Hacettepe University Graduate School of Social Sciences

Department of International Relations

ESTABLISHMENT OF NUCLEAR POWER PLANT IN TURKEY AND ITS PROBABLE EFFECTS ON TURKISH FOREIGN POLICY

Akın Dalbudak

Master's Thesis

Ankara, 2009

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KABUL VE ONAY

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TEŞEKKÜR

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ÖZET

DALBUDAK, Akın. TÜRKİYE'DE NÜKLEER SANTRAL KURULMASI VE TÜRK DIŞ POLİTİKASI ÜZERİNDEKİ MUHTEMEL ETKİLERİ, Yüksek Lisans Tezi, Ankara 2009.

Bu tez, oldukça uzun zamandan beri Türkiye'de kurulması düşünülen nükleer enerji santralinin kurulması halinde, bunun Türkiye'nin dış politikasına nasıl yansıyabileceğini ortaya koymaya çalışmaktadır. Tezde, nükleer santraller ve nükleer teknoloji üzerine bazı temel bilgilere sahip olmaksızın değerlendirme yapılamayacağı varsayımından hareketle, sırasıyla, bazı temel teknik noktalar açığa kavuşturulmaya çalışılmış ve bu temel bağlamında, teknolojinin uluslararası ilişkilerdeki öneminden yola çıkarak, nükleer santral ve nükleer santraller aracılığı ile nükleer teknoloji transferinin, Türkiye'nin ulusal gücünü arttıracağı sonucuna varılmıştır. Artan ulusal gücünün, Türkiye'nin diğer devletlerle ilişkisinin daha barışçıl olmasına yol açacağı; bu durumun, Türkiye ile çatışmayı maliyetli, işbirliği yapmayı kazançlı hale getireceği ise tezin temel savıdır. Savın temel dayanakları nükleer enerji santrallerinin Türkiye'nin enerji sorununun çözümüne önemli katkılar sağlayacağı ve nükleer teknoloji transferinin ülkede hem nükleer bilim alanında hem de tıp, tarım, metalürji gibi başka pek çok alanda bilimsel bilginin gelişimine katkı sağlayacağıdır. Nükleer silah konusu teze dâhil edilmemiş, konu enerji ve teknoloji bağlamında ele alınmıştır. Çalışma sırasında kitaplar, süreli yayınlar, raporlar, internet üzerinden erişilebilen bilimsel materyaller ve kişisel olarak gerçekleştirilen röportajlar kullanılmıştır.

Anahtar Kelimeler: Nükleer santral, Nükleer Teknoloji, Türkiye'nin Enerji İhtiyacı, Ulusal Güç, Türk Dış Politikası

ABSTRACT

DALBUDAK, Akın. ESTABLISHMENT OF NUCLEAR POWER PLANT IN TURKEY and ITS PROBABLE EFFECTS ON TURKISH FOREIGN POLICY, Master's Thesis, Ankara, 2009.

This thesis tries to expose that how it would reflect on Turkish foreign policy to build a nuclear power plant in Turkey which has long been thought. In the thesis, from the point of view that it is impossible to carry out an evaluation without having some basic knowledge on nuclear power plants and nuclear technology, respectively, some basic points were tried to be uncovered and in the context of this base, it is concluded that Turkey's national power would be increased via nuclear power plants and nuclear technology transfer through the nuclear power plants. Basic assertion of the thesis is that increased national power of Turkey would cause Turkey's relations with other states to be more amicable; this situation would lead scrimmaging with Turkey to be more costly and cooperating with Turkey to be more beneficial. Basic foundations of the assertion are that nuclear power plants can make important contributions to Turkey's energy needs and transferring nuclear technology can make contributions for the development of scientific knowledge both in nuclear science and in lots of fields like medicine, agriculture, metallurgy. Issues of nuclear weapons are not included to the subject and were approached in the context of energy and technology. During the study, books, periodicals, reports, scientific materials that are accessible via internet and personal interviews are used.

Key Words: Nuclear Power Plant, Nuclear Technology, Energy Need of Turkey, National Power, Turkish Foreign Policy

CONTENTS

ABBREVIATIONS

BEIR	: Academy of Sciences Committee on Biological Effects of Ionizing Radiation
BOTAŞ	: Boru Hatları ile Petrol Taşıma A.Ş
BP	: British Petrol
BWR	: Boiling Water Reactor
CAE	: Commission of Atomic Energy
CCGT	: Combined Cycle Gas Turbine
CERN	: Conseil Européen pour la Recherche Nucléaire
ÇNREC	: Çekmece Nuclear Research and Education Centre
DGEMP	: Direction Générale de l'Énergie et des Matières Premières
ECCS	: Emergency Core Cooling System
EU	: European Union
FBR	: Fast Breeder Reactor
GDP	: Gross Domestic Product
GY	: Gray
GW	: Giga-Watt
H	: Equivalent Dose
HLW	: High Level Waste
HWR	: Heavy Water Reactor
IAEA	: International Atomic Energy Agency
IEA	: International Energy Agency
ITU	: İstanbul Technical University
IU	: İstanbul University
Kgoe	: Kilogram Oil Equivalent
Kw	: Kilo-Watt
LWGR	: Light-Water-cooled Graphite-moderated Reactor
ICRP	: International Commission on Radiological Protection
LHC	: Large Hadron Collider
LOCA	: Loss of Coolant Accident
Mb/d	: Million Barrels per Day
MW	: Mega-Watt
MTOE	: Million Tons of Oil Equivalents

N.P.P	: Nuclear Power Plant
OE	: Oil Equivalent
OECD	: Organization for Economic Cooperation and Development
PET	: Positron Emission Tomography
PWR	: Pressurized Water Reactor
R	: Roentgen
SPECT	: Single Photon Emission Computer Tomography
Sv	: Sievert
TEI	: Turkey Electricity Institution
TMI	: Three Mile Island
TRU	: Trans-Uranic Element
U	: Uranium
UCS	: Union of Concerned Scientists
UNSCEAR	: United Nations Scientific Committee on the Effects of Atomic Radiation
U.S.A	: United States of America
VVER-1200	: Vodo-Vodyanoi Energetichesky Reactor (Water-Water Energetic Reactor)
WASH-1400	: Reactor Safety Study Realized by Prof. Norman Rasmussen in 1975

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INTRODUCTION

In this thesis, the subject of building a nuclear power plant in Turkey and its probable effects on Turkish foreign policy will be examined. Thesis is consisting of two chapters. In the first chapter, which is divided into two parts, the essence will revolve around the nuclear techniques and nuclear energy which is achieved via nuclear power plants. Due to the reason that nuclear energy is a sub-field of nuclear technology, it is preferred to observe nuclear power plants under the main topic of nuclear technology. There are many areas of nuclear applications which are also attempted to be observed under the topic of "Nuclear Technology and Its Applications". Goal of the first part is to constitute a scientific background for political debates. Owing to the core of this thesis, the first part of the first chapter will be just a brief and basic introduction to the nuclear energy issue. In the second part, nuclear energy will be studied not in technical details but by comparison to other sources of energies and opposing approaches to nuclear power plants will be put together to analyze in the aspect of productivity, accident risks, nuclear waste and storage question, economic costs, and environmental threats. This study also appeals to experts' ideas via personal interviews. In the thesis, there are personal opinions of four scientists– Osman Kemal Kadiroğlu, Yalçın Sanalan, Sümer Şahin and Okan Zabunoğlu, - whose scientific domain is nuclear energy and technology directly. At the end of the second part, it is expected to have an estimation of whether building a nuclear power plant is a good idea or not. Next part of this thesis is devoted to the nuclear technology and its applications. In this part application fields of nuclear technology will be introduced briefly. This part also declares the end of the first chapter.

Second chapter is devoted to understand whether building a nuclear power plant will effect Turkish foreign policy or not. Although nuclear power plants and nuclear technologies are tended to be observed from the respect of mass destruction weapons, this thesis is not going to include that side of nuclear issues. Instead, reflections of nuclear technology's and its benefits' on Turkish foreign policy will be observed. First part of this chapter will start with a brief history of Turkey's failed attempts to build a nuclear power plant. In this part, reasons behind failures are aimed to be exposed. Through this part, the way foreign relations obstructed the process of building a nuclear power plant in Turkey will be exposed. To reach this aim, be some personal interviews will be used. Although the main course of the thesis is technology acquirements, energy issues are observed with basics because it is also an important component for the survival of all modern states. Then, the relation between technology and international affairs will be stated. In this context it will be tried to examine how Turkey will be affected and gain experience in its foreign policy as a result of building nuclear power plant and obtaining nuclear technology. The notion of power is accepted to be the main conjunction between nuclear technology –including energy side- and foreign policy. Study ends with conclusion.

CHAPTER I

NUCLEAR ISSUES FROM TECHNICAL SIDE

Part I. NUCLEAR TECHNOLOGY AND NUCLEAR POWER PLANTS

Due to the subject of this thesis, it is essential to make a brief, definitional introduction to nuclear technology without going into technical details.

Nuclear technology is the application of nuclear sciences which includes reactions and productions related to nucleus and these applications contain wide fields of study.[1] Mainly, it is possible to divide nuclear technology into two areas of applications. First, nuclear energy, which is created via nuclear power plants, and second, nuclear techniques, which includes the medicine, industry, agriculture, environment, food security, consumer productions, military implements, space studies...[2] Also, it is expectable that application fields of nuclear technologies will expand as studies on nuclear area increases.

I.A Nuclear Power Plants

Nuclear power plant is a facility in which heat is produced in a reactor by the fissioning of nuclear fuel and used to drive a steam turbine.[3] To be able to evaluate the subject of nuclear energy, some basic information about atoms as a source of energy must be understood. So, this part will start by introducing the context of atom, fission and fusion, which are the basic processes of producing nuclear energy. After this very brief and basic introduction, general features and operation systems of nuclear power plants will be discussed.

I.A.1 Atom

As mentioned above, to understand how nuclear power plants work, it is required to know some basic information about atoms.

Substances come into existence from atoms and atoms are the basic building stones of everything. But in reality, atoms are also come into existence from smaller parts which are

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[1] *Nükleer teknoloji ve Reaktörler*, http://www.nukte.org/reaktorler. 19.11.2007.
[2] Ali Külebi. (2007). **Türkiye'nin Enerji Sorunları ve Nükleer Gereklilik**, Ankara: Bilgi, p. 142.
[3] Nebraska Energy Office, *Glossary*, available at: http://www.neo.ne.gov/statshtml/glossaryn.htm. available on: 22.11.2007.

called proton, neutron and electron. The first two particles, protons and neutrons, are located in the centre of atoms and mainly they constitute the weight of the atom. This centerpiece is called “nucleus” of atom. While protons carry positive electric charge, electrons carry negative charge and neutrons are neutral. As the number of protons and neutrons increases, weight of the atom increases too. Accumulation of neutrons and protons constitutes the weight of the atom. For instance, there are 92 protons and 143 neutrons in Uranium, so weight of Uranium is 92 + 143= 235. It is shown as Uranium-235 or U-235.

There is also an important point in this issue. In atoms, mission of the neutron is to keep pieces of atom together and every nucleus can become stable only if it has a determined number of neutrons. That is, number of neutrons designates the stability of atoms. If the number of neutrons is under or above the required number, atoms become unstable[4] and when an atom becomes unstable, it tries to send away the excessive pieces or energy to become stable. If/when they send away this energy or piece(s), this may be harmful for the living creature. These unstable atoms are called “radioactive substances”.[5] The higher the difference between the number of neutrons and protons of an atom, the more radioactive that atom is. As the nucleus of atom gets heavier, the need for the neutron increases to keep the nucleus together.

I.A.2 Fission and Fusion

Nuclear energy can be defined as follows; it is an energy which emanate from disintegration or association of nucleus. When a nucleus is disintegrated or associated, a great amount of energy is released. Chemically, association process of atom is called fusion and disintegration process of atom is called fission. Here, it is required to unfold the contexts of “fission” and “fusion” basically to understand these processes.

As mentioned above, disintegration of nucleus, that is fission, produces great amount of energy and this process is realized via bombarding heavy nuclei with neutrons. Bombarded atoms (for example Uranim-235 for most of the nuclear power plant designs), release two or three neutrons and these neutrons in turn can cause further Uranium atoms to split.[6]

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[4] John G. Collier, Geoffrey F. Hewitt. (1976). **Introduction to Nuclear Power**, New York: Hemisphere Publishing Corporation, p. 9.
[5] Bob Burton. (1990). **Nuclear Power, Pollution and Politics**, London: Routledge, p. 3.
[6] John G. Collier, Geoffrey F. Hewitt. **Introduction to Nuclear Power**, p. 13.

Basically, to make fusion happen, atoms of hydrogen must be heated to very high temperatures; so they have sufficient energy to be associated. Again, this process releases great amount of energy.

I.A.3 Nuclear Power Plants: How They Work and General Features

Under this topic, technical features of nuclear power plants will be examined in detail to constitute a scientific background for further discussions.

As it was defined above, nuclear power plants are systems that use the heat which arise from controlled chaining chemical disintegration reactions to produce electric energy. Basically, producing energy via nuclear power plants has the same principle with producing energy via gas or coal plants in respect of thermodynamics. The difference between them is the source of the heat. In a nuclear power plant, the energy released from continuous fission of the atoms in the fuel as heat is used to generate steam and the steam is used to drive the turbines which produce electricity.[7] Process of producing electricity by nuclear power plants is shown by Figure-1.

[7] World Nuclear Association. *Electricity Generation-Nuclear Power Reactors*, available at: http://www.world-nuclear.org/how/npreactors.html, available on: 25.11.2007.

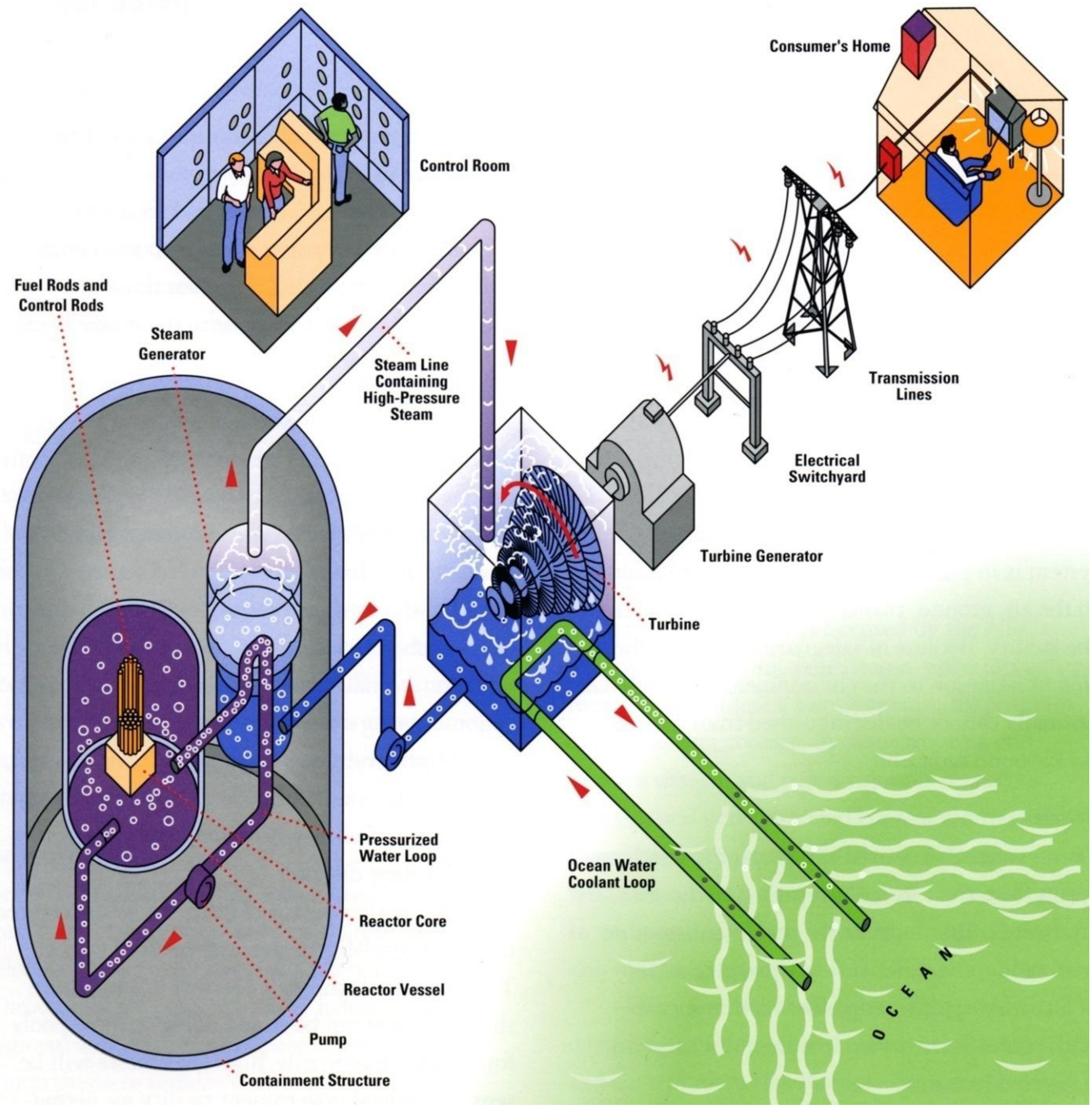

Figure-1. Layout for a Pressurized Water Reactor Type Nuclear Power Plant[8]

Nuclear power plants at the present time use heavy atoms as the source of energy. In the nature, although there are some heavy atoms, uranium-235 which contains too much neutrons and protons in the nucleus is almost the only source for nuclear energy used in today's nuclear power plants.[9] The percentage of U-235, which is the type of uranium that fissions easily in natural Uranium, is less than 1 percent and so to make the uranium usable as fuel, its U-235

[8]Souther California Edison, available at: http://www.sce.com/NR/rdonlyres/A050B788-F86C-448A-9A66-8FABD9F302B4/0/NuclearEnergy_process.jpg, available on: 09.05.2009.
[9] Vural Altın. (2006). *Nükleer Enerji*, available at: http://www.nukte.org/node/119, available on: 24.11.2007.

content is increased to between 3 percent and 5 percent using a process which is called enrichment.[10]

Scientists found out that when the nucleus of uranium-235 atom is bombarded by the neutrons, it is immediately broken up to two (sometimes three) parts and this breakup gives birth to nuclear energy. In the artificial environment, (in nuclear power plants) when nucleus of uranium-235 is broken up into two or three parts, two or three neutrons diffuse to environment randomly and they hit other uranium-235 atoms. Result of this process is a chain reaction in which every breakup generates the nuclear energy.

Even though there are different types of nuclear power plants, the part in which nuclear energy is produced consists of the same main components.[11] These are mainly fuel, moderator, coolant and control rods.

- Fuel: This is the material in which nuclear reaction is obtained and it is embedded in a zirconium cladding. Almost all of the nuclear power plants use Uranium as the fuel for now.
- Moderator: Moderator is used to slow down the moving neutron which is generated as a result of disintegration because researches pointed out that the neutron's probability to hit the atom's (Uranium's) nucleus increases if it moves slowly. Generally water is used as the moderator and it is placed in between the fuel rods.
- Coolant: This is the gas or liquid that is used to transport the heat produced during the fission from the fuel. The coolant may be water, deuterium, helium and so on.
- Control Rods: They are used to control the energy production and finish it when necessary. As explained above, disintegration is realized via neutrons and control rods obsorb these neutrons.

Furthermore, there are additional systems used to measure the heat, pressure, level of radioactivity, power level and so on.

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[10] Nuclear Energy Institute. *Processing Uranium to Make Fuel*, available at: http://www.nei.org/howitworks/nuclearpowerplantfuel/ available on: 29.11.2007.
[11] *Nükleer Reaktörlerin Ana Bileşenleri*, available at: http://www.nukleer.web.tr/ available on: 23.11.20007.

During the nuclear reaction in nuclear power plants, approximately 0.1% of the original mass is converted into energy.[12]

I.B Nuclear Power Plants from Critical Respect

Using of nuclear power plants has long been discussed in Turkey, but almost all debates generally revolve around the politics, rather than scientific aspects of this issue. Although this thesis is about politics, it is believed that it is impossible to assess such an issue without referring to indicators of natural science. So, it is aimed in this thesis to present a scientific outlook and an objective evaluation of nuclear power plants to construct a healthy background for political debates. Due to the reason that the first chapter is devoted to nuclear science and nuclear power plants, this issue will be assessed using the scientific data only. To reach this goal, numbers will be presented rather than opinions as much as possible. But, when referring to the opinions is necessary, opinions scientists, especially the ones studying on nuclear, will have the priority.

In this thesis, the issues which criticize nuclear power plants as highly risky, dangerous for environment and too costly, are investigated. So, in this part accident risks, nuclear waste and storage problem, economic costs and environmental threat perception will be observed to convey whether these criticisms are pointing the truth or not. Partly except the topics of economic costs of building a nuclear power plant and qualified people, all topics are somewhat related to the question on radiation. So, there is a need to know some basic information about radiation and this part is going to start by introducing radiation. As issue of radiation become clearer, it will be easier to analyze the radiation related topics objectively.

