeen, T., et al. (n.d). *Approaches to evaluation of proliferation resistance of nuclear energy systems* [online]. International Atomic Energy Agency. [accessed 01 December 2010]. Available at: http://www.iaea.org/NuclearPower/Downloads/INPRO/Files/PRADA/approaches.pdf

Psomopoulos, C., Skoula, I., Karras, C., Chatzimpiros, A., and Chionidis, M. (2009). *Electricity savings and CO2 emissions reduction in buildings sector: How important the network losses are in the calculation?* Elsevier Ltd., Energy 35 (2010) 485–490.

Qader, M. (2009). *Electricity Consumption and GHG Emissions in GCC Countries.* Energies 2009, 2, 1201-1213; doi:10.3390/en20401201. [pdf]

Radan, S. (2010). *Strategic Planning Will Focus on Climate Change* [online]. Khaleej Times: [accessed 01 January 2011]. Available at: http://www.khaleejtimes.com/DisplayArticle08.asp?xfile=data/theuae/2010/January/theuae_January408.xml&section=theuae

Rambo, S. (1996). *Three Mile Island. [online].* [accessed 06 May 2010]. Available at: http://www.pbs.org/wgbh/pages/frontline/shows/reaction/readings/tmi.html

Ratanakorn, S. (2010). *Site selection and evaluation in Thailand* [online]. International Atomic Energy Agency. [accessed 01 January 2011]. Available at: http://www.iaea.org/NuclearPower/Downloads/Infrastructure/meetings/2010-06-TM/SITE.SELECTION.AND.EVALUATION.IN.THAILAND.pdf

Rauf, T., and Vovchok, Z. (2009). *A Secure Nuclear Future* [online]. International Atomic Energy Agency. [accessed 31 December 2010]. Available at: http://www.iaea.org/Publications/Magazines/Bulletin/Bull511/51104871013.html

Rhodes, R. (1993). *Chernobyl. Public Broadcasting Service . [online].* [accessed 06 May 2010]. Available at: http://www.pbs.org/wgbh/pages/frontline/shows/reaction/readings/chernobyl.html

Rizzo, P. (2010). *Strategic Environmental Assessment (SEA), Proposed Nuclear Power Plant Complex Western Region, Abu Dhabi Emirate, UAE.* Abu Dhabi: Rizzo Associates Inc. [pdf]

Robinson, S. (2010). *World Future Energy Summit, How to reduce Carbon emmissions: Capture and Store It* [online]. TIME in partnership with CNN. [accessed 31 October 2010]. Available at: http://www.time.com/time/specials/packages/article/0,28804,1954176_1954175,00.html

Rogner, H.-H., Zhou, D., Bradley, R., Crabbé, P., Edenhofer, O., and Hare, B. (2007). *Introduction. In Climate Change 2007: Mitigation. Contribution of Working Group III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change* [online]. [accessed 29 October 2010]. Available at: http://www.ipcc.ch/pdf/assessment-report/ar4/wg3/ar4-wg3-chapter1.pdf

Romeo, L. M., Calvo, E., Valero, A., and Vita, A. D. (2009). *Electricity consumption and CO2 capture potential in Spain.* Energy 34 (2009) 1341–1350, Elsevier Ltd. [pdf]

ROWA. (2005). Environment impacts of the arab oil and gas sector. *In Proceedings of the Arab Regional Conference on Energy for Sustainable Development .* Cairo, Egypt,: UNEP-Regional Office for West Asia.

Salman, A. (n.d). *Nuclear Power Plant Site Selection* [online]. International Atomic Energy agency. [accessed 01 January 2011]. Available at: http://www.iaea.org/OurWork/ST/NE/NEFW/documents/RawMaterials/TM%20JOR/26%20NUCLEAR%20POWER%20PLANT%20SITE%20SELECTION%203.pdf

Samuelsohn, D. (2007). *Bush-led talks spark diplomats' debate over post-Kyoto* [online]. [accessed 29 October 2010]. Available at: http://www.earthportal.org/news/?p=508

Schneider, M., Thomas, S., Froggatt, A., and Koplow, D. (2009). *The World Nuclear Industry Status Report 2009 With Particular Emphasis on Economic Issues* [online]. German Federal Ministry of Environment, Nature Conservation and Reactor Safety: [accessed 21 December 2010]. Available at: http://www.bmu.de/files/english/pdf/application/pdf/welt_statusbericht_atomindustrie_0908_en_bf.pdf

Shultis, J., and Faw, R. (2008). *Fundementals of nuclear science and engineering. 2nd ed.* USA: Taylot & Francis group. pp341-385.

Sime, R. (1997). *Lise Meitner: A Life in Physics. [online].* [accessed 05 May 2010]. Available at:http://www.ucpress.edu/book.php?isbn=9780520208605

Sime, R. (2005). *From Exceptional Prominence to prominent exception. [online].* [accessed 05 May 2010]. Available at: http://www.mpiwg-berlin.mpg.de/KWG/Ergebnisse/Ergebnisse24.pdf

Sims, R. E., Schock, R. N., Adegbululgbe, A., Fenhann, J., Konstantinaviciute, I., and Moomaw, W. (2007). *Energy supply. In Climate Change 2007: Mitigation. Contribution of Working Group III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change* [online]. [accessed 30 October 2010]. Available at: http://www.ipcc.ch/pdf/assessment-report/ar4/wg3/ar4-wg3-chapter4.pdf

Sokolov, Y. (2008). *Competitiveness of Nuclear Energy: IAEA´s Perspective and Study Results for Europe* [online]. International Atomic Energy Agency. [accessed 16 May 2010]. Available at: http://www.iaea.org/NewsCenter/Statements/DDGs/2008/sokolov121108.html

Sovacool, B. (2008). Valuating the greenhouse gas emissions from nuclear power: A critical survey. *Economy Policy, Vol 36* , 2940 - 2953.