I.B.1 Radiation and Its Effects

Under this topic, there will be two parts. While in the first part, introduction to radiation, the reader will be introduced to some technique terms like ionizing radiation, equivalent dose, effective dose, et cetera without going into deep details, in the second part, efforts will concentrate on some basic information on exposure to radiation. The second part will also deal with the issue of low radiation and its effects which is vital part of this thesis. Unless the discussion on the low doses of radiation and its effects on human are understood, there is no

[12] John G. Collier, Geoffrey F. Hewitt. **Introduction to Nuclear Power**, p. 14.

way for assessing the radiation issue and so no way for assessing the nuclear power plants which is the main subject of this thesis.

I.B.2 Introduction to Radiation

Radiation can be defined as follows; "Energy which is radiated by atoms when they are moving or changing state. It can take the form of electromagnetic waves, such as heat, light, X-rays, or gamma rays, or streams of particles such as alpha particles, beta particles, neutrons or protons."[13]

To be able to understand what the numbers mean, there is also need to know what the radiation dose and its units are. The terms ion dose, energy dose, equivalent dose, effective dose are explained as follows:

-Ion Dose: "It is the amount of electrical load in 1 kilogram of air, which is produced by ionizing radiation throughout their paths. Unit of ion dose is Roentgen (R)"[14]

-Energy Dose: It is the absorbed dose which indicates the energy that radiation transfers not only to air but also to any substance. Unit of the energy dose is Gray (Gy)[15] 1 Gy means 1 Joule energy absorption for a kilogram of a substance.[16]

-Equivalent Dose: "It is the scale of biological effects of ionizing radiation. Alphas, Betas and Gammas have different effects on body. For example, the equal energy dose of alpha and beta, have different effects and effect of alpha is to be stronger than beta's. Because of this difference, there is radiation weighting factor (a number). This number, for Beta and Gamma is 1, for Alpha it is 20. For protons and neutrons it changes between 5 and 20 depending on their energy. Radiation weighting factor is symbolized by the letter q. Symbol of Equivalent Dose is H and its unit is Sievert (Sv). It is calculated via the formula follows; H (Sv) = Gy x q."[17] Equivalent dose is one of the most important concepts in discussing the radiation and its effects.

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[13]Boğaziçi University, *Nuclear Glossary*, available at http://www.nuce.boun.edu.tr/glossary.html, available on: 25.01.2009.

[14] Yüksel Atakan. (2006). *İyonlayıcı Radyasyon*, Yeni Ufuklara,(in Bilim ve Teknik Journal) Nisan, Tübitak, p. 4.

[15] Ibid.

[16] Ibid.

[17] Yüksel Atakan, *İyonlayıcı Radyasyon*, p. 4-5.

-Effective Dose: “Different parts of the body are affected by radiation differently. Due to this reason, to determine the dose from which whole body is affected and to compare the effects, this term (effective dose) is generated. Unit of the Effective Dose is the same with the unit of equivalent dose: Sv. Effective dose helps us to take into account the random hazard risks for whole body or organs separately which stems from being irradiated.

- Collective Dose: It is the sum of the doses taken by people in whole society. It is important while calculating the radiation risk[18]

I.B.2.1 What Does Radiation Mean for Us?

Although it is thought by the ordinary people, who is not familiar with the radiation issue, that exposure to radiation does not come into agenda of peoples’ daily life unless they are not near to a nuclear power plant or near to radioactive wastes, the fact is so much different than this.

There are lots of sources of radiation around us. Mainly, it is possible to talk about natural sources and artificial sources. Natural sources can be listed roughly as cosmic rays of sun, earth’s surface (stones, vegetables and moreover houses we live in), all living creatures, (including human body itself) air and water. When it comes to artificial sources, nuclear bomb tests, nuclear power plants, ionizing radiation which is applied in medicine, devices like television, watches conteining phosphorous or other things, et cetera can be given as examples. To make comparisons, there will be some numbers which point to radiation released from nuclear power plants and from some natural sources under the topic of “Some Comparisons.”

I.B.2.2 Denominations of Radiation

This part, as mentioned above, is very vital for understanding the main idea of the thesis. It is impossible to obtain the data for the effect of low radiation on human beings. The controlled tests are impossible to be applied on human beings ethically and there is no historical data on effects of low level radiation. In addition, due to different reactions of different creatures to radiation, the tests that can be applied to animals would supply erroneous data. Under certain threshold, effects of ionizing radiation (which is commonly known only as “radiation”) are not comprehensible/observable. There are no low dose tests applied to human beings to find

[18] Yüksel Atakan, *İyonlayıcı Radyasyon*, p. 5.

out whether it is harmful or not due to reason that those tests are not ethical. Although it is supposed that damage to individual cells will occur at lower doses, harmful effects occur principally above a threshold dose that must be exceeded before they are manifested as clinical damage.[19] This threshold dose will be given below but firstly there is need to give some pre-information about the threshold dose. Exerts to determine that threshold dose concentrate on people and animals who are exposed to radiation. The data on human are collected through the people in Japan, who survived after the atomic bomb although they were radiated, people who were radiated by medical treatment, people who were somehow radiated by ionizing rays and people who live around the nuclear power plants.[20] Via observing these people, scientists gather quantitative information which makes them able to compare people who were radiated by ionizing radiation with the ones who were not radiated. Differences between these groups deduce the effects of radiation.

Before observing the effects of radiation, denominations, on which risk and level of hazard stem from radiation are depended, must be shown. They are listed by Yüksel Atakan as follows:

“Proportion of Dose: As the dose increases, risk also increases.

Duration of Dose: As the duration, in which determined proportion of dose is taken, increases, risk diminishes.

Sort of Ionizing Ray: Dense ionizing rays like Alphas are more effective than sparse ionizing rays like Betas or Gammas.

Sort or sensitivity of Subjected Tissue: Different types of tissues are affected from radiation differently.

Age of the Creature: Old creatures are less sensitive to the radiation than the young or infant creatures.

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[19] UNSCEAR. (2000). *Annex G: Biological Effects at Low Radiation Doses*, available at: http://www.unscear.org/docs/reports/annexg.pdf, available on: 25.01.2009, p 75.
[20] Yüksel Atakan, *İyonlayıcı Radyasyon*, p. 13.

Collective Dose: Rate of per head dose arose from the irradiation of all community. Collective dose is used to calculate the risk of dose."[21]

In our environment, 15.000 radiation particles crush to human body in every second[22] which come from both natural and artificial sources. The unit by which radiation is scaled is Sievert (Sv). Due to the reason that 1Sv is a very huge radiation mass for humans, what is commonly used in general is mSv, that is 1/1.000 Sv, or µSv, that is 1/1.000.000Sv. 1mSv includes 700.000.000 radiation particles. Every single mSv increases the risk of cancer with degree of 1/80.000. This means, from every 80.000mSv radiation, 1 cancer event is expected[23] (just expected, not obsolete). This is the independent conclusion of U.S national Academy of Sciences Committee on Biological Effects of Ionizing Radiation (BEIR) and United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR).[24] International Commission on Radiological Protection (ICRP) gives approximately the same result: 1/100.000

I.B.3 Threshold Dose and Low Radiation Problem

I.B.3.1 Threshold Dose

Hazards, which occur from radiation, are grouped into two categories. First is the early/immediate hazard and second is the late hazard. Firstly, immediate hazards will be illuminated and then late hazards will be discussed.

There is a need for a very high value of dose to observe the immediate clinical hazards of radiation; "500mSv" (500000µSv) at once. As the exposure to radiation increases, the amount of the damage increases. Based on the reason that after exceeding threshold dose, occurrence of the hazard is not random, these are called deterministic hazards.[25] Burn on skin and cataract can be given as the results of the dose exceeding the threshold.[26] There are threshold doses which imply important cornerstones on this issue. Here, two of them will take place; 4000 mSv (4000000µSv) and 7000 mSv (7000000µSv). If a person is exposed to 4000 mSv radiation, death probability of that person in 30 days is 50%. This probability means that if all

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[21] Yüksel Atakan, *İyonlayıcı Radyasyon*, p.12.
[22] Bernard L. Cohen. (1995). **Çok Geç Olmadan, Bir Bilim Adamının Gözüyle Nükleer Enerji**, (Translated by Miyase Göktepeli), Ankara Tübitak, p. 12.
[23] Bernard L. Cohen, **Çok Geç Olmadan, Bir Bilim Adamının Gözüyle Nükleer Enerji**, p. 20
[24] Bernard L. Cohen, **Çok Geç Olmadan, Bir Bilim Adamının Gözüyle Nükleer Enerji**, p. 17
[25] Yüksel Atakan, *İyonlayıcı Radyasyon*, p.12
[26] Ibid.

individuals in a society are exposed to 4000 mSv, half of them may die in 30 days, because, direct information on radiation-induced cancer is available from epidemiological[27] studies on human.[28] 7000 mSv presents a new term; "fatal dose". According to scientists of UNSCEAR, fatal dose is 7000 mSv. That is, if a person who is exposed to 7000mSv, would die probably unless measures were taken to save that person. Being aware of both damaging dose threshold (4000 mSv) and fatal dose threshold (7000mSv) is important for being able to compare other dose levels which come from natural environment or artificial environment like nuclear power plants.

Late hazards may occur years after the exposure. Even if damages on cells occur immediately, it is accepted that hazards (cancer), which are not ill disposed, can arise if a threshold is exceeded. It is also supposed that ill disposed hazards may occur even if dose rate is very little and there is no threshold for them. Here, there appears a very vital problem about the late hazards because there is no scientific evident which demonstrates the late hazards of radiation. Although it is supposed that there are late hazards, none of the suppositions has statistical base neither for individuals nor for societies including the survivals of Japanese people who were subjected to radiation because of the atomic bomb used in Hiroshima and Nagasaki. Due to the reason it is not obvious that who will be subjected to the hazard, late hazards are called stochastic hazards[29]

I.B.3.2 Low Dose Problem

Low doses problem is expressed in UNSCEAR report of biological effects at low radiation doses (Annex G) as follows: "At lower levels of exposure, however, quantitative estimates of risk are not so readily obtained, and inferences need to be made by downward extrapolation from the information available at higher doses"[30] Because of this reason, scientists generally extrapolate the risks of low levels of radiation based on the hypothesis that the frequency of their (radiation-induced cancer) induction increases proportionally with the radiation dose.[31]

A linear, no threshold dose-response relationship has generally been adopted by national and international bodies for assessing the risks resulting from exposures to low doses of ionizing

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[27] Epidemiology: Study of disease spread in populations. It focuses on groups rather than individuals and often takes a historical perspective.
[28] UNSCEAR. *Annex G: Biological Effects at Low Radiation Doses*, p. 75.
[29] Yüksel Atakan, *İyonlayıcı Radyasyon*, p.12.
[30] UNSCEAR. *Annex G: Biological Effects at Low Radiation Doses*, p. 75.
[31] Ibid.

radiation. This hypothesis implies that the risk of cancer increases with increasing exposure and that there is no threshold, i.e., no dose below which there is absolutely no risk. As yet no definitive experimental data are available on this issue.[32]

Moreover, some scientists also claim that irradiated cells and tissues below the levels of radiation, at which effects can be measured, may result in a beneficial effect termed hormesis or may result in an adoptive response that reduces the amount of damage caused by subsequent radiation exposure.[33] There have also been suggestions by researchers that at very low doses, radiation may have no effect at all; because they think that there must be a threshold for dose response.

On the other side, it is impossible to distinguish the ionizing radiation-induced cancer and genetic hazards from the cancer and genetic hazards resulted in due to the other reasons like smoking. Scientists are able to conclude that reasons of these kinds of hazards are the results of ionizing radiation only if they could see the statistical difference of cancer and genetic hazard between the societies who were irradiated and who were not irradiated. If there is a statistically significant increase in cancer cases in irradiated society, scientists can conclude that these problems (cancer and genetic hazards) arise from radiation. Here, the problem is that, this kind of study has to be very detailed, comprehensive and long-termed. Up to now, the most comprehensive study that has been carried out for 60 years is the study on 100.000 Japan people who survived after the bombing of Hiroshima and Nagasaki. Results of this study are very surprising and meaningful. According to the study, which observes the Japanese people who were irradiated and who were not irradiated, by the time these people were 55 years old, there were no observable difference but after that age, (55) death rates among people, who were NOT irradiated, increased.[34] (Half of those 100000 people are still alive, so the study is going on)

Briefly, in fact there is no absolute risk or hazard proved by scientists via experiments or observations for the low doses of irradiation. There is only an assumption that even the low doses present risk because scientists are fully adapted to precautionary principle which means that if there is an irreparable risk for environment, it must be assumed that hazard is absolute

[32] Ibid.
[33] Ibid.
[34] Yüksel Atakan, *İyonlayıcı Radyasyon*, p.13.

even if there is no scientific evident. If it is taken into account that all people are exposed to radiation from the natural environment, it may be easier to perceive this reality. So, as Cohen points, risks of low doses are overestimated by scientists intentionally.[35] Doses in natural environment are also shown in the frame aforementioned low doses. If all doses from zero to threshold doses were deathly risky for living creatures because of the nature's itself and there would be no life on earth. Since the life on earth began, radiation exists in all over the world and it does not cause the death of any living creatures.

I.C How Big is the Danger People Face Because of Nuclear Power Plants?

Under this topic, the risk will be described, which comes into existence from nuclear power plants, via referring to numbers as much as possible. So this part is going to start by some introductory numbers and their reflection on nuclear power plants. On the other side, describing the effects of ionizing radiation –especially low doses of radiation- will be more explanatory if some comparisons are stated here. So, there will be to comparisons between the doses of radiation released from the nuclear power plants and other man-made and natural radiation sources.

I.C.1 Exposures to Public from Nuclear Power Plants

While estimating the exposures to public from nuclear power plants, scientists face some problems because there are different types of nuclear reactors and so scientists had to classify them, for the most part, by their coolant systems and moderators; light-water-moderated and –cooled pressurized or boiling water reactors (PWRs, BWRs), heavy-water-cooled and –moderated reactors (HWRs), gas-cooled, graphite-moderated reactors (LWGRs).[36] "The committee (UNSCEAR) derives average releases of radionuclides from reactors based on the reported data and these averages are used to estimate the consequent exposures for a reference reactor."[37] Also the factors, which are geographical location of the reactor, the release points, distribution of the population, food production and consumption habits and the environmental pathways of radionuclides, influence the calculated dose.[38] "The concentration of the released radionuclides in the environment are generally too low to be measured except close to the

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[35] Bernard Cohen, **Çok Geç Olmadan: Bir Bilim Adamının Gözüyle Nükleer Enerji**, p. 44.
[36] UNSCEAR. (2000). *Annex C: Exposures to the Public From Man-Made Sources of Radiation*, available at: http://www.unscear.org/docs/reports/annexc.pdf, available on: 25.01.2009, p 182.
[37] Ibid.
[38] Ibid.

nuclear facility and then for a limited number of radionuclides only."[39] On the other side, calculation of dose estimates includes atmospheric and aquatic transport and environmental transfer of the released radioactive materials.[40] Although there are all of these difficulties, scientists could obtain required information on annual average doses to individuals in representative environmental conditions. The average population density is 400 people/km^2 in 50 km of the site. Also, "because of the variability in annual releases, normalized releases have been averaged over a five year period to assess the collective dose".[41] Quantitative dose levels were scaled as follows:

> For the model site, the annual average effective doses to individuals estimated from release data and assuming the total collective dose for a reactor type exposes a single local population group (400 people/km^2 to 50 km) are 5µSv for PWRs, 10µSv for BWRs and HWRs, 2µSv for LWGRs and 0.04µSv for FBRs. In comparison, reported annual individual doses from a number of nuclear reactor sites are in the range 1-500 µSv.[42]

I.C.2 Some Comparisons

Here, some numbers will be given which are expected to help the reader to understand if nuclear power plants are as dangerous as they are said or not. It seems that comparing the radiation which is released from nuclear power plants with some natural sources is a reliable way for this goal. Moreover, similar comparison will be performed with other man-made radiation sources.

I.C.2.1 N.P.Ps vs. Natural Radiation Sources in Terms of Radiation

The "natural radiation sources", mainly means cosmic rays, which come into existence from the sun and stars, terrestrial radiation, which come into existence from earthen, water, air, and building materials and so on. As mentioned before, all kinds of life forms are living under a radiation rain which surrounds everywhere. The evaluations of UNSCEAR in the Annex B (Exposures from Natural Radiation Sources) indicate that average annual effective dose to the world population from natural radiation sources is approximately 2.4 mSv[43]. (2400µSv) More detailed information can be gathered from Table-1 which gives the average worldwide exposure to natural radiation sources. This table shows us cosmic and cosmogenic sources, external terrestrial radiation, inhalation exposure and ingestion exposure as the main sources

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[39] UNSCEAR. *Annex C: Exposures to the Public From Man-Made Sources of Radiation*, p 186.
[40] Ibid.
[41] UNSCEAR. *Annex C: Exposures to the Public From Man-Made Sources of Radiation*, p 187.
[42] Ibid.
[43] UNSCEAR. (2000). *Annex B: Exposures from Natural Radiation Sources*, available at: http://www.unscear.org/docs/reports/annexb.pdf, available on: 25.01.2009 p. 112.

of exposure. At the end of the table, total average effective annual doses, whose typical ranges differ from 1-10 mSv, were given.

Table-1: Average Worldwide Exposure to Natural Radiation Sources[44]

Source of Exposure	Annual Efective Dose (mSv)	
	Average	Typical Range
Cosmic Radiation		
Directly Ionizing and Photon Component	0.28(0.30)[a]	
Neutron Component	0.10(0.08)	
Cosmogenic Radionuclides	0.01(0.01)	
Total Cosmic and Cosmogenic	*0.39*	0.3-1.0[b]
External Terrestrial Radiation		
Outdoors	0.07(0.07)	
Indoors	0.41(0.39)	
Total External Terrestrial Radiation	*0.39*	0.3-0.6[c]
Inhalation Exposure		
Uranium and Thorium Series	0.006(0.01)	
Radon (^{222}Rn)	1.15(1.2)	
Thoron (^{222}Rn)	0.10(0.07)	
Total Inhalation Exposure	*0.48*	0.2-10[d]
Ingestion Exposure		
^{40}K	0.17(0.17)	
Uranium and Thorium Series	0.12(0.06)	
Total Ingestion Exposure	*0.29*	0.2-0.8[e]
Total	2.4	1-10

a Result of previous assessment [U3] in parentheses
b Range from sea level to high ground elevation
c Depending on radionuclide composition of soil and building materials
d. Depending on indoor accumulation of radon gas
e. Depending on radionuclide composition of food and drinking water

This shows us that; annual dose from natural radiation sources for an individual is 240 times bigger than what BWRs and HWRs (Natural annual dose average, 2.4mSv, is equal to 2400 µSv; BWRs and HWRs release 10µSv, so 2400µSv/10µSv= 240) which releases the highest doses. From another respect, it can be deduced that when a HWR or a BWR is used,

[44] UNSCEAR. *Annex B: Exposures from Natural Radiation Sources*, p. 140, Table 31.

additional dose which comes from these nuclear power plants is 0.01 mSv (10µ Sv =0.01 mSv). As pointed before there is 2.4 mSv natural radiation dose around us. With a HWR or with a BWR, total dose will be 2,41 mSv which is between typical 1-10 mSv. The same calculation shows that just because of breathing, people exposed to radiation 126 times more in comparison with exposure to radiation from BWRs and HWRs and furthermore it is 29 times bigger than being exposed to the radiation due to ingestion.

There is another figure (Figure-2) below that compares the probability of cancer which stem from various agents, of course, the figure below does not show all agents that cause cancer. In this figure, the values below the medicines are estimated according to downward extrapolation, so they are the most pessimistic extrapolations. From this figure, it is obvious that cancer risk which stem from nuclear power plants are absolutely negligible in compare with the probability which stem especially from nutrient-alimentary and from tobacco. Also like all others, probability from medical irradiation and sun rays must be kept in mind because these sources always exist in our lives.

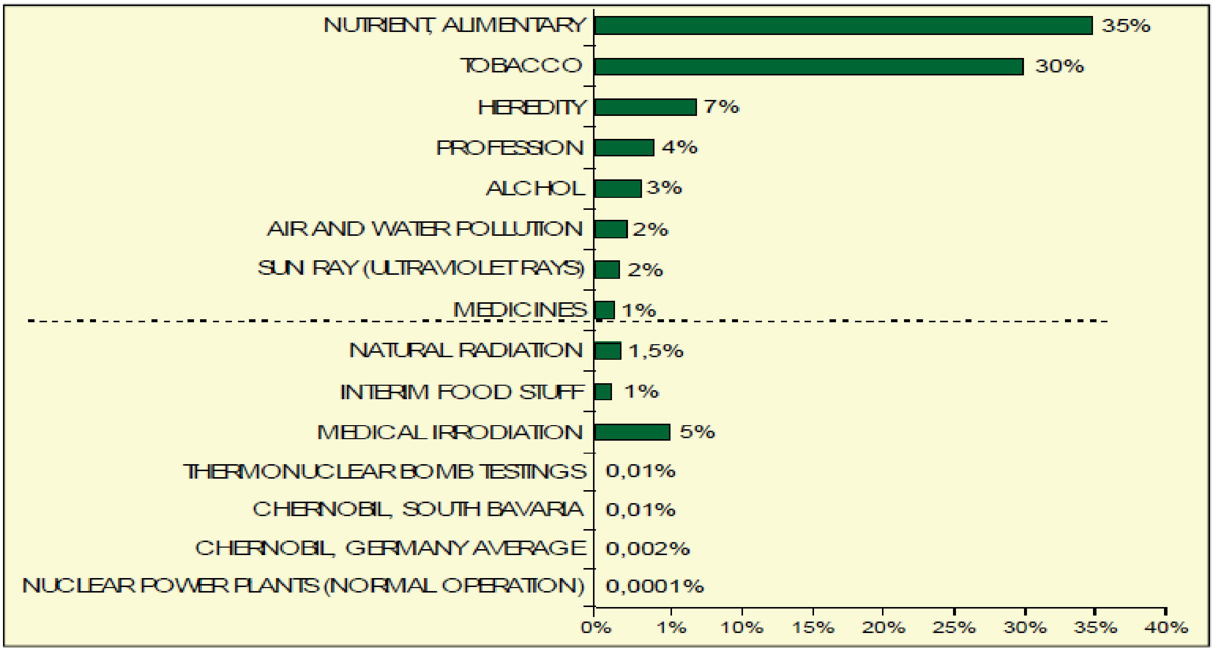

Figure-2: Comparison of Some Cancer Probabilities (Including Some Natural Sources)[45]

I. **C.2.2 N.P.Ps vs. Coal Power Plants in Terms of Radiation**

In Germany, radiation release from nuclear power plants was compared with radiation release from coal power plants. Chosen power plants were the ones that generate 1GW/Year

[45] Yüksel Atakan, *İyonlayıcı Radyasyon*, p. 14-15.

electricity and study was realized via comparing the radioactive materials which were released from the plants. (Chosen nuclear power plant is a PWR) According to the results, while the nuclear power plant was releasing 2μSv, coal power plant was releasing 7μSv radiation doses.[46] While the radiation from coal power plant is alpha, which transfers intense energy to body (the more intense the radiation transfer energy to body, the more harmful it is), radiation from nuclear power plant were beta and gamma, which transfers less energy to body than alphas.[47] Although, according to this study, nuclear power plants are much safer than coal power plants, it must be noted that radiation released from both plants are under the natural radiation doses. (Average natural radiation dose is 2.4 mSv = 2400μSv)

I. D Main Debates on Nuclear Power Plants

I.D.1 Nuclear Safety

Every aspect of a nuclear power plant must be scrutinized carefully to avoid all kinds of accidents because nuclear power plants' operation process is deeply involved with radioactive materials and these materials can be very harmful to both environment and human. The main goal of the nuclear safety perception is to keep radioactive materials under control in any circumstance and if an accident happens despite all measures taken and some radioactive materials leak out from nuclear facility the goal is to keep radioactive material in boundaries which is not harmed.[48] So, nuclear safety can be understood as the ability of facility and workers to prevent accident and ability of mitigating the harmful effects of the accident.[49]

"The fundamental principle applied to the safety of nuclear installations is the concept of defense-in-depth, which means having in place multiple levels of barrier against radiation.[50]" "In this way a deficiency or failure at one level can be compensated for or corrected at another level[51]" Defense-in-depth principle conditions barriers against radioactive leakage and security systems which ensure durability of the barriers as a prerequisite.[52]

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[46] Yüksel Atakan, (2006), *Kömürlü Santrallerin Çevrede Oluşturduğu Radyasyon Dozu*, Bilim ve Teknik, Mayıs, p. 49.
[47] Ibid.
[48] Benan Başoğlu, *Nükleer Güvenlik*, available at: http://www.nukleer.web.tr/ available on: 09.02.2008.
[49] Ibid.
[50] International Atomic Energy Agency. *Promoting Safety in Nuclear Installations*, available at: www.iaea.org/Publications/Factsheets/English/safetynuclinstall.pdf available on: 09.02.08, p. 1.
[51] Ibid.
[52] Muhammet Barık, Şule Ergün. (2007). *Nükleer Santrallerde Derinliğine Savunma*, Türkiye Kazaların Çevresel ve Teknik Araştırması Ulusal Çalıştayı, Gazi Üniversitesi, Ankara.

I.D.1.1 What is Nuclear Power Plant Accident?

When accident risks are taken into account for nuclear power plants, it is possible to talk about infinite number of scenarios but the main safety concern has always been the possibility of an uncontrolled release of radioactive material which leads to contamination and consequent radiation exposure off-side.[53] What leads this result is known as core meltdown accident. Of course, core meltdown accident is not the only accident kind but it is assumed to be the most severe one.

For the accident risk calculations, there are controversial approaches from different organizations. Due to the reason that it is impossible to include all these ideas, assertions of Union of Concerned Scientists (UCS) who concludes that nuclear power is more risky than it is analyzed by scientific methods will be mentioned. Union of concerned Scientists, in fact, does not constitute the opposite side but they are criticizing the risk calculations. On the other side some other scientists claim that nuclear power plants are the safest energy sources in the world and the needed measures were taken. This part will start by introducing UCS and later the other opinions.

According to UCS, risk assessments mention merely about accident probabilities and do not include the potential accident consequences and moreover the accident probability calculations are seriously flawed.[54] What UCS's criticizings focus on are briefly described as follows;

- "The risk assessments assume nuclear plants always conform with safety requirements, yet each year more than a thousand violations are reported.
- Plants are assumed to have no design problems even though hundreds are reported.
- Aging is assumed to cause no damage despite evidence that aging materials killed four workers.

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[53] World Nuclear Association, *Safety of Nuclear Power Plants*, available at: http://www.world-nuclear.org/info/inf06.html available on: 29.08.2008.
[54] David Lochbaum. (2000). *Nuclear Plant Risk Studies: Failing the Grade*, available at: http://www.ucsusa.org/clean_energy/nuclear_safety/nuclear-plant-risk-studies-failing-the-grade.html, available on: 29.28.2008.

- Reactor pressure vessels are assumed to be fail-proof, even though embrittlement forced the Yankee Rowe plant to shut down
- The risk assessment assume that plant workers are far less likely to make mistakes than actual operating experience demonstrates
- The risk assessment consider only the threat from damage to the reactor core despite the fact that irradiated fuel in the spent pools represents a serious health hazard"[55]

Although severe core meltdown accident is put into words frequently, it has never happened yet[56]. Core meltdown accident is melting of the fuel of nuclear power reactor.[57] All scientific studies agree that by meltdown accident, there will never be distinguishable immediate or late hazard to humans[58] but public generally is not convinced about the safety of nuclear power plants against this reality. The most important reason of this is, public's unconsciousness about the containment.

> In avoiding such accidents the industry has been outstandingly successful that in 12000 cumulative reactor-years of commercial operation in 32 countries there have been only two major accidents to nuclear power plants-Three Mile Island and Chernobyl, the latter being of little relevance outside the old Soviet bloc.[59]

Mission of the containment of nuclear power plants is to keep the radioactivity inside.[60] Actually it is enough if it could keep radioactivity inside for a couple of hours because there are systems which isolates the radioactivity from atmosphere and so even if containment keep the radioactivity inside for a couple of hours, hazard which may occur from core meltdown accident would be mainly prevented.[61]

In fact, the core meltdown issue has to be observed in respect of the way that causes meltdown accident happens. Problem leading to core meltdown accident stems from the inability of a major coolant pipe, which is used to remove the heat produced in the core, to do its duty due to a certain reason; for instance, if a major coolant pipe ruptures, heat cannot be removed from the core, although the fission chain reaction is terminated, decay radiation still generates heat and this may lead core to be melt, if no emergency core cooling system starts

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[55] Ibid.
[56] Bernard Cohen, **Çok geç olmadan Bir Bilim Adamı Gözüyle Nükleer Enerji**, p. 53.
[57] Ibid.
[58] Ibid.
[59] World Nuclear Association, *Safety of Nuclear Power Plants*.
[60] Bernard Cohen, **Çok geç olmadan Bir Bilim Adamı Gözüyle Nükleer Enerji**, p. 54.
[61] Ibid.

injecting coolant into the core.[62] This inability of coolant system to take the heat from the core is called LOCA and this may lead to core melt down if LOCA happens along with the failure of all (at least four redundant and diverse) emergency core cooling systems. So the problem to deal with is LOCA. In nuclear power plants, there are some precautions to prevent such an accident but although there are these precautions, if LOCA occurs, there is another system that helps the reactor to be cooled. This is called the Emergency Core Cooling System (ECCS) which injects water to the reactor if accidents occur and Reliability of the ECCS systems was discussed during the first years of 1970s but intense researches from 1975 to 1978 proved that ECCS systems are reliable.[63]

Here, there is a need to turn back to the issue of containment because there are two disaster scenarios put forward about the containment. One of the problems is steam pressure. It is that, if a LOCA occurs, very hot water may flow into the containment and fill it with steam which increases the internal pressure and may cause explosion of ceiling of the containment.[64] Actually this scenario is not accepted as a realistic scenario by scientists and they do not take this scenario into account.

Second scenario is more realistic. It is about the postulated explosion of the hydrogen in containment. The anxiety is the same with the first scenario's anxiety. According to the researches, even if all hydrogen explodes at once, this cannot breakdown the containment and also indicators show that this is not a serious problem.[65]

I.D.1.2 Accident Probability

Probability of core meltdown accident was tried to be put forward by Rasmussen in his report of WASH-1400. In his report, he asserted that probability for a containment not to be able to stop radioactive leak and breakdown is 30%. This seems too high but this report includes the steam pressure which is not being taken into account by scientists and overestimates its risk and no other scientist find it reliable.[66] Recent studies on this issue assert that this probability is 1-3%.[67] Here there is a point that needs to be discussed. This study does not mean that risk of releasing radiation from nuclear power plants is 1-3%; it means that if a core meltdown

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[62] John R. Lamarsh and Anthony J. Baratta. (2001). **Introdution to Nuclear Engineering**, Upper Saddle River: Prentice-Hall Inc, p. 682.
[63] Bernard Cohen, **Çok geç olmadan Bir Bilim Adamı Gözüyle Nükleer Enerji**, p. 62.
[64] Bernard Cohen, **Çok geç olmadan Bir Bilim Adamı Gözüyle Nükleer Enerji**, p. 64.
[65] Bernard Cohen, **Çok geç olmadan Bir Bilim Adamı Gözüyle Nükleer Enerji**, p. 66.
[66] Bernard Cohen, **Çok geç olmadan Bir Bilim Adamı Gözüyle Nükleer Enerji**, p. 69-70.
[67] Bernard Cohen, **Çok geç olmadan Bir Bilim Adamı Gözüyle Nükleer Enerji**, p. 70.

occurs, the risk of containment failure is 1-3%. Probability of core meltdown is not included in this 1-3% and it is also asserted to be very low by scientists. When core damages considered directly (including all kinds of risks), the result is very encouraging. "The US Nuclear Regulatory Commission specifies that reactor designs must meet a 1 in 10000 year core damage frequency, but modern designs exceed this. US utility requirements are 1 in 100.000 years, the best currently operating plants are about 1 in 1.000.000 and those likely to be built in the next decade are almost 1 in 10.000.000"[68]

On the other side, scientists from the Turkish Atomic Energy Authority declare that probability of a nuclear accident is 1 to one million.[69]

I.D.1.3 Experts' Evaluations on Safety Issues

Prof. Dr. Okan Zabunoğlu's view on this issue is as follows: "Since the start of nuclear power production, 2 serious accidents occurred. The first one, Three Mile Island (TMI), occurred in the USA in 1979. The core of the reactor was damaged and radioactivity was released from the core; but it was contained in the heavy-concrete building, called "containment". Although the vicinity was evacuated and several stressful days were lived through, the TMI accident did not cause any significant effects on the environment. Effects were confined within the containment. Main damage was monetary. Seven years later, in 1986, Chernobyl accident happened in Soviet Union (in today's Ukraine). Chernobyl resulted from a series of operator errors that were made during performing some tests on the reactor. Although it would be expected that the reactor could become unstable, several warning signs were ignored and necessary measures were not taken... It consisted of a sequence of events hard to follow and believe. The worst part, however, stemmed from the lack of containment. In fact, the probability of occurrence of a Chernobyl-like accident in a Western-standard reactor is estimated to be of the same order as getting harmed by a meteor falling onto the earth. One may not find this as a realistic assessment, and it would not be easy to prove it to the public convincingly. However, it may be helpful to think along the following lines, simply visualizing life in developed countries. Keep in mind that around 85 % of nuclear reactors are located in developed countries. In all those countries, the level of welfare is higher; people are more sensitive on safety and security issues, more conscious on environmental matters, more alert to risks... And citizens of those countries find risks involved in nuclear power acceptable

[68] World Nuclear Association, *Safety of Nuclear Power Plants*.
[69] Fethiye Akyol, et al. *Public Awareness of Nuclear Energy*, available at: http://kutuphane.taek.gov.tr/internet_tarama/dosyalar/cd/3881/Nuclear/Nuclear-29.PDF , available on: 16.05.2008.

according to their own standards of living. Such considerations may at least present some food for thought"[70]

Prof. Dr. Osman Kemal Kadiroğlu asserts safety problem as follows: "There is always possibility of breakdown for all machines and those broken-down machines may harm environment and people around. This possibility is included in all man-made things. It is true for nuclear power plants too. If some abnormal events are experienced, which should not be experienced during normal operation, and then it is possible to talk about an accident. Accidents are classified according to their consequences they led. Due to reason that nuclear accidents' consequences could be very baneful, they are controlled very seriously. Controls begin before the construction begins and keep going along the nuclear power plants lifetime. Even the unessential accidents are reported to International Atomic Energy Agency (IAEA) and most of the reports are unessential. Probability of serious accident depends on the type of the nuclear power plant. Until this year, there had been two major accidents and these accidents are almost the same. Chernobyl accident was a disaster and environment was effected seriously but the other accident, Three Mile Island, had no effect on environment. If the reactor you decided to build is designed according to latter one, there will not be leaking to outer world. Probability of a major accident is about 1/1000000 and probability of major accident to lead harmful effect on environment or to kill people is less than 1/1000000."[71]

Another observation is from Prof. Dr. Sümer Şahin. He also asserts this issue in accordance with Okan Zabunoğlu and Osman Kemal Kadiroğlu. He says; "There are multi-graded security walls in nuclear power plants. Protection stars from fuel. Now, fourth generation nuclear power plants are developed and according to tests their fuel can produce 750.000 MWh day/per ton. After tests, fuel kept its integrity and stayed in perfect strength. According to calculations depending on tests, it was searched out that even if there is no protection against the fuel after it is used, radioactive material will not leak to ground for ten thousand years. As I said before, protection starts from the fuel, fuel is in a bed, bed is in a metal cover which is very safe and second grade, reactor has its own vessel 3.4 grades and finally reactor has containment. Here I'm talking about Western model. These kind of nuclear power plants do not explode, even if it explodes, there will be no radiation leaking to outside. For 50 years, nuclear energy is being used in the aircraft carriers and submarines, there are 450 nuclear

[70] Interview with Okan Zabunoğlu, Ankara, 24.11.2008.
[71] Interview with Osman Kemal Kadiroğlu, Ankara, 11.11.2008.

power plants on the ground but there are 2000 nuclear power plants in the sea. Only a Russian submarine crushed but there is no example belongs to American or European countries. These accident risks absolutely do not require us to give up from nuclear power plants. They are the safest facilities. They are safer than hydraulic, thermal facilities. The safest facilities are nuclear facilities which are constructed with Western technology."[72]

I.D.2 Nuclear Waste and Storage Issue

One of the most problematic issues of nuclear energy to deal with has always been the question of nuclear wastes. It is very important to find out whether there are solution/solutions for this problem or not. Generally it is accepted as an unsolved problem of nuclear energy producing by anti-nuclear front but experts of this issue are not as concerned as the owners of opposing ideas. Although comparisons between controversial approaches are intended to be made, it is not very necessary for this topic because anti-nuclear front's assertion rest on a simple reason. They claim that humanity has not been able to find a reliable way to neutralize the harmful effects of the nuclear waste. Due to the reason that opponent's claim does not present scientific justifications, assertions of scientists will take place. Within these offers, two of them are the most popular ones and will be tried to be evaluated. On the other side, some references will be presented to compare the wastes of nuclear power and thermal power. This comparison can be seen under the topic of "environmental effects". Some recent technologies developed, approaches and efforts to overcome the issue of nuclear waste will also be presented.

What makes nuclear waste so important is that some of them keep harmful radiating materials for very long years. For example technetium-99 is a side-product of uranium disintegration and its half life period is 200.000 years.[73] Furthermore, according to experts, all wastes must be kept away from the environment for 10 times longer than their half life period to ensure that they are safe. That is, for technetium-99, there is a need to wait for 200.000x10=2.000.000 years. Other nuclear wastes' half life vary widely and some of them are very long; for example; Phosphor-32=14 days, Americium-241=400 years, Beryllium-10=1.600.000 years, Iodine-129=15.700.000 years Potassium-40=1.000.000.000 years, Thorium-232=14.000.000.000 years, Rhenium-187=50.000.000.000 years. As mentioned

[72] Interview with Sümer Şahin, Ankara, 22.06.2008.
[73] Vural Altın, (2004), *Nükleer Enerji*, Yeni Ufuklara, (in Bilim ve Teknik Journal), Ağustos, p. 18.

above, to ensure their safety, there is a need to wait 10 times longer than what is presented here.

There are ideas offered by scientists to solve this problem and some of them are as follows: First solution is to transfer used fuels into cooling pool that was built in the area of nuclear power plant. Cooling pools protect the workers and public from radiation and takes the heat away from the fuel. Second, nuclear wastes are kept in aboveground dry facilities. In these facilities wastes are locked up in heavy containers which are containing steel, plumbic and concrete. Third offer is to bury nuclear wastes into the bedrock of ocean. This way is very useful to be rescued from wastes but here, the problem is that it is not easy to remove those wastes from the ocean. Fourth, sending and burying the wastes in faraway islands; but this is also risky because there are lots of volcanic movements in most of them and it is very expensive to send nuclear wastes to those islands. Another problem is the opposition of people who live near those islands. Fifth offer is to send nuclear wastes to space but this is also very risky because while sending them, a spaceship accident may occur and moreover there are lots of nuclear wastes and also there is need for too much hurls. So this option is not useful. Sixth option is the one that is currently being used in nuclear power plant owner states. It is to bury nuclear wastes into deep down under the ground. Finally, the seventh offer – probably the one that deserves the most attention to be paid- is transmutation of nuclear wastes into non-radioactive, so harmless materials. As intended at the beginning of this topic, two of the offers -sixth and seventh offers- will separately be evaluated because the sixth offer is the one currently being used and seventh one has been the most encouraging method on this issue.

I.D.2.1 Burying Nuclear Wastes

Burying nuclear wastes has been discussed among lots of scientists and it is agreed that this way of getting rid of nuclear wastes is the most useful and safe one. Finland has begun to bury nuclear wastes under the ground. This option is claimed to be safe due to some scientific studies and it is expected to solve this problem for a long time. Although some opposing views do not agree with this idea, most of the experts of this issue are confident. Burying nuclear wastes, of course, does not mean that all wastes will be sent underground without any measure but here the problem is whether it is possible to bury nuclear wastes in a way that they will not be harmful to the environment. To be able to assert this issue there is a need to be aware of what is planned to do technically, so, this problem will be introduced with references to technical issues without going into too deep. Here, only the most radioactive wastes will take place.

First of all, the problem must be stated clearly. From 18 months of energy producing in a big nuclear power plant, approximately 15 tons of highly radioactive waste is generated.[74] This option sees the solution at burying these 15 tons of nuclear wastes 500-1200 meters under the surface of the ground. But what some people feel anxious about is the probability of buried wastes to harm people and environment. So, there is a need to know whether it is possible or not and why. That is, the danger is somehow contact and dissolution of waste with underground water and reaching to wells, rivers and land[75]. Here, there is a need to be aware of the fact that the only way for buried wastes to harm public and environment is to get involved with the underground water.[76] To understand whether this event is possible or not, there is a need to know about the measures taken to prevent wastes to get involved with underground water. The first step is to "vitrify" this nuclear waste. This step, vitrifying, is extremely important because radioactive materials are not able to move out of glass unless the glass is abraded or broken out. Glass is abraded 1/100.000.000 in a year.[77] If glass is broken, the active nucleuses which can leak to environment are only the ones which placed at the surface of the location that breaks[78]. That is, all materials can never leak to the environment even if the glass is broken. Second step is to put these glasses in protection vessels which are made of rustproof steel and the next step- the third step- is to add stabilizer to increase the durability of waste.[79] Fourth step is to add waterproof vessel, fifth step is to the external layer against abrasion, and sixth step is a hive against being pierced and finally the seventh step is to use an external filling to keep water out.[80] All these steps constitute a construction and this construction is put in underground galleries which are in the rock formation.[81]

What is feared is the access of radioactive materials to underground water because it is said that if radioactive materials access to underground water, it will also access to water public is using. Via using two scenarios, it is possible to test the probability of danger which threatens

[74] Bernard Cohen. **Çok geç olmadan Bir Bilim Adamı Gözüyle Nükleer Enerji**, p. 132.
[75] Bernard Cohen. **Çok geç olmadan Bir Bilim Adamı Gözüyle Nükleer Enerji**, p. 133.
[76] Okan Zabunoğlu. (1994). *Nükleer Atıklar*, Bilim ve Teknik, Haziran, p. 28.
[77] Vural Altın, (2002). *Enerji*", Yeni Ufuklara, (in Bilim ve Teknik Journal), Ocak p. 16.
[78] Ibid.
[79] Bernard Cohen. **Çok geç olmadan Bir Bilim Adamı Gözüyle Nükleer Enerji**, p. 139.
[80] Ibid.
[81] Vural Altın, *Enerji*, p. 16.

public health due to burying method. First scenario assumes underground water to reach radioactive material and second scenario assumes radioactive material to get out of the construction in which it was confined and reach to humidity. Both scenarios want to find out if radioactive materials could reach public water and harm people and so, after evaluating the scenarios, it will be supposed that radioactive materials got involved with underground humidity and it will be tried to deduce whether this humidity (which has radioactive materials with it) may pose a danger to environment.