Stanton, C. (2010). *Nuclear programme will clean up the skies* [online]. The National. [accessed 08 December 2010]. Available at: http://www.thenational.ae/business/energy/nuclear-programme-will-clean-up-the-skies

Stavins, R. (2001). *Experience with Market-Based Environmental Policy Instruments* [online]. [accessed 29 December 2010]. Available at: http://www.rff.org/documents/RFF-DP-01-58.pdf

Streimikiene, D. (2008). *The role of nuclear energy in Lithuania under various post-Kyoto climate change mitigation regimes.* Energy 33 (2008) 1005–1014, Elsevier Ltd. Science Direct.

Takada, K. (2006). *Microscopic World -3.3 Nuclear Fission* [online]. The World of the Atomic Nucleus. Kyushu University. [accessed 09 May 2010]. Available at: http://www.kutl.kyushu-u.ac.jp/seminar/MicroWorld3_E/MicroWorld_3_E.html

TGOAD. (2008). *The Abu Dhabi Economic Vision 2030* [online]. The Government of Abu Dhabi: [accessed 01 January 2011]. Available at: http://gsec.abudhabi.ae/Sites/GSEC/Content/EN/PDF/Publications/economic-vision-2030-executive-summary-mandate2,property=pdf.pdf

Thinkquest. (1998a). *Basic Nuclear Fission.[online].* Retrieved, [online]. [accessed 09 May 2010]. Available at: http://library.thinkquest.org/17940/texts/fission/fission.html

Thinkquest. (1998b). *The Nuclear Fission Power Plant* [online]. [accessed 11 May 2010]. Available at: http://library.thinkquest.org/17940/texts/fission_power/fission_power.html

UAEInteract. (2010). *Abu Dhabi is planning to achieve growth by 6-7% in real GDP over the period 2008-2012* [online]. [accessed 12 December 2010]. Available at: http://www.uaeinteract.com/docs/Abu_Dhabi_is_planning_to_achieve_growth_by_6-7_in_real_GDP_over_the_period_2008-2012/43357.htm

UN. (2005). *Air Quality and Atmospheric Pollution In the Arab Region* [online]. United Nations. [accessed 19 December 2010]. Available at: http://www.un.org/esa/sustdev/csd/csd14/escwaRIM_bp1.pdf

UN. (2008). *World Population Prospects: The 2008 revision population database* [online]. United Nations population division. [accessed 12 December 2010]. Available at: http://esa.un.org/unpp/p2k0data.asp

UN. (2009). *Meetings Coverage* [online]. United Nations, Department of Public Information, News and Media Division, New York: [accessed 28 October 2010]. Available at: http://www.un.org/News/Press/docs/2009/envdev1069.doc.htm

UNFCCC. (n.d). *Glossary of climate change acronyms* [online]. United Nations Framework Convention on Climate Change : [accessed 01 November 2010]. Available at: http://unfccc.int/essential_background/glossary/items/3666.php

USCB. (2010). *U.S. Census Bureau* [online]. [accessed 28 December 2010]. Available at: http://www.census.gov/

Vaillancourt, K., Labriet, M., Loulou, R., & Waaub, J.-P. (2008). *The role of nuclear energy in long-term climate scenarios: An analysis with the World-TIMES model.* Energy Policy 36 (2008) 2296–2307, Elsevier Ltd. [pdf]

Wachter, B. D. (2007). *Life expectancy of nuclear power plants* [online]. Leonardo Energy, The Global Community for Sustainable Energy Professionals. [accessed 31 December 2010]. Available at: http://www.leonardo-energy.org/drupal/node/1530

Weart, S. (2009). *The Carbon Dioxide Greenhouse Effect* [online]. The Discovery of Global Warming, American Institute of Physics. [accessed 28 October 2010]. Available at: http://www.aip.org/history/climate/co2.htm

Weitzman, M. (1974). *"Proces vs. quantities" .* The review of Economic Studies 41:477-491.

WNA. (2006). *Energy Analysis of power systems*. from world nuclear association: www.world-nuclear.org

WNA. (2010a). *Nuclear Power in the United Arab Emirates* [online]. World Nuclear Association. [accessed 09 December 2010]. Available at: http://www.world-nuclear.org/info/UAE_nuclear_power_inf123.html

WNA. (2010b). *Advanced Nuclear Power Reactors* [online]. world nuclear association. [accessed 01 December 2010]. Available at: http://www.world-nuclear.org/info/inf08.html

Wolde-Rufael, Y., and Menyah, K. (2010). *Nuclear energy consumption and economic growth in nine developed countries.* Energy Economics, Elsevier B.V.

Wright, R. (2008). *Environmental Science, 10th ed. .* Upper Saddle River: Pearson Practice Hall. pp332-333.

Yin, R. (1994). *Case Study Research: Design and Methods, 2nd ed.* Thousand Oaks, Calif. pp13.: Sage Publications.