Starting with the first scenario; when it is supposed that some water reached to rock formation, it should firstly abrade the at least the half of the rock[82] in which the protection construction is stated, and then pass beyond all those seven obstacles. Furthermore there is a point for which a major attention must be paid. The water which is supposed to excess all these obstacles is not something like river going underground; this underground water is actually humidity. So, its abrasion power is much poorer than normally leaking water which is seen around us. Here at this point, the glass must be briefly described. If the underground humidity somehow exceeds other obstacles and reaches finally the glass, (which is expected to take thousands of years) it will probably have to stop at that point. This guess depends on an antique proof. Small glass sculptures from old Babel were found in riverbeds in leaking water and they were not abraded although they were washed by river waters for 3000 years.[83] It also must be remembered that the glass is abraded 1/100.000.000 in a year and the glass which is used to confine nuclear waste will be subjected to the abrasion power of humidity, which is very poor when it is compared with the leaking water. From all these information, scientists are generally convinced that accession of underground humidity to radioactive material is almost impossible for the epoch along which radioactive materials have to be confined.

When it comes to the second scenario, it will tried to be found out whether radioactive materials are close to exceed those seven barriers and get out of the construction. For radioactive materials, the first barrier is glass in which the waste was confined. As the glass gets dissolved, waste comes into open and this is expected to take 100.000.000 years for waste to come into open completely as mentioned before. Even if waste could exceed glass, it will have to face with a wall made of rustproof steel and only 1 cm stainless steel can separate

[82] Bernard Cohen, **Çok geç olmadan Bir Bilim Adamı Gözüyle Nükleer Enerji**, Figure 18, p. 138.
[83] Bernard Cohen, **Çok geç olmadan Bir Bilim Adamı Gözüyle Nükleer Enerji**, Figure 18, p. 139.

radiation from environment for 1000 years[84]. Here, the problem is, rustproof steel becomes fragile when it receives high radiation but it does not mean all radiation will escape at once when it is broken. Granted that radiation could exceed this rustproof steel, it also will have to exceed pass beyond the rock in which this construction was embedded. Here there is a point which must be repeated and kept in mind. As Vural Altın points, if the glass and stainless steel are broken, the only nuclei which can leak to the environment are the ones which placed at surface. So the amount of waste which can leak to the environment will be very low. As a result, for nuclear wastes, it will take very long time to reach underground humidity and the amount will probably be at the levels that are not harmful.

So, there is a need to observe the situation that what would happen if radioactive materials could have ability to access underground humidity. People, who are anxious, assume that underground humidity would move vertically and reach to rivers which supply daily use of water. This anxiety is not realistic because, underground humidity cannot move vertically, it moves horizontally and its speed is 25-30 cms in a day. While the place to bury nuclear wastes is selected, this place will be chosen as far as possible place to underground water. So, the underground humidity with nuclear waste can reach to underground water which is 100 km away, it will take 1000 years. Moreover, these nuclear waste's nuclei are heavier than water and so the underground humidity can never easily carry these materials away from its places.[85] Most of the radioactive materials are expected to stay with the rocks. Of course there is a need for further information about related materials' (glass, stainless steel and the others) behavior under high levels of radiation.

I.D.2.2 Transmutation

Transmutation is converting dangerous radioactive materials into harmless materials.[86] Method of transmutation has been paid great attention recently; for instance, while research institutions in France are legally in charge of studying on transmutation technology, this kind of work is going on in U.S.A; England is also planning to start this program and moreover Japan and Europe pursuing these studies.[87] Via this method, some improvements were achieved and it would be better if this method's potential is described with an example. The most striking instance is obtained from technetium-99. As presented above, technetium-99 is

[84] Vural Altın, *Enerji*, p. 16.
[85] Ibid.
[86] Vural Altın, *Nükleer Enerji*, p. 18.
[87] Ibid.

a very radioactive nuclear waste with a very long half life period; 200.000 years but transmutation method has converted this very radioactive waste into completely harmless material. Scientists added a single neutron to technetium-99 and transformed it to technetium-100[88]. Half life of technetium-100 is only 15.8 seconds. That is, 200.000 years diminished to 15.8 seconds. But, however there is great success on technetium, this technology is still pre-mature and being tried yet.

Transmutation is tried to be advanced in two ways. First is the laser technology and second bombardment of radioactive waste by neutrons and protons.[89] Both of these ways have their problems. For example, although laser technology was able to convert iodine-129, whose half life is 15.700.000 years into iodine-128, whose half life is couple of minutes; there is a need for very powerful system because the amount of iodine-129, whose half life was diminished from 15.700.000 years to couple of minutes, was less than 1/1.000.000.000 of 1µgram iodine.[90] So, laser technology is not a certain solution currently.

The second way, which seems highly encouraging, is not consisting of just one way and they are being advanced. There are some different types of propositions on transmutation issue. One of these ways is to make changes in the design of currently used nuclear power plants and make way for transformation via neutrons which are generated as a result of fission.[91] Scientists work on this kind of nuclear power plants. Another devise on this issue is to draw benefit from accelerators. Accelerators, in this way, are expected to disintegrate heavy and unstable atoms, which are called trans-uranic elements (TRUs), into smaller stable nuclei. Although this way also requires energetic neutrons to be used, in old times these energetic neutrons could not be produced but the new generation accelerators could almost overcome this issue.[92] While old accelerators could convert electrical energy into "particle bunch" no more than 5%, new generations are able to convert 50% of electrical energy.[93]Another transmutation machine was devised at the end of 1999s with the help of Russian scientists.

The most popular approach to this issue is using accelerators, which is called accelerator-driven system (ADS) and Japan, Italy, France, Russia, Germany and U.S.A. work on it. It is

[88] Ibid.
[89] Vural Altın, *Nükleer Enerji*, p. 19.
[90] Ibid.
[91] Vural Altın, *Nükleer Enerji*, p. 20.
[92] Ibid.
[93] Ibid.

quite expectable that as nuclear energy becomes more serious alternative for energy supply, all these studies will be paid more attention.

Since the first nuclear power plant was established and started to be used in 1957 in U.S.A, technology on nuclear sciences advanced extremely. Today, both burying and transmutation methods are very encouraging for solving the nuclear waste problem. As the time passes, this technology will advance faster than it is used to since 1957. Today, scientists have more opportunities than their predecessors had had and so, next decades will probably offer better, safer and stronger solutions to this problem. On the other side, even if Turkey establishes nuclear power plants which will take a long period, it will face nuclear waste problem decades after. During this period, nuclear waste problem is expected to be solved.

I.D.2.3. Experts' Evaluations on Nuclear Waste and Storage Issue

Okan Zabunoğlu's assertion is as follows: "First of all, there is a need to know what the nuclear fuel is. Nuclear fuel is in the form of long, thin rods bundled together, called "assembly". The rods are usually made of Zircaloy (an alloy of zirconium) and contain fuel cylinders, called "pellet". Each pellet is about the size of the uppermost part of our little finger and each rod is like a 3.5-4.0 meter-long little finger. When the reactor cannot be made critical with its existing inventory (in other words, when it can no longer be operated), about one third of the assemblies are replaced by fresh fuel. Those taken out are "spent fuel". Spent fuel is of the same shape and form as fresh fuel, and that is often what is referred to as nuclear waste. That is, "long, thin metallic rods" are what we are talking about. There is no other high-activity waste or emission from nuclear power plants. About 96 % of spent nuclear fuel consists of valuable materials (95 % uranium and 1 % plutonium), the remaining 4 % is fission products and other actinides. What happens in a nuclear reactor causes 5 % of the fuel to change its composition. And one fifth of this 5 % is a valuable material (plutonium) that did not exist in fresh fuel and does not exist in nature. Spent fuels are stored in water pools on reactor site. Pool storage has been practiced for years with no harmful effects to workers or environment. In the long-term, it is planned to dispose HLW and/or spent fuel into geological formations deep underground. Technically, geological disposal has found general acceptance around scientific circles, and risks associated with it are estimated to be much lower than risks encountered in alternative electricity-production schemes. For a country like Turkey, it would not be meaningful to talk about a nuclear waste issue. To be clearer, let me give you a numerical example. In 2005, the total installed capacity of Turkey was around 40000 MW-electric and the total generation amounted to 160 billion kWh. If this amount of electricity were to be produced only by nuclear power plants, about 23 plants (each with a power of 1000 MWe) would be required. In that case, the total amount of spent nuclear fuels discharged from those 23 plants during about 20 years would hardly fill an Olympic swimming pool (with a depth of nearly 10 meters). That tells us about the size of the spent fuel (or waste) problem. It will take many years for us to encounter such an issue, many years after we build and operate tens of reactors."[94]

Prof. Dr. Yalçın Sanalan also thinks that this issue will not cause problem for Turkey. He says that "nuclear wastes are dangerous. Why? It is because; its radiation does not come to an end. Again, it is not a severe problem for us because material will come from America or France or England… They already want wastes back. Probably we will sell it to America. These wastes will somehow definitely be used by them."[95]

Osman Kemal Kadiroğlu's assertion is as follows: "We engineers called this as waste problem. We used to think about the methods, processes and so on. Actually, what people call problem is boredom which cannot be solved, but, here what we engineers call as problems are in fact not problems because we know the solutions but we have not chosen a certain one. All the nuclear wastes can be stored in a football stadium. One important thing to note is that, it is not economic to apply reprocessing methods. Some of the countries like France, China, England reprocess nuclear wastes but America stores them and thinking about reprocessing them in the future.

Here it must be emphasized that reprocessing the nuclear wastes diminishes the amount of nuclear waste and shortens the decaying period. Also, nuclear wastes come out of the reactor three years after you loaded it and these wastes have to be stored around the reactor for 20 years. That is, we need to choose one of the solutions 20 years after."[96]

Following idea belongs to Sümer Şahin. "Because nuclear energy is the densest kind of energy, wastes of nuclear energy are also at the lowest level. According to the information given by International Energy Agency, amount of all nuclear reactors' radioactive waste is

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[94] Interview with Okan Zabunoğlu.
[95] Interview with Yalçın Sanalan, Ankara, 22.10.2008.
[96] Interview with Osman Kemal Kadiroğlu.

about 500 cubic meters. If we remember that there are almost 450 nuclear power plants, there are almost $1m^3$ wastes for each of the nuclear power plant in 1 year. It is very easy to control this waste. Dangerous waste is not only nuclear waste. Chemical wastes are also very dangerous, medical wastes are also very dangerous. Amount of production of the most poisonous industrial wastes per year in the world is 10 million m^3. They are not less dangerous than nuclear wastes and they are even more dangerous, they kill immediately, cause every kind of genetic trouble. Amount of other secondary industrial wastes is 1 billion m^3. That is, if we compare the wastes of nuclear facility with other wastes produced by industry, amount of nuclear wastes are ignorable."[97]

I.D.2.4 Safety Culture

Safety culture is a perception which directs minds to safety issues at every level from design to construction due to significance of facility. The main point of safety culture is to prevent human error via benefitting from human mind's ability of detecting and eliminating potential problems. What is expected from safety culture is to improve attitude that is necessary to ensure safety requirements. From managers to staff, members of all levels must concentrate on minimizing the probability of problems.

The idea of safety culture came in to agenda after Chernobyl and this idea asserts that lack of knowledge and understanding of risk by employees causes disasters. The report published by International Atomic Energy Agency's report in 1991, whose name is Safety Culture, makes a definition as follows:

> Safety Culture is that assembly of characteristics and attitudes in organizations and individuals which establishes that, as an overriding priority, nuclear plant safety issues receive the attention warranted by their significance.[98]

Safety culture requires all staff, who involved in safety issue, to dedicate themselves to the works which has a bearing on the safety of nuclear power plants.[99] That is safety culture requires more than written rules, strict implementation of practices because safety culture requires adoption in safety issue mentally as much as possible and requires staff to be in

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[97] Interview with Sümer Şahin.
[98] International Energy Agency. (1991). *Safety Culture*, IAEA Safety Reports, Vienna, available at: http://www-pub.iaea.org/MTCD/publications/PDF/Pub882_web.pdf, available on: 09.05.2009. p. 4.
[99] Ibid.

alertness. Way to this goal requires every organization with a bearing on safety issues to make its responsibility well known and understood in a safety policy statement.[100] So, it needed to be as clear as possible. "Organizations with a positive safety culture are characterized by communications founded on mutual trust, by shared perceptions of the importance of safety and by confidence in the efficacy of preventive measures"[101] Atomic Energy Agency's Report on safety culture also manifests universal features of safety culture. These are as follows[102]:

— *Individual awareness* of the importance of safety.

— *Knowledge and competence,* conferred by training and instruction of personnel and by their self-education.

— *Commitment,* requiring demonstration at senior management level of the high priority of safety and adoption by individuals of the common goal of safety.

— *Motivation,* through leadership, the setting of objectives and systems of rewards and sanctions, and through individuals' self-generated attitudes.

— *Supervision,* including audit and review practices, with readiness to respond to individuals' questioning attitudes.

— *Responsibility,* through formal assignment and description of duties and their understanding by individuals.

To reach aimed goals, there are some requirements that must be fulfilled by different bodies. According to Atomic Energy Agency's report, they were listed as requirements at policy level, requirements on managers and response of individuals.[103] According to report, the highest level affecting nuclear power plants' safety is the legislative level at which national basis for safety culture is set and governments has a major responsibility of protecting public from danger related to nuclear plants.[104] In the report, it is evaluated that one of the most important

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[100] International Atomic Energy Agency. *Safety Culture*, p. 7.
[101] Hamaideh, Shaher H., (2004), *Safety Culture Instrument: A Psychometric Evaluation*, Ph.D. thesis, University of Cincinnati, available at: http://www.ohiolink.edu/etd/send-pdf.cgi/HAMAIDEH%20SHAHER%20H.pdf?acc_num=ucin1091123297, available on: 08.05.2009.
[102] International Energy Agency. *Safety Culture*, p. 5.
[103] Ibid.
[104] International Atomic Energy Agency. *Safety Culture*", p. 7.

necessity of safety culture is sufficient experienced staff which lets duties to be carried out in good health and necessary resources must be devoted for the training of the staff.[105]

I. D.3 Economics of Nuclear Power

Another subject that worth to observe is the cost of building and operating a nuclear power plant. Under this topic, issue of whether nuclear power plants are preferable to other kinds of energy sources will be examined. So, here, a comparison will take place among coal, oil, natural gas, and nuclear in respect of costs of fuel and electricity generation

In contradiction to common knowledge that nuclear power is more costly than other forms of energy, nuclear energy is competitive with fossil fuel for electricity generation despite relatively high capital costs and the need to internalize the waste disposal and decommissioning costs and moreover if the social health and environmental costs of fossil fuel are taken into account, producing electricity with nuclear energy is outstanding.[106]

I.D.3.1 Costs

Costs of generating electricity vary considerably depending on countries' access to energy sources. While direct access to fossil sources reduces the costs of energy obtained by the fossil fuels, most of the countries do not have this option and because of this reason, nuclear arises as a competitive alternative for those countries like Turkey. Nuclear fuel costs including spent fuel management are on average 0.5 US-cent/kWh.[107] Fuel accounts for a relatively small part of nuclear generation costs (approximately 20%). In recent years, fuel cycle costs decreased significantly leading to reduced fuel costs for all types of nuclear power plants globally.[108] On the other side, another vital point comes across that, technical improvements such as the introduction of advanced fuel designs can allow higher burn up levels, leading to efficiency gains and a reduction in costs and it is estimated that a 40% reduction in nuclear fuel cycle costs has occurred since 1990 in real terms.[109] From 2002 to 2006, uranium prices have increased dramatically (soared from 20 US$/kg at the lowest in

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[105] International Atomic Energy Agency. *Safety Culture*", p. 4.
[106] World Nuclear Association. (2009). *The Economics of Nuclear Power*, available at: http://world-nuclear.org/info/inf02.html, available on: 20.04.2008.
[107] World Energy Council. (2007). *The Role of Nuclear Power in Europe*, available at: http://www.worldenergy.org/20.asp, available on: 23.04.08 p. 18.
[108] Ibid.
[109] Ibid.

2002, to more than 50 US$/kg in 2006) and this trend is set to continue but its effects on electricity generation are small because fuel's contribution to the overall costs of electricity produced is relatively small, and there are rapid scientific advances, so even a large fuel price escalation will have relatively little effect.[110] For example, doubling of uranium market price would increase the marginal generating costs of nuclear between 5%-10% but doubling of gas market prices would increase generating costs 70%-80%. According to the world energy council, for a large pressurized water reactor (PWR), in absolute terms, a fivefold increase in Uranium price will only double the fuel cost (expressed in US cents) from 0.25 to 0.50 cents/kWh, a 10% increase in the total generating cost (assumed here to be 2.5 cents/kWh)[111] Moreover, front-end costs to fuel costs must be added up. Front-end expenses are uranium purchase, conversion to fluoride, enrichment, fuel element manufacture and back-end expenses, spent fuel management, high-level waste storage and final disposal and finally transport.[112] Table-2 shows the fuel costs in total generating costs for nuclear, Gas CCGT and coal plants.

> For the next 40 years, a range of 50 to 80 US$/kg seems likely considering the expected start-up of new low-cost mines which makes a uranium contribution of 1.5 to 2.5 €/MWh.
> Back end services include spent fuel management and ultimate high-level waste conditioning and disposal. The cost varies from 1 to 4 E/MWh[113]

Table-2: Fuel Costs in Total Generating Costs[114]

	Nuclear	Gas CCGT*	Coal**
Fuel (€/MWh)	4.5 to 8.5	27 to 45	15-22

* CCGT efficiency = 60% on LHV, gas at 3.6 to .0 Euro/Gigajoule
** Coal Plant efficiency = 42% on LHV, coal at 45-70 US$/ton CIF, 6000kcal/kg

Due to the reason that Uranium cost is less than 10% of overall costs of nuclear generation, the fuel cost is not sensitive to movements in commodity prices. Table-3 is exposing this situation.

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110 World Nuclear Association. *The Economics of Nuclear Power*.
111 World Energy Council. *The Role of Nuclear Power in Europe*", p. 18.
112 World Energy Council. *The Role of Nuclear Power in Europe*", p. 60.
113 Ibid.
114 Ibid.

Table-3: An Example of Uranium Price Influence on Generating Cost (€2001/MWh)[115]

Uranium Price	26 USD/kg	52 USD/kg	104 USD/kg
Generation Cost	3.7	4.4	5.9
Fuel (burn-up 60 GWd/t)	27.7	28.4	29.9
Total	-2.5%	-	+5%

Source: DGEMP 203 8% discount rate 1 €=1US$, Series of EPR, fuel (NB These estimates include all front-end expenses, as well as back-end provisions for used fuel management.)

One of the factors which effect the electricity production via nuclear power plants is "availability". Increased availability results in an increase in the production of electricity which means a decrease in the production of electricity costs.[116] Since 1990, availability climbed to greater levels both in US and Europe. While in US, from 1990 to 2005, availability factors rose from 71% to 90%, this factor rose from 74% to 84% in Europe and Russia this is 66% to 78%[117] These increases from 1994 to 2004 are equivalent to adding 18 large (1000 MWe) reactors to the US fleet and 22 large units for whole Europe and moreover operation and maintenance costs per kWh have decreased as availability factors have increased.[118]

When costs of generating energy in respect of energy outputs of fossil (coal and fuel oil) and nuclear fuel are compared, it is obvious that cost of nuclear power plants fuel is lower than others. For example, when 1000MWh as the reference value taken into account, comparison shows the results as follows;

1000MWh power plant's requirements for 1 year: (Table-4)

Table-4: Fuel Requirements of Thermal Reactors[119]

Fuel Oil	Coal	Uranium
2.000.000 tons	2.600.000 tons	30 tons

[115] World Energy Council. *The Role of Nuclear Power in Europe*, p. 61.
[116] World Energy Council. *The Role of Nuclear Power in Europe*, p. 17.
[117] Ibid.
[118] Ibid.
[119] TAEK. *Sürdürülebilir Kalkınma ve Nükleer Enerji*, available at: http://kutuphane.taek.gov.tr/internet_tarama/dosyalar/cd/3915/bolum4.html available on: 26.04.2008.

The most important technical factor, which affects the costs according to world energy council, is the level of fuel burn up.[120] Increasing fuel burn up contributed significantly to the reduction in the fuel cycle costs and higher burn up levels also leads fuel-load cycle periods to be prolonged. [121] Burn up levels has advanced since the establishment of the first nuclear reactor and it will probably reach higher fertility as the nuclear science advance. So, numbers given above to compare fuel oil vs. Coal vs. Uranium will probably change in the future and this change will be in favor of nuclear.

Another point that must be mentioned is the subject of "external costs". "External cost arises when social or economic activities have an impact on society not fully accounted for in producer costs or compensated for through market price."[122] For instance, as a coal power plant operates, it threatens public health but decision makers of the plant do not take this into account. So, although these are real costs to society, here the environmental costs are external. When nuclear power is considered as an example to external costs, it includes health and environmental damages from uranium mining, and further processing of uranium as well as waste management for spent fuel.

According to this information, it can be deduced that, the less external costs a power plant cause, the more preferable it is. Table-5 below represents the external costs of electricity production in Euro-cents/kWh. Due to reason that the table reflects national conditions, all numbers have uncertainties.

Table-5: External Costs for Electricity Production in Euro-cents/kWh[123]

	Coal/Lignite	Peat	Oil	Gas	Nuclear	Biomass	Hydro	PV	Wind
Austria	-	-	-	1-3	-	2-3	0.1	-	-
Belgium	4-15	-	-	1-2	0.5	-	-	0.6	0.05

[120] World Energy Council. *The Role of Nuclear Power in Europe*, p. 17.
[121] Ibid.
[122] World Energy Council. *The Role of Nuclear Power in Europe*, p. 40.
[123] World Energy Council. *The Role of Nuclear Power in Europe*, p. 41.

Denmark	4-7	-	-	2-3	-	1	-	-	0.1
Germany	3-6	-	5-8	1-2	0.2	3	-	0.6	0.05
Finland	2-4	2-5	-	-	-	1	-	-	-
France	7-10	-	8-11	2-4	0.3	1	1	-	-
Greece	5-8	-	3-5	1	-	0-0.8	1	-	0.25
Ireland	6-8	3-4	-	-	-	-	-	-	-
Italy	-	-	3-6	2-3	-	-	0.3	-	-
Netherlands	3-4	-	-	1-2	0.7	0.5	-	-	-
Norway	-	-	-	1-2	-	0.2	0.2	-	0-0.25
Portagual	4-7	-	-	1-2	-	1-2	0.03	-	-
Spain	5-8	-	-	1-2	-	3-5	-	-	0.2
Sweden	2-4	-	-	-	-	0.3	0-07	-	-
UK	4-7	-	3-5	1-2	0.25	1	-	-	0.15
Average	4.1 - 7.3	2.5 - 4.5	4.4 - 7	1.3 - 2.3	0.4	1.2 - 1.6	0.4 - 0.5	0.6[12]	0.1 - 0.2[1]

Source: ExternE Study by the European Commision, 2001

When the Table-5 is investigated, it is apparent that nuclear option has lower external costs in compare with other kinds of energy sources but the biomass in Netherlands.

From all these data, it is possible to deduce that technological advances reduced costs of generating electricity although prices increase. In the future, it can be expected that technological advances would help us to diminish costs more even if new mines would not be opened.

When it comes to decommissioning, it is clear that it is not a big part of the cost of generating electricity from the nuclear power plants. According to the evaluation of world energy council's report, decommissioning costs do not fundamentally alter the economics of nuclear power because the cost of decommissioning constitutes the %3 of investment[124]. "For most reactors to be built, the contribution of decommissioning to levelised lifecycle generation cost would be 0.5 to 1€MWh at most."[125]

I.D.3.2. Experts' Evaluations on Costs

Okan Zabunoğlu's assertion is as follow; "Fixed capital cost of a NPP is high, higher than a comparative coal plant and about the same as a hydro-electric plant. Capacity factor is a measure of the rate of return on investment, and a higher rate of return is always desirable. And when the investment is greater, it is more desirable. When it comes to operating costs, nuclear and coal have about the same contribution to the cost of power. As for fueling costs, nuclear is considerably advantageous. The comparison between the costs of power from nuclear and coal depends on quality and price of coal, which changes from mine to mine, from region to region, from country to country. In general, nuclear is slightly cheaper, but that should not be taken as a rule."[126]

Osman Kemal Kadiroğlu says that "There is something being misunderstood. To determine whether nuclear is cheap or expensive, we need to look at the costs of kWh of generated electricity and it is measured by standardized unit: cent per kWh; US cent. Cost of electricity generated in new nuclear power plants is 3.5-4 cent. So, what does it depend on? First investment capital is high and this capital is generally taken from banks. If the rate of interest is high, cost of electricity will be high too. In addition, cost of fuel, cost of "waste management", and cost of decommissioning are added. After all these costs are calculated, overall cost of generated electricity is 3.5-4 cent. When compared with other energy sources, picture is almost as follows: Cost of natural gas is 3.4-4 cent, coal 4-5 cent, petroleum 11 cent. That is nuclear power plants are almost the cheapest. There is also an additional advantage. Nuclear power plants' fuel is very cheap because of its abundance. Now, Uranium is very cheap and abundant but even if fuel costs change, costs will not be affected more than 30% of raise. When we think natural gas, petroleum or coal, we see that 60-70% of the cost of

[124] World Energy Council. *The Role of Nuclear Power in Europe*, p. 62.
[125] Ibid.
[126] Interview with Okan Zabunoğlu.

electricity generation comes from fuel costs. If gas or petroleum prices increases, you have to increase electricity prices but it is not true for nuclear."[127]

Sümer Şahin claims that "First investment costs are high in nuclear power plants but when we consider this issue in terms of facilities' life, the cost for unit kWh, nuclear power plants is the cheapest because fuel cost is low in nuclear power plants. Wind power generated by wind turbines is linear with the third power of the wind's speed. That is, if speed of wind decreases 1/2, power will decrease to 1/8, if it decreases to 1/3, power will decrease to 1/27. Wind turbines' have a load factor, at most, 20%. That is, if you build a 1 MW_e wind turbine, under the best conditions, 0.2 MW_e power will it generated, in average. Capacity factor in today's nuclear power plants is more than 90%. The load factor of new nuclear power plants built by South Korea is claimed to be 98%. That is, 1000 MW_e nuclear facility equals to 5000 MW_e wind power plant. When you build 1000 MW_e nuclear power plant, it takes 4 km^2 of territory. 1 MWh wind turbines' wing sizes are 100 m. You need 5000 wind turbine at sufficient distances to generate electricity equals to one single 1000 MW_e nuclear power plant. It is very infertile. The nuclear power plants pay investment cost back within one to three years. Modern nuclear power plants' life is calculated to be 60-100 years. It means, after you take your money back within 1 or 3 years, than it will pay for you for the rest of its life.[128]

I.D.3.3. Environmental Effects

Environmental effects of nuclear power plants are one of the subjects that have been discussed without referring to the scientific data and as a result of this problem, it is generally assumed that nuclear power plants are very harmful to environment but this does not reflect the reality.

There are some essential criteria that must be considered while evaluating the environmental effects of an electricity generating system. These are, natural source consumption, system's effect on atmosphere, system's effects on water sources, usage of territory, secure transportation, responsibility in waste management, recycle in wastes.[129] When we bear these

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[127] Interview with Osman Kemal Kadiroğlu.
[128] Inerview with Sümer Şahin.
[129] B. Gül Göktepe. *Enerji Sistemlerinin Çevresel Risk Algılaması*, available at: http://kutuphane.taek.gov.tr/internet_tarama/dosyalar/cd/4115/pdf/257.pdf, available on: 26.04.2008.

criteria in mind, nuclear energy is the most convenient option in respect of energy-environment-economy coactions.[130]

Moreover, according to Ferruh Ertürk's assertion, fossil energy sources cause important environmental problem. Ferruh Ertürk exhibits that while evaluating the environmental effects of electricity generating power plants, there are levels that must be considered. These levels are extraction of fuel, transportation construction of power plant energy production, elimination of liquid, gas and solid wastes.[131]

Ferruh Ertürk believes that the Leopold matrix is helpful for comparing the environmental effects of fossil and nuclear fuels. The table-6 below allow us to see the comparison of nuclear and fossil fuels via Leopold matrix. In these matrices, numbers at upper-left shows the intensity of effect and numbers at down-right shows the importance of the effect.

Table 6: Environmental Effects of Coal, Oil and Nuclear Power Plants According to Leopold Matrix [132]

1. Environmental Effect Evaluation of Coal Fired Power Plant

Fuctions / Effects	Source Extraction	Fuel Processing	Transportation	Energy Transformation	Energy Transportation
Air pollution	2 / 1	2 / 1	1 / 2	10 / 10	1 / 1
Water pollution	8 / 7	9 / 8	2 / 1	9 / 7	1 / 1
Solid Wastes	10 / 10	8 / 10	1 / 1	10 / 9	1 / 1

[130] Ibid.
[131] Ferruh Ertürk. (2007). *Nükleer Enerji ve Çevre*, Bilim ve Ütopya, Ocak, Volume 51, p. 54.
[132] Ferruh Ertürk. (2007). *Nükleer Enerji ve Çevre*, Bilim ve Ütopya, Ocak, Volume 51, Figure 2.4, p. 55-56-57.

Usage of Territory	**10 / 9**	**7 / 6**	**8 / 7**	**9 / 8**	**9 / 8**
Flora	**10 / 9**	**6 / 7**	**7 / 8**	**9 / 10**	**6 / 7**
Fauna	**10 / 9**	**5 / 6**	**6 / 7**	**9 / 8**	**6 / 6**

2. Environmental Effect Evaluation of Oil Power Plant

Fuctions / Effects	Source Extraction	Fuel Processing	Transportation	Energy Transformation	Energy Transportation
Air pollution	**2 / 1**	**5 / 4**	**8 / 4**	**10 / 10**	**1 / 1**
Water pollution	**8 / 7**	**9 / 8**	**9 / 10**	**9 / 7**	**1 / 1**
Solid Wastes	**2 / 1**	**2 / 1**	**1 / 1**	**1 / 1**	**1 / 1**
Usage of Territory	**9 / 8**	**9 / 8**	**10 / 9**	**9 / 8**	**9 / 8**
Flora	**8 / 9**	**7 / 8**	**8 / 9**	**8 / 9**	**6 / 7**
Fauna	**7 / 8**	**7 / 8**	**8 / 9**	**8 / 9**	**6 / 6**

3. Environmental Effect Evaluation of Natural Gas Power Plant

Fuctions / Effects	Source Extraction	Fuel Processing	Transportation	Energy Transformation	Energy Transportation
Air pollution	2 / 1	2 / 1	1 / 1	10 / 10	1 / 1
Water pollution	3 / 2	3 / 2	1 / 1	9 / 7	1 / 1
Solid Wastes	2 / 1	2 / 1	1 / 1	1 / 1	1 / 1
Usage of Territory	9 / 8	4 / 3	9 / 8	9 / 8	9 / 8
Flora	3 / 4	2 / 3	7 / 8	4 / 5	6 / 7
Fauna	2 / 3	2 / 2	5 / 6	4 / 5	6 / 6

4. Environmental Effect Evaluation of Nuclear Power Plant

Fuctions / Effects	Source Extraction	Fuel Processing	Transportation	Energy Transformation	Energy Transportation
Air pollution	3 / 2	2 / 1	1 / 1	1 / 1	1 / 1

Water pollution	**3** / **2**	**2** / **1**	**1** / **1**	**9** / **7**	**1** / **1**
Solid Wastes	**7** / **8**	**9** / **10**	**1** / **1**	**10** / **10**	**1** / **1**
Usage of Territory	**5** / **4**	**4** / **3**	**1** / **1**	**9** / **8**	**9** / **8**
Flora	**3** / **4**	**2** / **3**	**2** / **2**	**1** / **1**	**6** / **7**
Fauna	**3** / **4**	**2** / **3**	**2** / **2**	**1** / **1**	**6** / **6**

4. **Comparison of Different Types of Power Plants in Respect of Environmental Effects**

Type of Power Plant	Total Intensity of Environmental Effects	Total Importance of Environmental Effects
Coal	**192**	**185**
Fuel Oil	**188**	**181**
Natural Gas	**121**	**116**
Nuclear	**108**	**105**

These tables show the differences clearly and presents that the nuclear power plants are more favorable than fossil fueled power plants. Also, it must be noted that the least value of this matrix is 60 because there are 60 numbers in each table and the smallest number that can be given is 1. That is, if there would be a free and limitless energy source, which has no harmful effects and no transportation costs, it would be marked 60.

Another comparison put forward by world energy council also implies the same thing as Ferruh Ertürk's study. The figure-3 shows the CO_2 emissions of different types of energy sources in their life cycle.

Energy	gCO_2 emitted per kWh (life cycle analysis)
Coal	800 – 1050 (different technologies)
Gas	430
Photovoltaic	60 – 150 (different manufacturing countries)
Wind	3 – 22 (different manufacturing countries)
Nuclear	6
Hydraulic	4

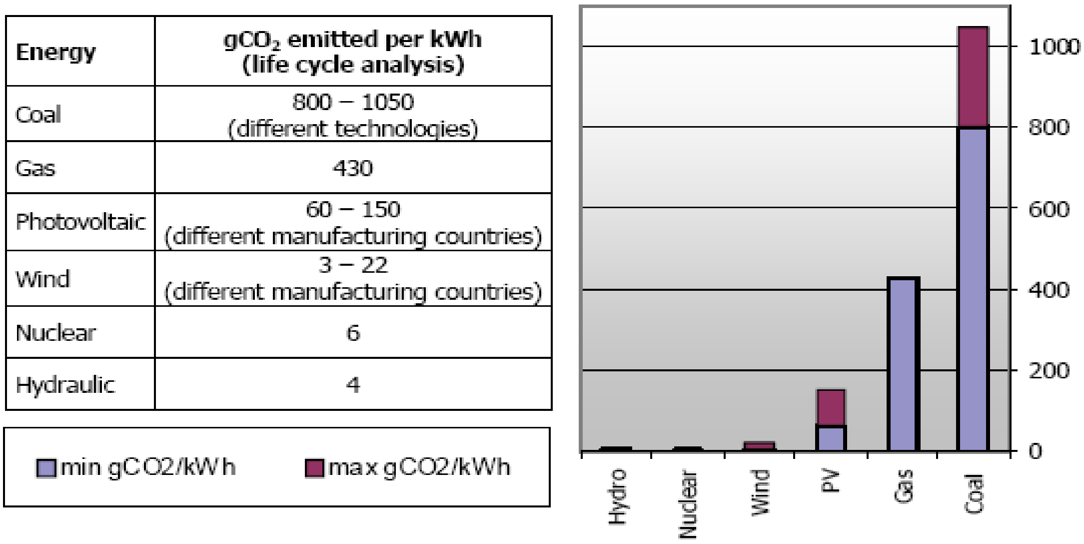

Figure 3: CO_2 Emissions of Different Types of Energy Sources in Their Life Cycle[133]

PART II NUCLEAR TECHNOLOGY AND ITS APPLICATIONS

Nuclear technology, of course, is not only consisting of nuclear energy but also it comprises various fields of scientific studies. These fields of studies are probably more important according to the majority of scientists than the electricity which is generated by nuclear power plants. When these fields of application considered, it is obvious that there are lots of fields but in this thesis, some introductory information about 5 main topics will be given. These application fields of nuclear technology are medical applications, industrial applications, researches (accelerators, research reactors), agriculture and stockbreeding and finally water and environment.

II.A Medical Applications

This is one of the most important and necessary fields of study of nuclear science. As is known well, there is a discipline called nuclear medicine. For more than 100 years, ionizing

[133]World Energy Council. (2007). *Performance of generating Plants*, World Energy Council, available at: http://www.worldenergy.org/documents/pgp_es_final_cmyk_print.pdf available on: 14.05.2008.

radiation has been increasingly applied in medicine and now it is one of the most essential parts for diagnosis and therapy.[134] Globally, about the radioisotope applications in health, there is a growth in the number of procedures involving the use of isotopes and with this a commensurate growth in the number of procedures requiring different isotopes.[135] Nuclear medicine techniques help doctors to observe inner parts of human body via combining computers, detectors and usage of radioactive materials.[136] The main applications are to attain vision by radiation and to destroy tumors and cells.[137] These techniques are

- Positron Emission Tomography (PET)
- Single Photon Emission Computer Tomography (SPECT)
- Cardiovascular Visualization[138]

The illnesses determined by nuclear medicine are listed as follows:

- Tumors
- Aneurism
- Disorder in some tissues and missing blood
- Anomaly of blood cells, anomaly of thyroid or lung functions and insufficient functioning of these tissues
- Other illnesses of goiter and thyroid
- Illnesses of bone and joints

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[134] UNSCEAR. (2000). *Annex D: Medical Radiation Exposures*, available at: http://www.unscear.org/docs/reports/annexd.pdf , available on: 10.05.2008, p: 295.
[135] International Atomic Energy Agency. (2007). *Nuclear Technology Review 2007*, available at: http://www.iaea.org/OurWork/ST/NE/Pess/assets/ntr2007.pdf available on: 04.05.2008, p. 29.
[136] Türkan Yöney, (2003), *Nükleer Tıp Nasıl Çalışır*, Bilim ve Teknik, Kasım, p. 102.
[137] TAEK. *Tıbbi Uygulamalar*, available at: http://www.taek.gov.tr/bilgi/bilgi_maddeler/tibbiuygulama.html, available on: 10.05.2008.
[138] Türkan Yöney, *Nükleer Tıp Nasıl Çalışır*".

- Congestion of bile way[139]

II.B Industrial Applications

Industrial applications of nuclear technology are also wide. For example, by nuclear techniques' applications in industry, it is possible to check the quality of industrial goods, leakages and splits can be determined via the usage of radioactive nuclei which are called "tracer".[140] Also, level, intensity, humidity measurements of production of steel, rubber, paper, plastic, sugar, and cement can and generally be realized via nuclear techniques.[141] Also, applications like flow rate of rivers, tracing the underground waters' movements can be realized by nuclear techniques.[142]

II.C Researches

Nuclear technology is being benefited in lots of scientific researches by the scientists. For example scientists, working on geology, archaeology, anthropology benefit from nuclear technology as well as the scientists working on physics, medicine and so on.

II.C.I Accelerators

One of the main concerns of nuclear physics has revolved around the accelerators in recent years. Accelerators are used to analyze the internal structure of nucleus via tracing the refracting and scattering of the pieces which are sent by accelerator to nucleus.[143] Because the accelerators are expected to contribute scientific studies, there are important efforts to advance this technology. Two of the most known accelerators are Tevatron in USA and LHC in CERN.

Another important utilization field of accelerators is the transmutation issue on which scientists have been striving to find solution for nuclear waste problem. Namely transmutation, is the way to follow and to achieve this goal, neutrons are needed. Accelerators are used to meet the need for neutrons and powerful accelerators can produce neutrons by

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[139] Türkan Yöney, "*Nükleer Tıp Nasıl Çalışır*".
[140] *Nükleer Teknolojinin Kullanım Alanları*, available at: http://www.nukleer.web.tr/ available on: 11.05.08.
[141] TAEK, *Endüstriyel Uygulamalar*, available at: http://www.taek.gov.tr/bilgi/bilgi_maddeler/endust_uygulama.html , available on: 11.05.08.
[142] Ibid.
[143] Vural Altın, (2006), *Hızlandırıcılar*, Yeni Ufuklara,(in Bilim ve Teknik Journal), Ekim, Tübitak, p. 2.

spallation.[144] This subject was observed under the topic of "Transmutation". So, no details will take place here

II.C.II Research Reactors

The main application fields of research reactors are radioisotope production, neutron beam applications, silicon doping and material irradiation for nuclear energy systems as well as teaching and training for human resources development.[145]

II.D Agriculture and Stockbreeding

II.D.I Agriculture

Usage of nuclear techniques in agriculture is increasing day by day. Basically, usages of nuclear techniques in agriculture are as follows;

- "Radioisotopes are used in studies which targets to create more alimentary, enduring food, and to get more fertility from agriculture.

- Radioisotopes let scientists to trace the way of manure which is absorbed by plants.

- Preventing flies from harming plants.

- Measurement of humidity rates in ground which lets saving the water"[146]. (When water problems of Turkey and the Middle East region are remembered, importance of this study could be better understood.)

II.D.II Stockbreeding

Radioisotope tracing has wide application areas in stockbreeding too. Increase in animal product, fertile utilization from bait, feeding animals, tracing the breeding of animals, diagnosis of illnesses are some of them and benefits from the application of nuclear science in

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[144] World Nuclear Association. (2009). *Accelerator-Driven Nuclear Enery*, available at: http://www.world-nuclear.org/info/inf35.html, available on 21.05.2008.
[145] *Nuclear Technology Review 2007*, p. 25.
[146] TAEK. *Tarım ve Hayvancılık*, available at http://www.taek.gov.tr/bilgi/bilgi_maddeler/tarim_hayvan.html , available on: 12.05.08.

stockbreeding are much better, quick, absolute and right in compare with other kinds of techniques.[147]

II.E Environment

Scientist could establish very advanced and environmentalist technologies with isotopes and radiation. Wide variety of products is irradiated to diminish their harmful effects of them and scientists succeeded it with a little energy consumption and chemical processes.[148]

II.E.I Water

Climate regime determines the occurrence and distribution of water resources both in surface water bodies and in aquifers.[149]Isotope contents in precipitation, rivers and groundwater help to understand the relationship between water cycle and climate and moreover isotope data are extremely useful in unraveling the impacts of climate variability on water resources.[150]

II.E.II Air

Air pollution especially in large cities is an important problem for people because it is caused by suspended particulates and these particulates can penetrate deeply into lungs remain there for a substantial time.[151] Nuclear analytical techniques are very helpful at this point because scientists can determine and assess the reasons of air pollution which may let them to take measure against this threat via determining the elemental composition of air particulate matter.[152]

General Evaluation for Chapter I

When the scientific indicators of nuclear power plants are observed, in general it is observed that it is not easy to put forward opposing suggestions, in respect of both its energy implications and technological applications, against nuclear power plants.

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[147] Ibid.
[148] TAEK. *Radyasyon Teknolojisi ve Çevre*, available at: http://www.taek.gov.tr/bilgi/cevre/radyasyontek.htm , availale on 14.05.2008.
[149] International Atomic Energy Agency. *Nuclear Technology Review 2007*, p. 40.
[150] Ibid.
[151] Ibid.
[152] Ibid.

Fear of radioactivity has been discussed in our country without having any scientific knowledge about it and nuclear power plant was presented as a kind of establishment which is very risky and deathly. But, as UNSCEAR's study shows, nuclear power plants are absolutely not as risky or deathly as they are introduced. Moreover, radiation level, which is released from nuclear power plants, is lower than natural radiation levels. Nuclear waste problem is one of the most challenging issues but Turkey will not going to face such a problem for a foreseeable future because there will probably not be great number of nuclear power plants built in Turkey within next 20 years and so there will not be a lot of nuclear waste. Also, as the technology advances, nuclear waste problem is expected to be solved. When it comes to costs, the situation is not very different from radiation and waste questions. Although first capital costs are much higher than oil and gas, operation costs are lower and here what is very important is electricity generation costs from nuclear power plants are not very dependent on uranium prices as mentioned under the topic of "Costs". On the other side, one of the most important issues is environmental effects and nuclear power has absolute superiority over fossil fuels and it is as safe as renewable energy sources.

Although nuclear technology issues are discussed frequently in Turkey, almost all discussions are limited with nuclear power plants and arguers ignore applications of nuclear technology in lots of fields. It is generally agreed by scientists that nuclear science and its applications in industry, technology, agriculture, stockbreeding and other fields of applications are much more important than generating electricity. According to Sümer Şahin it is impossible to achieve nuclear technology without having nuclear power plants.[153] This is a matter of having nuclear technology or not and the way passes from having a nuclear power plant.

At this point, it may be beneficial to point another fact that has been subject to unjust critics. There is a claim which says that the world is abandoning these facilities. This assignation has two deficiencies. First is, as the Appendix-1 shows, there are 43 nuclear power plants under construction including Taiwan. This number belongs to January 5 2009. The same number was calculated to be 34 in 2006-2008 World Nuclear Association report which was published in January 14 2008. So, less than 1 year, 9 more nuclear power plants are started to be constructed. That is, world is not going to abandon nuclear program. It will also be useful to give this additional information that on January 10 2007, European Commission recognized

[153] Interview with Sümer Şahin.

that nuclear energy will remain a key component of the EU's energy mix.[154] Additionally, Sweden, Switzerland, England, France decided to regenerate their dated nuclear power plants.

Second deficiency is more crucial. When the Table-7 is observed carefully, it can be seen that nuclear power plants, which are under construction, concentrate mostly in Asia. Main reason is that, while in underdeveloped Asia population is going to grow, population of developed Europe is going to diminish. The table below shows this reality.

Table-7: Population of the World and Its Major Areas[155]

Major Area	1750	1800	1850	1900	1950	1999	2050	2150
Population size (millions)								
World	791	978	1262	1650	2521	5978	8909	9746
Africa	106	107	111	133	221	767	1766	2308
Asia	502	635	809	947	1402	3634	5268	5561
Europe	163	203	276	408	547	729	628	517
Latin America and the Caribbean	16	24	38	74	167	511	809	912
Northern America	2	7	26	82	172	307	392	398
Oceania	2	2	2	6	13	30	46	51

So, the situation is that, Europe, as being an already energy contented region, is going to need less energy than today due to its diminishing population while Asia, with growing energy need due to its growing population, is going to need more energy than today. That is why while there is no significant increase in the numbers of nuclear reactors in Europe, there are lots of nuclear power plants under construction in Asia. There are also under construction or planned nuclear power plants in some underdeveloped European countries. Here, there is a need for brackets for U.S.A. Population growth of U.S.A is set to be continued for the foreseeable future. Although there is no power plant under construction, there are 12 power plants planned to be build.

[154] European Atomic Forum, EU *Energy Initiative Recognises Role of Nuclear Energy in European Energy Future*. available at: http://www.foratom.org/index.php?option=content&task=view&id=337, available on: 23.01.2008.
[155] United Nations. available at: http://www.un.org/esa/population/publications/sixbillion/sixbilpart1.pdf, available on: 25.01.2009, p. 6.

Another criticism must also be evaluated. This point is, whether the decision to build a nuclear power plant is a political decision as asserted by Mustafa Kibaroğlu[156] or not. What is claimed in this study is that, in contrast to Mustafa Kibaroğlu's assertion, building a nuclear power plant is absolutely not a political decision. Aim of building a nuclear power plant must never be a subject to political decisions; instead, efforts to reach this goal must be maintained out of realm of politics. Best example of this way has been given in South Korea. Since 1970s, no matter which government charged, South Korea has been pursuing its national nuclear program decisively and continuously as a state policy.[157] Moreover, Mustafa Kibaroğlu had asserted that nuclear technology is 1940s, 1950s, 1960s' technology which means it is old and Turkey must adopt newer technologies. [158] Mustafa Kibaroğlu's point of view for this subject is ill-thought and very vulnerable to criticism too. Yes, roots of nuclear technology go back to 1940s, 1950s or 1960s but this does not mean that nuclear technology is obsolete or something out of circulation. When this matter is considered from this angle, then it also has to be accepted that neither Turkey nor any other developed (or developing) country must produce planes, cars, ships and so on because these are much older than nuclear studying. First plane had flied in 1903; first car with four-stroke cycle engine was fired up in 1864.

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[156] Interview with Mustafa Kibaroğlu.
[157] Ahmed, Yüksel Özemre. (2002), **Ah, Şu Atomdan Neler Çektim**, İstanbul, Pınar, p. 142-143.
[158] Interview with Mustafa Kibaroğlu, Ankara, 18.11.2008.

CHAPTER II

NUCLEAR TECHNOLOGY AND TURKISH FOREIGN POLICY

PART I. FORMER ATTEMPTS TO ESTABLISH N.P.Ps: WHY TURKEY FAILED?

This part is allocated to history of Turkey's attempts to establish a nuclear power plant. What is aimed in this part is just a try to present the reasons behind the failures of attempts to establish a nuclear power plant which are evaluated by interviewers in the second part. For this aim, there will be a brief outline of attempts at the beginning, and then interviews including Sencer İmer and Esat Kıratlıoğlu will take place. Also, views from Mustafa Kibaroğlu will be stated.

Although all attempts have failed up to now, exerts on establishing a nuclear power plant in Turkey have been on agenda since 1965. Turkey is one of the first few countries who realized the importance of nuclear researches. With the goal of taking step for nuclear research, in 1955, Turkey assigned a treaty called Atom for Peace and in 1956, İstanbul University (IU) and İstanbul Technical University (ITU) set up a nuclear research centre called Çekmece Nuclear Research and Education Centre (ÇNREC). In 1956, Commission of Atomic Energy (CAE) and 1982, Turkey Atomic Energy Institution was established.

For energy production, the first step was taken by CAE in 1965 and primary observations were realized by Etude Administration of Electricity Affairs. As a result, it was decided to start to build a nuclear power plant in 1970 but because of political chaos and desertion of all electricity affairs to Turkey Electricity Institution (TEI) resulted in loss of interests and abandonment of building the nuclear power plant.

In 1972, a new department in CAE was organized and with the studies of this department Akkuyu was chosen for the facility and for an agreement, interviews with the Sweden consortium ASEA-ATOM/STAL LAVAL started but because of the economic crisis in Turkey and political reluctance, this project was abandoned again.[159] Here, one of the

[159] Dr. Ulvi Adalıoğlu, *Türkiye'de Nükleer Enerjinin Tarihçesi ve Gelişim,* available at: http://www.nukte.org/node/122, available on 12.17.2008.

important points is that, Sweden government decided to lift this process because they were reluctant to interact with a state that is not democratic.[160]

In 1982-1985 periods, a new bid realized according to turnkey rules but after than Turkey changed the rules to build-operate-transfer system. Because of this reason, only one firm (AECL) entered to bid but, because of the disagreement on guarantee of energy purchasing conditions, this project again failed. Lastly, in 1996 new bid was opened for this aim for Akkuyu but in this period, lots of bribe gossips, negative reactions of so-called environmentalists and pressures from foreign states, again, resulted in failure.[161] The last attempt is realized in 2006 and this process is still going on while these lines are being written.

This brief introduction actually ignores very important points of Turkey's failed attempts to build a nuclear power plant and have nuclear technology. When the reasons behind the failures are observed, it seems that these failures stemmed from both external and internal factors.

Mustafa Kibaroğlu says that Turkey was not able to constitute a well defined national strategy for this issue but the most important obstacle has been Western countries' fear of giving this technology to Turkey.[162] Western countries were afraid of giving nuclear technology to Turkey because they were anxious that Turkey could transfer this technology to third parties.[163] Specifically, United States has feared a Turkish Pakistani connection. United States obtained some information especially from India, Greece and Israel which instigated the fears of United States' politicians.[164] So, USA, suppressed supplier firms and countries to dissuade them from transferring nuclear power plants and nuclear technology.[165] That is, one of the most important reasons behind the failure of building a nuclear power plant in Turkey is fears of West.

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[160] Ahmet Yüksel Özemre, (2008), *Yeni Nükleer Enerji Kanunu Türkiye'yi Nereye Götürür*? Stratejik Analiz, Ocak, p. 26.
[161] Ali Külebi. **Türkiye'nin Enerji Sorunları ve Nükleer Gereklilik**, pp. 185-186.
[162] Mustafa Kibaroğlu, (1997), *Turkey's Quest for Peaceful Nuclear Power*, The Nonproliferation Review, Spring- Summer, Monterey, p. 33.
[163] Ibid.
[164] Mustafa Kibaroğlu, *Çernobilin 20. Yılında Nükleer Santraller ve Türkiye Sempozyumu*, 10 Haziran 2006, TMMOB Elektrik Mühendisleri Odası Ankara Şubesi, 10.06.2006 Ankara: Hermes, p. 100.
[165] Mustafa Kibaroğlu, *Turkey's Quest for Peaceful Nuclear Power*, p. 33.

What Sencer İmer says on this issue is in accordance with Mustafa Kibaroğlu's assertions. Sencer İmer says that "It has almost been 40 years that Turkey is trying to obtain this technology. Failure is not about only awkwardness of Turkey. This process was obstructed by foreign countries' systematic efforts to prevent Turkey from obtaining nuclear technology. Their efforts come into existence in different forms. One of them is offering the model of build-operate-transfer. During his energy ministry I was Yusuf Özal's consultant. He, at that time, made a mistake and decided to overcome this issue by build-operate-transfer system. This decision was a form of foreign countries' efforts to fetter Turkey from acquiring nuclear technology. There are politicians, bureaucrats and businessmen who serve for the interests of foreign countries consciously or unconsciously. I am sure he was good intentioned but he was imposed* to chose this model. This is a reality, and a mistake of manager. When world was newly introduced to nuclear technology, it was easier to transfer this technology. As the time passed, situation changed. Furthermore, Turkey could not put forth its decisiveness for consideration. Trying to realize this task by build-operate-transfer system is an indicator of Turkey's weakness for this issue. For instance, Taiwan did not apply build-operate-transfer system. The same thing is valid for South Korea too."[166]

Ömer Ersun's evaluation on the reasons of failures is very certain. He says; "There are not reasons; there is only a single reason; incapability of our responsible politicians."[167] Ömer Ersun also gives an example and says "When I was an ambassador at Ottawa, Taşnaks and Greeks led a campaign to prevent Canada from selling nuclear reactor to Turkey. There was a Canadian during the conversations, who was aiming to prevent Turkish people from a nuclear episode with high humanistic ideals, confronted me. I was sure that he was bought by money. After a year, Greek government gave a medal to that Canadian man."[168]

As being a witness of the process, the former Minister of Energy and Natural Resources, Esat Kıratlıoğlu explains the reasons behind the failures of building a nuclear power plant during his and Yusuf Özal's ministry. He exposes the reasons of his period as follows: "When, we decided to construct a nuclear power plant and give a start to communications for a nuclear power plant in Mersin Akkuyu, we called for tenders and came to an agreement with a Sweden-Finn consortium called ASEA-ATOM among the firms that attended to bid.

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* By saying "he was imposed", Sencer İmer meant that Yusuf Özal was "persuaded" to follow this model.
[166] Interview with Sencer İmer, Ankara, 09.01.2009.
[167] Interview with Ömer Ersun. Ankara, 31.07 2008.
[168] Interview with Ömer Ersun.

According to assent, the nuclear power plant, that the consortium was going to build, had 990 Megawatt power with 1 billion costs and 900 million dollars of the cost was to be met as credit from this consortium and 100 million dollars was to be met by Turkey. After this agreement, Sweden government ordered a poll and asked for an opinion on this agreement to its people. Result of the poll was positive and after short time, they sent the article which approved the construction of 1 billion dollars cost nuclear power plant. This article was arrived my ministry on 11.09.1980 in the afternoon. Due to reason that I had some works to do at that time, I decided to give this news to my Prime Minister Süleyman Demirel and to assemble a day after. But, because in the night that bounds 11 September to 12 September, 12 September 1980 coup d'état was realized, this project could not be fulfilled; that article remained on my desk."[169] During the ministry of Yusuf Özal, Turkey had tried to establish a nuclear power plant by build-operate-transfer model. Esat Kıratlıoğlu asserts the period Yusuf Özal as follows: "During Yusuf Özal's period, attempt to build a nuclear power plant via build-operate-transfer system failed too. Because, at that time, it was impossible to get private sector to build a NPP. Because, building a nuclear power plant was totally an unknown subject. Hoping private sector to overcome this issue is meant being unaware of Turkey's realities. In conclusion, private sector could not overcome this task."[170]

Following evaluations belong to Osman Kemal Kadiroğlu. "Construction of a single nuclear power plant takes in 5 years but an election period is 4 years. It is also costly and a load for economy. So, in Turkey, there is no government which accepts to pay that much money from which next government would benefit. But they talk about it. They try to establish nuclear power plant by bids but it is impossible by this way. We must make an agreement with a country and make a program. All the countries build nuclear power plants in this way. This way is probably imposed by Western states with discourses like democracy, liberal economy and they probably ruin this issue. We failed again."[171]

On the other side, Dr. Soner Aksoy, current chief of "Expertise Commission of Industry, Trade, Energy, Natural Resources, Information and Technology", has a different point of view He says "There was not a serious political willpower; second, there were problems

[169] Interview with Esat Kıratlıoğlu, Yalova, 21.07.2008.
[170] Interview with Esat Kıratlıoğlu.
[171] Interview with Osman Kemal Kadiroğlu.

within the ministry of energy. But, construction of nuclear power was discussed as a state, did not discussed as private sector. This was the main mistake I think."[172]

Turkey's inability of succeeding these attempts seems result of both internal and external factors. It is clear that unless politicians in Turkey are undecided, effects of external factors are captive to remain marginal and ineffective. Best example of this reality seems to be South Korea. After a long lasting civil war, South Korea pulled itself together and today South Korea is one of the major nuclear technology owners in the world. Although Turkey had decided to gain this technology long before than South Korea, it has not been able to overcome this task.

Part II. Turkey's Energy Situation and Nuclear Energy

Energy is one of the most important inputs and basic needs of states' economic social development. "The growth of the national economies is realized only with an increased use of energy."[173] Also, energy is one of the most important cursors of national welfare because as a state reaches higher level of living standards, its energy consumption increases too. Today too, energy consumption is concentrated within developed countries. For example United States of America consumes 25% of world energy alone. Europe, Japan, China, India are also important energy consumers of the world.

Due to these reasons, all states have to provide continuous, secure, clean, cheap energy and have to diversify energy resources.[174] This part is dedicated to evaluate whether Turkey needs nuclear power plants to meet its energy demand or not. From this respect, there is a need to be aware of world's energy situation to understand and evaluate Turkey's energy situation because it will be meaningful only if the situation of Turkey is observed in comparison to world. In this part, it will be tried to present some introductory basic information on energy and energy situation of world and then energy situation of Turkey will be observed briefly. In this part, there will be some statistics on energy but due to the reason that it is not possible to reach latest statistics from all over the world; statistics that are going to be used here will

[172] Interview with Soner Aksoy, Ankara, 31.07.2008.
[173] Sencer İmer, *Strategic Implications of Energy*, presented at Economic Committee of the 48th ATA General Assembly in Conrad Hotel Istanbul, 11 October 2002.
[174] Necdet Pamir, *Türkiye ve Dünyada Enerji, Türkiye'nin Enerji Kaynakları ve Enerji Politikaları*, available at: http://www.metalurji.org.tr/dergi/dergi134/d134_73100.pdf, available on: 31.12.2008. p. 9.

belong to 2004, 2005, 2006 or 2007. Because fossil fuels are the most important energy supply to the world consumption, there will be brief observation on fossil fuels of world.

II. A. Introductory Information on Energy

If energy is generated from a process by using several systems it is called "secondary energy source", if it is not so, then it is called primary energy source. For instance, while coal and natural gas are primary energy sources, electricity is secondary because electricity is generated from natural gas, coal, nuclear oil, wind, sun et cetera. On the other side, electricity which generated from water is accepted as primary energy source.

There are different types of energy but each energy source's value can be expressed according to one another's value via calculating sources' intensities. That is, it is possible to express, mere figure of speech, coal's energy value according to oil's value. Generally, it is preferred to use a common unit to express the value of sources. This unit, usually, is joule. During this study, term "oil equivalent" (oe), which expresses other sources of energy in terms of to oil, will be used. The acronym that is going to be used frequently is Mtoe which means "Million Tons of Oil Equivalent".

II. A. 1 World's Energy Situation

Total primary energy supply of the world in 2006 was 11741 Mtoe and world energy demand was almost 8084 Mtoe in 2006.[175] For OECD countries, total primary energy supply is 5590 Mtoe. When world total is considered, this means there is almost 1565kg oil equivalent energy per individual but this consumption is unjust because while 68% of this consumption belongs to 15% of world population, 32% belongs to the rest 85% of the total population.[176]

According to Key World Energy Statistics which is published by International Energy Agency in 2008, by the end of 2006, 80.9% of total primary energy supply comes from fossil fuels (Oil, Natural Gas and Coal), 6.2% comes from nuclear, 2.2% comes from hydro, 10.1%

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[175] International Energy Agency. (2008). *Key World Energy Statistics*, available at: http://www.iea.org/textbase/nppdf/free/2008/key_stats_2008.pdf, available on: 30.12.2008, pp. 6 and 28.
[176] Vural, Altın. (2007). *Enerji Dosyamız*, Yeni Ufuklara,(in Bilim ve Teknik Jounal), Ocak p. 2 (some of the numbers updated by the author).

comes from combustible renewables and 0.6% comes from other energy sources (geothermal, solar, wind, heat etc).[177]

Due to reason that subject of this thesis is nuclear power plants; there will be a little further information on nuclear. According to reference scenario of IEA's 2006 outlook, despite world nuclear power generating capacity increases from almost 368 GW to 416 in 2030, its share in primary energy mix will decrease but according to alternative scenario, both amount and share will increase as a result of increase in electricity generation from 368 to 516.[178] On the other side, high fossil prices made nuclear power plants more competitive and as long as gas prices are above $4.70 and coal prices are above $70 per ton, nuclear power will be cheaper than both.[179]

II. A. 2. Oil

When the supply of oil is observed in International Energy Agency's report of "World Energy Outlook 2006", it is said that according to the surveys conducted by Oil and Gas Journal, there are 1293 billion barrels of proven[180] oil at the end of 2005 and these reserves increase by 1.2% per year.[181] According to British Petrol's (BP) statistical review of world energy which is published in 2008, total proven oil reserves are almost the same with Oil and Gas Journal's. According to this BP's review, there are 1237.9 billion barrels of proved oil reserves[182]. Most of the oil reserves concentrated in Middle East Region accounting for 62% of world total.[183] According to the same report, "the world's proven reserves including non-conventional oil could sustain current production levels for 42 years."[184]

When it comes to demand, World Energy Agency puts forward a projection up to 2030. According to this projection, primary oil demand will keep growing steadily at an average

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[177] International Energy Agency. *Key World Energy Statistics*, p. 6.
[178] International Energy Agency. *Key World Energy Statistics*, p. 43.
[179] Ibid.
[180] According to the report, proven oil reserve implies the "oil that has been discovered and expected to be economically producible".
[181] International Energy Agency. (2006) *World Energy Outlook 2006*, report available at: http://www.iea.org/textbase/nppdf/free/2006/weo2006.pdf, available on: 30.12.2008, p. 89.
[182] British Petrol. (2008). "BP statistical Review of World Energy", available at: http://www.bp.com/liveassets/bp_internet/globalbp/globalbp_uk_english/reports_and_publications/statistical_energy_review_2008/STAGING/local_assets/downloads/pdf/statistical_review_of_world_energy_full_review_2008.pdf, available on 03.02.2009, p. 6.
[183] International Energy Agency. (2006) "World Energy Outlook 2006", p. 89.
[184] Ibid.

annual rate of 1.3%.[185] Nominally, oil demand in 2005 was 84 million barrels per day (mb/d) but will reach 99 mb/d in 2015 and 116 mb/d in 2030. The biggest part of demand comes from developing and transition countries with 70% of total expected demand. Transport sector absorb most of the increase in total oil demand.[186]

The most important problem on these issues is the unequal distribution of oil reserves in the world. Most of the oil reserves are concentrated in Middle East region with rate almost 65% of total.

II. A. 3. Natural Gas

According to the 2006 energy report of IEA, proven resources amounted to 180 trillion cubic meters at the end of 2005.[187] BP's survey on the same issue reports that proven natural gas reserves amounted to 177 trillion cubic meters.[188] When current rates of consumption are considered, it is estimated to be sufficient for 64 years.[189]

Demand for natural gas is expected to increase for the next few decades. IEA evaluates that use of natural gas will increase by 2.5% per year till 2030 and it is said that natural gas is preferred due to cost competitiveness and environmental advantages.[190] As is for oil, the most important demand for natural gas is asserted to come from developing and transition countries because of increasing industrial output and commercial activities.[191]

II. A. 4. Coal

Coal is the most abundant fossil fuel in the world. Proven coal reserve in 2007, according to BP's survey, is around 850 billion tones.[192] This reserve estimated to be sufficient for 155 years at current production rates. Distribution of coal is much more balanced in compare to oil and natural gas.

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[185] International Energy Agency. *World Energy Outlook 2006*, p. 86.
[186] International Energy Agency. *World Energy Outlook 2006*, p. 85.
[187] International Energy Agency. *World Energy Outlook 2006*, p. 114.
[188] British Petrol. *BP statistical Review of World Energy*, p. 22.
[189] International Energy Agency. *World Energy Outlook 2006*, p. 114.
[190] Ibid.
[191] Ibid.
[192] British Petrol. *BP statistical Review of World Energy*, June 2008, p. 32.

Demand for coal will grow at an annual rate of 1.8% until 2030.[193] "Coal's share in the global energy mix remains broadly constant at around one-quarter over the projection period".[194] Most of the demand comes from the developing Asia, especially from China and India and these countries are responsible from 2/3 of total increase until 2030.[195]

II.B. Energy Issues of Turkey

As Necdet Pamir points in his article that although continuous, secure and cheap energy is very important both for nation and industry, the situation of Turkey in this issue is almost opposite to this absolute necessity.[196] In this part, Turkey's energy situation will be presented briefly in compare to rest of world. One of the significant indicators of welfare of countries is their electricity consumption per individual. From this respect Turkey's situation does not constitute a cheering tableau. According to 2005 values, while world average of electricity consumption per individual is 1560 kgoe the same value in Turkey is 1270 kgoe. When we consider total energy consumption per capita in OECD countries in kgoe, it is seen that Turkey comes almost at the bottom of the list. The list given in Table-8 below allows this comparison to be clearer.

Table-8: Energy Consumption per capita in OECD countries in Kgoe[197]

1	Iceland	31,306	
2	Norway	24,295	
3	Finland	17,178	
4	Canada	16,766	
5	Luxembourg	16,402	
6	Sweden	15,230	
7	United States	13,515	
8	Australia	11,309	
9	New Zealand	9,746	
10	Belgium	8,688	
11	Switzerland	8,279	
12	Japan	8,220	
13	Austria	8,090	
14	Korea, Republic of	8,063	

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[193] International Energy Agency. *World Energy Outlook 2005*, p. 126.
[194] Ibid.
[195] Ibid.
[196] Necdet Pamir, *Türkiye ve Dünyada Enerji, Türkiye'nin Enerji Kaynakları ve Enerji Politikaları*.
[197] Electricity consumption per capita - OECD members ranking. Available at: http://dataranking.com/table.cgi?TP=ee02-3&LG=e&RG=1&FL=&PR=1, available on: 13.04.2009.

15	France	7,585	
16	Germany	7,175	
17	Netherlands	7,057	
18	Denmark	6,864	
19	Czech Republic	6,511	
20	Ireland	6,500	
21	Spain	6,213	
22	United Kingdom	6,192	
23	Italy	5,762	
24	Greece	5,372	
25	Slovakia	5,136	
26	Portugal	4,799	
27	Hungary	3,883	
28	Poland	3,586	
29	Turkey	2,053	
30	Mexico	1,993	

When it is considered that Turkey's population is almost the same with Germany, comparing Turkey with Germany is suitable. Energy consumption of Germany is almost 3.5 times bigger than Turkey's. If Turkey wants to be a developed country it has to grow its energy consumption to the level of developed countries like Germany. Energy consumption gap between Turkey and Germany also exposes the gap in living standards and industrialization level. Unless Turkey increases its energy consumption to a level around Germany's, there will still be energy gap to meet for Turkey.

Energy intensity is another important factor to mention. Energy intensity is energy use per unit of gross domestic product.[198] This factor's decisiveness can be understood better by looking at energy indicators of USA. Since 1973, although American economy has grown around 127%, its energy consumption increased around 30%. It means, while USA produces 1 dollar of gross domestic product, it uses 56% less energy.[199] A comparison will make it clear where Turkey stands in energy intensity in world and between OECD countries. According to 2005 values, energy intensity of Turkish economy is 0.25kgoe/$ which is below the world average 0.28kgoe/$. But when OECD countries are considered, it exposes that Turkey's energy intensity is far from being efficient. OECD average in energy intensity is

[198] International Energy Agency. *World Energy Outlook 2006*, p. 68.
[199] Necdet Pamir, *Türkiye ve Dünyada Enerji, Türkiye'nin Enerji Kaynakları ve Enerji Politikaları*, p. 1.

below 0.20 and in Switzerland, intensity is around 0.08.[200] Turkey, with these numbers, comes at the bottom of the OECD list.

Turkey's energy needs are met mostly by fossil fuels and Ministry of Energy and Natural Resources estimated that fossil fuels will keep its dominancy until 2030 in meeting of Turkey's energy demand.[201] There are different articles, reports or statistics which evaluates Turkey's energy situation but they, for the most part, give different numbers. For example, Necdet Pamir, in his article, quotes the speech of minister of Natural Sources and Energy from ministry's web site and says that Turkey used 77 Mtoe in 2001[202]. On the other side, according to International Energy Agency's report on Turkey's energy issues, Turkey's energy demand in 2003 was 64 Mtoe.[203] That is, according to International Energy Agency's statistics, Turkey's energy consumption in 2003 is far less than the consumption of 2001 which was declared by public authority. In this thesis, Turkey's official statistics will take place.

According to minister of Energy and Natural Sources Hilmi Güler's speech at budget discussions in 2009 on 23.12.2008, he said that in 2007 Turkey's primary energy consumption was 107.6 Mtoe and production was 27,5 Mtoe.[204] That is, Turkey imported almost 74.5% of its energy need. Hilmi Güler declared that distribution of general energy consumption by source is as follows; 32% natural gas, 31% oil, 29% coal, 8% renewable sources including hydraulic.[205]

Oil reserves of Turkey is small and it is found in south-east of the country. In his speech at budget discussions, Hilmi Güler stated that by the end of September 2008, remaining oil reserves of Turkey is 37.1 million tones. Due to this reason, Turkey's oil import amounted to 11.7 billion dollars, oil production import amounted to 7.3 billion dollars and oil production export amounted to 3.5 billion dollars[206]. In conclusion, Turkey had to pay 15.5 billion dollars

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[200] Vural Altın, *Enerji Dosyamız*, p. 5.
[201] Ministery of Energy and Natural Resources *Fosil Yakıtlar Genel Bilgi*, available at: http://www.enerji.gov.tr/index.php?dil=tr&sf=webpages&b=fosilyakitlar&bn=220&hn=220&nm=384&id=385 available on: 01.01.2009.
[202] Necdet Pamir, *Türkiye ve Dünyada Enerji, Türkiye'nin Enerji Kaynakları ve Enerji Politikaları*, p. 11.
[203] International Energy Agency. (2005). *Energy Policies of IEA Countries: Turkey 2005 Review*, available at: http://www.iea.org/textbase/nppdf/free/2005/turkey2005.pdf, available on: 01.01.2009.
[204] Ministery of Energy and Natural Resources. *2009 Budget Discussion Speech of Hilmi Güler, on 23.12.2008,* available at: http://www.enerji.gov.tr/duyurular/2009_Butce_Konusmasi.pdf, available on: 01.01.2009, p. 10.
[205] Ibid.
[206] Ministery of Energy and Natural Resources. *2009 Budget Discussion Speech of Hilmi Güler*, p. 61.

for oil. Increase in oil prices are also an important factor for these calculations. On the other side, it must be remembered that efforts to find new wells are far from being sufficient. In the event that there is an increase in the number of wells, new sources may be found.

When the situation of coal in Turkey is observed it appears that there are significant coal reserves in Turkey. According to General Directorate of Mineral Research &Exploration, there are 8.3 billion tones lignite; 1.1 billion tones pit coal; 82 million tones asphaltie and 1.64 billion tones bituminous schist in Turkey.[207] Here, the important point is 80% of the total reserves is not suitable to use in industry and heating but as Necdet Pamir points, if Turkey tries to use its lignite sources via suitable technologies, their fertility can be increased and so their economical value.[208] On the other side, researches to find new coal reserves are far from being sufficient.

There is also a need to observe hydroelectricity and renewables in Turkey. Hydroelectricity sources of Turkey are calculated to be 36000 MW and 36% of this source is currently being used. Ministry of Energy and Natural Sources declared that capacity illustration of hydraulic in Turkey is around 73% due to reasons like operation policy, climate conditions and downfall.[209]

Electricity generation in Turkey must also be observed. By the end of 2007, while installed capacity of Turkey is 40.836 MW, consumption was 191,6 billion kWh and electricity consumption demand increases by 7,5% per year which is significantly rapid. Electricity generation mostly depends on natural gas. Rate of natural gas on generating electricity is around 55%. This rate is followed by coal with 20,7% and hydro power with 18,2%. Due to reason that amount of downfall reduced within last couple of years, electricity generation from hydro-electric power plants was below the expectations. Necdet Pamir asserts that Turkey’s hydro-electric capacity can be increased to 160-180 billion kW per year which is asserted by official institutions to be 125billion kW.[210]

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[207] Maden Tetkik Arama.*Türkiye Maden Rezervleri*. available at: http://www.mta.gov.tr/v1.0/index.php?id=maden_rezervleri&m=5, available on: 02.01.2009.
[208] Necdet Pamir, *Türkiye ve Dünyada Enerji, Türkiye’nin Enerji Kaynakları ve Enerji Politikaları*, p. 19.
[209] Ministry of Energy and Natural Resources. *Hidrolik*, available at: http://www.enerji.gov.tr/index.php?sf=webpages&b=hidrolik&bn=232&hn=12&nm=384&id=387, available on: 02.01.2008.
[210] Necdet Pamir, *Türkiye ve Dünyada Enerji, Türkiye’nin Enerji Kaynakları ve Enerji Politikaları*, p. 20.

Renewable energy sources like wind, solar, geothermal are also substantial in Turkey. Due to reason that they are endless and harmless for environment, renewable energy sources are preferable. Solar is one of the most popular energy sources. According to information given by Ministry of Energy and Natural Sources, sun energy potential in Turkey is 380 billion kWh per year.[211] On the other hand, cost of generating energy from solar is still economically very high and so, for a near future, it will not probably be a main contributor to energy demands. Another renewable energy source is wind. In international Energy Agency's report on Turkey, Turkey's technical wind energy potential is 88000 MW and its economic potential is 10000 MW.[212] Turkey also has significant geothermal energy potential with 1/8 of the world total[213] and Turkey's technical thermal potential is 7500 MW and utilizable potential is 2843 MW.[214] Table-9 below shows Turkey's renewable energy sources put forward by IEA, with respect to primary supply, generation and final consumption including the projection until 2020.

Table-9: Turkey's Renewable Energy Sources[215]

	2003	2005	2010	2015	2020
Primary Energy Supply					
Hydro ktoe	3038	4067	4903	7060	9419
Geothermal, Solar and Wind ktoe	1215	1683	2896	4242	6397
Biomass and Waste ktoe	5748	5325	4416	4001	3925
Renewable Energy Production ktoe	**10002**	**11074**	**12215**	**15303**	**19741**
Share of Total Domestic Production (%)	42	8	33	29	30

[211] Ministry of Energy and Natural Resources. *Güneş Enerjisi*, available at: http://www.enerji.gov.tr/index.php?sf=webpages&b=gunes&bn=233&hn=12&nm=384&id=387, available on: 02.01.2009.
[212] International Energy Agency. *Energy Policies of IEA Countries: Turkey 2005 Review*", p. 123.
[213] International Energy Agency. *Energy Policies of IEA Countries: Turkey 2005 Review*", p. 121.
[214] Necdet Pamir, *Türkiye ve Dünyada Enerji, Türkiye'nin Enerji Kaynakları ve Enerji Politikaları*, p. 21.
[215] International Energy Agency. *Energy Policies of IEA Countries: Turkey 2005 Review*", p. 117.

Share of TPES (%)	12	12	10	9	9
Generation					
Hydro (GWh)	35330	47287	57009	82095	109524
Geothermal, Solar and Wind (GWh)	150	490	5274	7020	8766
Renewable (GWh)Energy Production ktoe	**35480**	**47777**	**62283**	**89115**	**118290**
Share of Total Generation (%)	25	29	26	25	25
Total Final Consumption					
Geothermal, Solar and Wind ktoe	1134	1385	2145	3341	5346
Biomass and Waste (ktoe)*	5748	5325	4416	4001	3925
Renewable Energy TFC (ktoe)	**6882**	**6710**	**6561**	**7342**	**9271**
Share of TFC (%)	11	9	7	6	6

* Fuel comsumption of outo producers used to generate electricity on site

Source: International Energy Agency.

Natural gas reserve of Turkey, like oil reserves, is limited too. Turkey's natural gas reserves asserted to be 6.6 billion cubic meters and by the end of October 2008, Turkey imported 31 billion cubic meters natural gas. [216] In the same date, 29.2 billion cubic meters natural gas was sold and 50% of this amount was used to generate electricity.[217] This implies a very desperate situation for Turkey because electricity, as being a vital input of industry, depends on imported source in proportion as 55%. This dependency is estimated to be over 60% by the end of 2020. As Necdet Pamir says there is no modern state in the world that generates its electricity from natural gas of which almost total is imported.[218] For instance, although United States of America meets its natural gas consumption only from its own sources, proportion of natural gas in generating electricity is 20% and is proposed to be limited with 33% in 2020.

[216] Ministery of Energy and Natural Resources. *Hilmi Güler's 2009 Budget Discussion Speech* on 23.12.2008 p. 65.
[217] Ibid 65.
[218] Necdet Pamir, *Türkiye ve Dünyada Enerji, Türkiye'nin Enerji Kaynakları ve Enerji Politikaları*, p. 18.

This proportion is planned to be 23% in Greece and 21% in Germany for the same period. This fault is one of the basic reasons of high electricity prices in Turkey which in turn harms Turkish economy by harming national production.

If a country uses its totally imported natural gas to meet 57% of electricity consumption, if a country uses its oil, whose 90% is imported, in transportation sector, it is unrealistic to expect that country to develop strongly.[219] This is the current situation of Turkey and must be corrected as soon as possible.

On the other side, price of imported fossil fuel amounted to 37 billion dollars in 2007[220]. This numbers show how big load Turkey had to carry despite its relatively weak and fragile economy.

Part III. DOES TURKEY NEED NUCLEAR POWER PLANTS TO MEET ITS ENERGY NEEDS?

Would nuclear power plants' contribution to overall electricity generation of Turkey be significant? Answer to this question can be evaluated by referring energy indicators and capacity factors. As declared before, Turkey's installed electricity capacity in 2007 was 42000 MW and generated electricity is 191.6 billion kWh. These numbers show that, efficiency of electricity generation from installed capacity in Turkey is around 52%, which is much lower than the objective 80%. Contribution of nuclear power plant to Turkey's overall electricity must be evaluated in accordance with this reality; otherwise evaluations will be based on the electricity which was not generated.

At this point, if additional electricity generation from nuclear power plants is taken into account, contribution of nuclear power plants can be noticed clearly. It is possible to assume variety of nuclear power plant to be constructed in Turkey, in this thesis, a VVER-1200, which is offered by a Russian consortium for the last competition held on September 24th, 2008, will be assumed to be built in Turkey. According to this offer, there are 4 units decided to be built in Akkuyu which means 4800 MWe capacity. Within total capacity, this projects' contribution will be almost 10.25% but because this calculation assumed that both Turkey's

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[219] Necdet Pamir, *Türkiye ve Dünyada Enerji, Türkiye'nin Enerji Kaynakları ve Enerji Politikaları*, p. 18.

[220] Ministery of Energy and Natural Resources. *Hilmi Güler's 2009 Budget Discussion Speech* on 23.12.2008 p. 61.

already installed capacity and probable nuclear power plant (VVER-1200) is used full-capacity, it does not reflect the actual situation. When capacity factors are taken into account, this nuclear power plant's contribution is to be more than calculated above. As mentioned above, according to numbers given by Hilmi Güler, Turkey's electricity capacity factor is 52%. This value implies that Turkey's electricity generation is 21840 MW. VVER-1200's capacity factor is around 90%[221], which equals to 4320 MW electricity. In sum, there would be 26160 MW electricity generation. According to these numbers, contribution of VVER-1200 in Turkey with 4 units would be around 16% which is close to world average 15%.

The nominal values stated above are based on the indicators of 2007 but Turkey's installed capacity factor may decrease or increase due to reasons like dryness, breakdown, downfall regime et cetera.

Also, there is a need to give an answer to another issue. Energy needs of Turkey increases by 7.5-8% each year which means that Turkey's energy need doubled within 15 years. So, would Turkey be able to meet its energy needs without taking nuclear energy into account? Does it make sense to completely ignore nuclear energy in meeting energy needs? Ömer Ersun, retired ambassador, thinks that ignoring nuclear energy is irrational and does not make sense.[222]

Dr. Soner Aksoy, answers this question in a more detailed way. "In 2023, Turkey's energy need will be 500 billion kWh and this need cannot be met even if we use all our coal and hydraulic resources. In addition, Turkey is depended on external sources and if pipelines are closed, it will cause a big problem for Turkey. There are also renewable sources but they are limited. From 2023, we will have problems even if we include all renewable sources. So, Turkey has to use nuclear energy which meets, at least, 10% of its energy needs in total portfolio. Today our electricity generation's 53% is from natural gas stations and this is depended on external sources. We need to decrease this proportion to 20-25% till 2023. We need nuclear for this too. If you buy enough nuclear fuel, you do not have trouble for 40-50 years, so it is not depended on external sources"[223]

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[221] Yu. G. Dragunov, et al. (2007), *Prospects for Development of VVER-type Pressurized Light-Water Reactor Installations*, Thermal Engineering, Vol. 54, No. 5, p. 345.
[222] Interview with Ömer Ersun.
[223] Interview with Soner Aksoy.

On the same subject, Esat Kıratlıoğlu, former minister of "Energy and Natural Sources", gives almost the same numbers. He says that "due to reason that Turkey's energy need will be 500 billion kWh in 2020 but energy potential is 330-340 billion kWh, there will be an energy gap. In this state, because of the energy gap we were convinced that Turkey needed to nuclear energy"[224]

Prof. Dr. Okan Zabunoğlu concludes that Turkey needs nuclear energy to meet its energy needs. He says that "Turkey would probably have had a big energy crisis near the turn of the century if natural gas had not been started being imported. Electricity consumption per capita is a direct measure of welfare. Turkey's electricity consumption per capita is only a little higher than the world average; 3 to 4 times lower than developed countries (OECD or EU average). Nowadays, each year an increment of about 8 % in electricity demand is expected. That is a healthy sign, showing that we are developing. What looks unhealthy is the source of the electricity. And a bothersome question is: Since we will need more each year, where will it come from? Import more natural gas or what? In any case, we need to use all our resources for producing electricity in a safe and environmentally acceptable manner. And we have to add nuclear generation to our existing capacity."[225]

For the same issue, Mete Göknel, the former general director of BOTAŞ (Boru Hatları ile Petrol Taşıma Anonim Şirketi-Petroleum Pipeline Corporation), thinks that Turkey can meet its energy needs without nuclear energy if it keeps importing its energy sources. The following lines reflect his thoughts. "Turkey's coal potential is enough for 20 years if it uses modern and clean technology according to 7-8% energy increment trend. If we find oil in Black sea and Cyprus area, it will be helpful. On the other side, if we want to use renewable energy sources, we have to build a backup unit. These backup units can be based only on thermal plants. Hydraulic is not suitable for this task because Turkey is not very rich in hydraulic. For backups, nuclear is the most suitable one and in waiting. While other states benefitting from nuclear power plants, I do not think it is a good idea to ignore nuclear power plants. In conclusion, nuclear power plants should absolutely be built in Turkey"[226]

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[224] Interview with Esat Kıratlıoğlu.
[225] Interview with Okan Zabunoğlu.
[226] Interview with Mete Göknel, Ankara, 15.12.2008.

Prof. Dr. Yalçın Sanalan, retired chief of department of “Nuclear Engineering” at Hacettepe University, says that “it may not be a requirement for the next three or five years but in the future we have to benefit from nuclear power plants. Turkey’s problem cannot be solved by wind power or something like that. There is still no power station which can generate 1000 MW in Turkey and we do not have lots of alternatives.”[227]

In addition, cost comparisons of major energy sources –namely hydraulic, coal, natural gas and nuclear- would be helpful to understand what nuclear power plants mean in meeting of Turkey’s energy need. To reach this aim, there is a need for costs of electricity generations from these energy sources but, because there is no nuclear power plant in Turkey, it is impossible to make such a comparison. Howbeit, it is believed that a comparison between costs of electricity generation in Turkey from hydraulic, coal and natural gas and average cost of nuclear energy in the world. In Turkey, electricity generation costs calculated to be 1,5 cent for hydraulic; 3-4,5 cent for coal; 9-13 cent for natural gas.[228] Average cost of electricity generation from best operated nuclear power plants in Europe and US are achieving 1.3 to 1.6 US cents per kWh[229]. Although this part is devoted to observe energy issues, there is a need for a superficial advert on the importance of technology transfer. Since Taiwan has a grasp of nuclear technology, costs of generating electricity is extremely low. According to local calculations surveyed in Taiwan, costs of electricity generation from nuclear power plants in 2006 and 2007 were between 2 and 2.2 cents.[230] Costs of producing electricity in Taiwan are exposed in Appendix 2.[231] These costs deserve to be attached great importance because it reflects advantage of acquiring this technology. Acquiring this technology requires technology transfer. Technology transfer for such an issue requires the state to be planned, to be contributor and to play leading role. At present, Turkey does not own this technology and one of the most important reasons of this is the model that Turkey follows. This model, which has been on the agenda of Turkey since the last nuclear law, excludes the state as a planner and expects private sector to overcome this issue alone. In the past, this mentality was called build-operate-transfer and again it was abortive. Today, Turkey failed again because private sector brought its interests to the forefront as usual and offered 21 cents/kWh to Turkey and finally, this offer was revised to 15 cents. The difference between acquiring this technology or

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[227] Interview with Yalçın Sanalan.
[228] Haluk, Dural. (2008), *Türkiye’nin Enerji Politikaları*, Bilim ve Ütopya, Vol: 166, Nisan, p. 6.
[229] World Nuclear Association. (2008). *The New Economics of Nuclear Power*.
[230] Through the Information Supplied by the Kuosheng Nuclear Power Plant..
[231] Ibid.

not reflects the difference between 2.2 cents and 21-15 cents. This fact was depicted by Ahmet Yüksel Özemre. He had said that choosing of nuclear power plant technology or technologies cannot be a function of operator's economical preferences.[232]

III. A. Center Piece of the Energy Issues: Base Load

On the other side, when a country's energy situation is to be evaluated, a very vital dimension, base-load, must be taken into account. This dimension also constitutes our basic assertion on energy issues of Turkey. Base-load is the minimum amount of power delivered or demanded over a given period at a constant rate.[233] That is, energy consumption of a country is not stable; shows yearly, monthly, daily, hourly undulations. But, there is a certain degree of energy consumption that is constantly demanded. In this context, base load is the primary necessity for states' development because base load meets the minimum and the basic energy need of a country. Unless a country secures its base load energy demand, there is no way of developing in health for that country. Due to its vital importance, base load must be continuous and most importantly, immune to external factors. The diagram below (Figure-4), taken from World Nuclear Association, is an illusion of base load.

[232] Ahmet, Yüksel Özemre. **Ah, Şu Atomdan Neler Çektim.**
[233] Nebraska Energy Office. *Glossary*, available at: http://www.neo.ne.gov/statshtml/glossaryb.htm, available on: 03.01.2008.

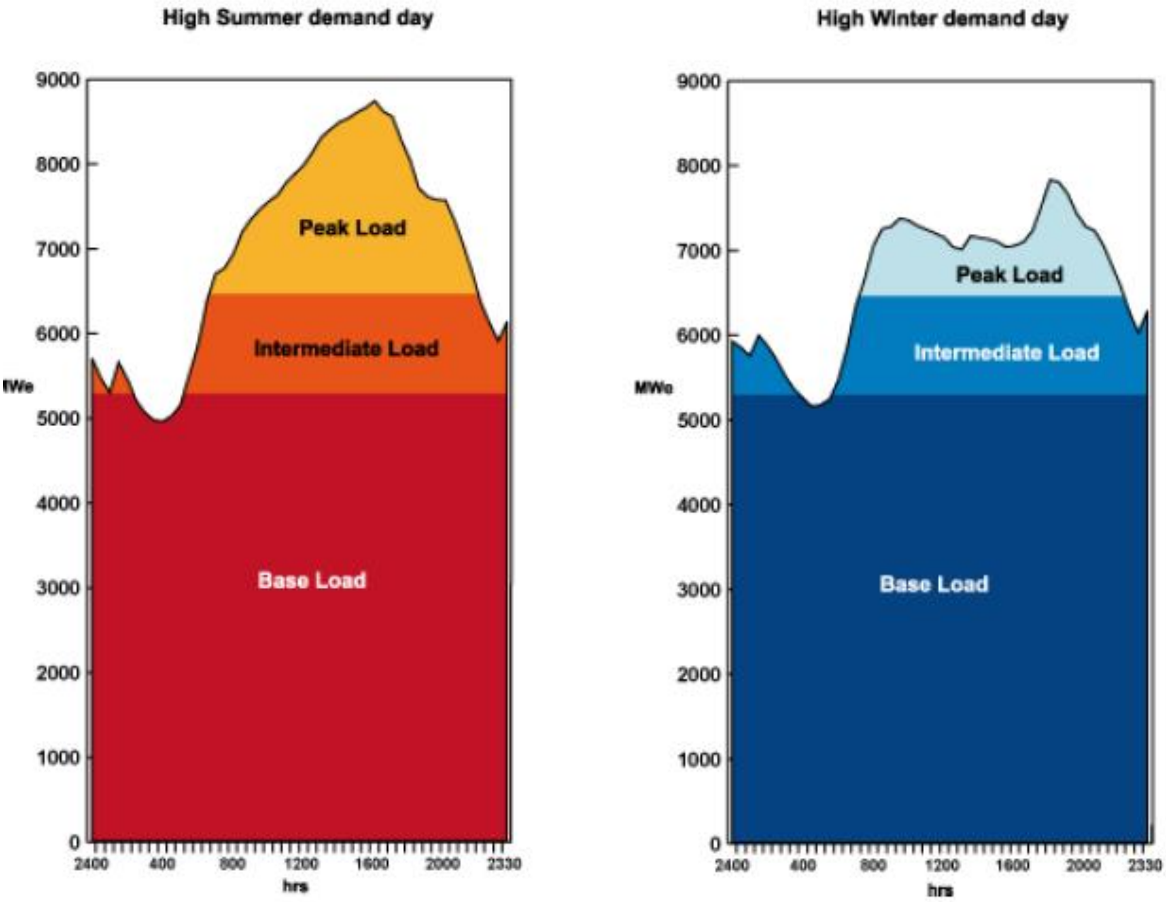

Figure-4: Load Curves for Typical Electricity Grid.[234]

Here, it is clearly seen that much of the electricity demand comes from base load and nuclear energy is considered to be a proven technology of large scale base load electricity generation.[235]

III. B. Kyoto Protocol and Turkey

Kyoto protocol, aiming to reduce released CO_2 levels to 1990's level, was signed in 1997. Supposed global warming was the main reason behind this act. Due to reason that so-called global warming is not proven to be occur as a result of man-made resources, this thesis do not rely on global warming but, because Turkey has signed this protocol, there is a need for a brief evaluation on this issue. It is debatable that whether Turkey did the right thing or did the wrong thing by approving Kyoto for its national interests, but now the reality is that Turkey did it. This reality is going to bring some conclusions for Turkey.

[234] World Nuclear Association, *World Energy Needs and Nuclear Power*, available at: http://www.world-nuclear.org/info/inf16.html, available on 16.01.2009.
[235] International Energy Agency. *World Energy Outlook 2006*, p. 343.

Turkey approved Kyoto protocol and so has to give up from energy production from fossil fuels to reduce carbon release, including the coal investment which is the cheapest energy source in Turkey's current energy profile.[236] That is, resources that do not release carbon have to be substituted for carbon releasing energy resources. This substitution confronts Turkey with high costs because this transformation requires new and wide investments.

Moreover, as declared before, Turkey's energy need is depended highly on fossil fuels. As Turkey give up from fossil fuels, Turkey's structural question of "base load" will come into agenda as a bigger problem than it is today. In this situation, the choices Turkey is going to face are hydraulic energy, renewable energy sources and nuclear energy. Except nuclear, these sources are not completely reliable when the issue is the base load.

IV.B Conclusion for Energy Issues

When Turkey's energy situation is compared with world, it seems that Turkey has to deal with deep structural problems. Although there is an absolute dominancy of imported fossil fuels on the electricity generation, Turkey has not conducted sufficient survey to increase the rate of local energy sources in total energy demand. This is one of the primary tasks to overcome for Turkey. Additionally, it is clear that Turkey suffers from very high energy intensity and has to correct this problem immediately. On the other side, in Turkey, electricity loss and leak proportion is above 25% which is far more than acceptable limits[237].

In conclusion, Turkey faces very crucial energy problems and long term development aims are depended on salvation of this problem. This salvation can be reached only if decision-makers approach this problem with scientific methods and outlook. Energy issues of a country cannot be a matter of daily, cursory approaches. It requires long term planning. So, in meeting its energy needs, Turkey must plan to meet a similar amount of its primary energy consumption by nuclear energy as USA, Japan, South Korea and some European countries such as France do.[238] With this outlook, it is also strongly believed that the most important problem that Turkey has to overcome is the issue of base load. Because, Turkey's base load source is depended on imported fuels and this implies a huge security of supply problem for

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[236] Haluk, Utku. *Nükleer Enerji Politikası ve Dikkate Alınması Gerekenler*, available at: http://yunus.hacettepe.edu.tr/~utku/NukEnerjiPlanl.doc, available on: 18.04.2008.
[237] TMMOB Makine Mühendisleri Odası. (2008). *Dünyada ve Türkiye'de Enerji Verimliliği Oda Raporu*,available at: http://www.mmo.org.tr/resimler/ekler/a551829d50f1400_ek.pdf, available on: 11.05.2009.
[238] Sencer İmer, *Strategic Implications of Energy*.

people, industry and in turn for economy. It is clear that the best opportunity to overcome this issue is to build nuclear power plants. Because, nuclear power plants can generate continuous electricity with 80-%90% capacity factor and additionally, nuclear power plants are immune to external factors (such as prices of fuels) much less than other sources of energy which insecure base-load need of Turkey and since nuclear energy is also cheaper than others, which increases the competitiveness of the Turkish industry.

PART IV. NUCLEAR POWER PLANTS AND TURKISH FOREIGN POLICY

IV. A. Power in International Politics

National interests, historically, are generally in conflict and power is one of the most important determinants of the question of whose interests will prevail.[239] So, there is a need to start by the definition of national power. The term "power" is used in the meaning of national power in the following lines.

IV. A. 1. Definition of National Power

Although power has always been a central concept for international relations, there is no compromised definition of this term between scholars of international relations and so the meaning of this concept is still ambiguous. One of the most popular definitions of power was put forward by Robert Dahl. Dahl defines power as the ability of A to get B what B otherwise would not do.[240] Morgenthau, on the other side, thinks that policy is a process of "power struggle" and can be a means as well as an aim.[241] Another definition, offered by Michael Barnett and Raymond Duvall, says that "power is the production, in and through social relations, of effects on actors that shape their capacity to control their fate".[242] Craig Nation thinks that power can be defined "as the ability to shape the operational environment in such a way as to encourage certain kinds of behavior and discourage or place beyond the pale

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[239] Theodore, A. Coulombis and J.H. Wolfe. (1978). **Introduction to International Relations: Power and Justice**, Eaglewood Cliffs, N.J., Prentice-Hall, p. 223.
[240] R. A. Dahl, (1957). *The Concept of Power*, Behavioral Science, No. 2, pp. 201-215.
[241] Hans Morgenthau. (1973). **Politics Among Nations: The Struggle for Power and Peace**, New York, Knopf, p. 137.
[242] Michael Barnett and Duvall Raymond, *Power in International Politics*, available at: http://www.eui.eu/SPS/Archives/People/Faculty/CurrentProfessors/PDFFiles/VennessonPDFfiles/Barnett_Duvall_Power_IO_2005.pdf, available on: 18.12.2008, p. 45.

various alternatives".[243] A. Coulombis Theodore and Wolfe J.H. make a definition as follows: "National power is the sum of attributes that enable state to achieve its goals even when they clash with the goals wills of other international actors."[244] Karl Deutsch defines power as follows: "Power, put most crudely and simply, is the ability to prevail in conflict and to overcome obstacles."[245] This study will be based on the Karl Deutsch's definition of power. There are much more definitions put forward for this term but no more definition will be stated here. On the other side, there is one point that must be stressed. Although some of the definitions include resistance and defense by implication as a result of their very comprehensive point of view, most of the popular definitions do not clearly comprise resistance and defense as the signs of national power but in this study resistance to external coercions and defending itself will be considered as the signs of national power too. For instance, during the Dardanelles War, Ottoman Empire did not have ambitions on any other international actors; it was defending himself. If definitions of power which do not include resistance and defense are accepted then it also has to be accepted that Ottoman Empire did not pose any power because it was not trying to force invaders to do something, it was just putting up resistance and trying to defend itself against them.

IV. A. 2. Characteristics and Components of National Power

National power, of course, is not a single unity but rather a resultant of some components like population, military, economics and et cetera. These components will be presented under the topic of "components of power". These components are also not objective but rather listed arbitrarily by the scholars. In the most common sense, components are observed in two ways; measurable components and immeasurable components. Measurable components are the ones that can be expressed by referring to numbers. For instance, militarily, number of tanks a state has; economically, GDP a state possesses; industrially, mass of steel that a state products in a year et cetera. Immeasurable components are the ones that cannot be expressed by referring to numbers like regime of a state; moral situation of a state's people. Actually, it is not possible to say that measurable components of power have absolute meaning for everybody and for every situation. For example, if a country experiencing terrorism problems within its own

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[243] R. Craig, Nation. *National Power*, **Theory of War and Strategy**, (in J. Boone Bartholomees, Jr. [Ed]) available at: http://www.strategicstudiesinstitute.army.mil/pdffiles/pub870.pdf, available on 18.12.2008, p. 163.
[244] Theodore, A. Coulombis and J.H. Wolfe. **Introduction to International Relations : Power and Justice**, p. 230.
[245] Karl, Deutsch. (1968), **The Analysis of International Relations**, New Jersey, Prentice-Hall, p. 22.

boundaries, it is pointless to have a nuclear bomb for this country because that bomb cannot be used but conventional weapons will be much more useful in comparison to nuclear bombs. So, it is clear that the meaning and measurability of the power a country has depend on the situation. Also, number of people is something measurable and, of course, a kind of power for a nation; but it may be a huge problem for a country if its nation is uneducated, unemployed or so on. These subjects will be denoted under the topic of characteristics of power. In this thesis, although immeasurable components are not rejected, only measurable components of power will be observed. Only exception of this principle will come into existence under the topic "D. Military", because although they are immeasurable, it is believed that ignoring the elements of military power like excellence of leadership and moral leads evaluation of military power to be very insufficient.

On the other side, in this thesis, power is treated as a means because as Coulombis and Wolfe puts, power is not a goal in and of itself.[246] Power is a tool to achieve national goals no matter how and in what respect it is defined.

IV. A. 2. 1. Characteristics of National Power

IV. A. 2. 1. 1. Power is Relative

In the context of international relations, power has a meaning when compared to others' power. As Morgenthau pointed "it is one of the most elemental and frequent errors in international politics to neglect… [the] relative character of power and to deal instead with the power of a nation as though it were an absolute".[247] For example, saying USA is a powerful state has a meaning only if whom it is compared to is known. That is, national power can be evaluated only in comparison to other actors' national power.

IV. A. 2. 1. 2. Power is Situational

Every element of power may not be convenient for every situation. That is, applicability of an element of power highly depended on the situation. "Power… must be relevant in the existing circumstances for the particular situation."[248] As mentioned by Theodore, A. Coulombis and

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[246] Theodore, A. Coulombis and J.H. Wolfe. **Introduction to International Relations : Power and Justice**, p.224.
[247] Hans, Morganthau. Politics Among Nations, p. 154.
[248] David Jablonsky. *National Power*, **Theory of War and Strategy**, p. 145.

J.H. Wolfe, preponderance of American military power was useless given the goal of freeing hostages alive during the Iranian hostage crisis.[249]

IV. A. 2. 1. 3. Power is Dynamic

Elements that constitute national power are not constant but rather they are always in an alteration. For instance, a strong economy may lose its power as a result of an international or a domestic economic crisis. A state's military power can be outdated by another state's advances in this field. On the other side, there are some scholars who believe that some of the national power components are in decline as a result of changing nature of international relations. They think that, for example, technology, economics or education are asserted to be more important than military power by some scholars in contrary to the past.

IV. A. 3. Components of National Power

As mentioned before, under this topic, measurable elements of national power will take place. The elements chosen here are, of course, not certain but they are generally offered by the scholars of international relations. What going to be mentioned as components of national power in this thesis is consisting of geography, population, economics and military.

IV. A. 3. 1. Geography

Geography has become a prominent field of study under the name of geopolitics. Location of a country has always been considered as one of the most important determinants of national power. Geographical position of a country determines the potentials and determines what to do to benefit from these potentials.[250] Geography includes implications of climate, size, topography as well as location. Some of the nations have been suffering because of the place they are located while some of them have been benefitting. From the respect of military, one of the most popular examples of these suffering countries was Poland. Cost of its location between Soviet Russia and Hitler's Germany was its existence during the Second World War. On the other hand, some countries used to have an important advantage like USA. This

[249] Theodore, A. Coulombis and J.H. Wolfe. **Introduction to International Relations : Power and Justice** p.231.
[250] Bilal Karabulut, (2007), *Uluslararası İlişkilerde Coğrafi Bağlam*, Jeopolitik, Vol. 44, Eylül, p. 65.

country has been protected by a huge ocean throughout its history. Great Britain and Japan have also been benefitting from the same protection. Moreover, Russia's foreign policy has been shaped by the goal of reaching warm waters, which is again a result of its location. Location has a significant effect on states from the point of view of climate. "The poorest and weakest states in modern times have all been located outside the temperate climate zones in either the tropics or in the frigid zone.[251] It is asserted that technological developments have mitigated the importance of geography but it must be accepted that these effects have limits. Geographical implications may change but geography has always been and will be an important factor for international relations.

IV. A. 3. 2. Population

Population, on its own, a power just because of its existence but there are some factors that make this power much more significant and imbalance/lack of these factors leave this power very limited. Some of these factors are age distribution, health, education and welfare. Also factors like moral, trust or so on should be taken into consideration but declared before, here only measurable things will be dealt with.

Large number of people is important point for national power but number of people should be in balance with the resources of country and it is advantage for a country to have population aged mostly between 15-65 years, which means productive years, old.[252] On the other side, military personnel highly depend on people resources. But, large number of population cannot, on its own, convert a state into a powerful one. For instance, Germany, with around 82 million of people is more powerful than Pakistan whose population is around 160 millions. Same comparison can be realized by observing England with a population of 60 million and Egypt with population of almost 70 millions.

Also, education level of people is very important factor for all nations. Uneducated masses are mostly a negative factor rather than being supplier of national power. Educated population is a propulsive force for every aspect of national power because it is a fundamental input from industrial output to military. So, education has directly, positive and multifaceted effects on national power.

[251] David Jablonsky. *National Power,* **Theory of War and Strategy**.
[252] Theodore, A. Coulombis and J.H. Wolfe. **Introduction to International Relations: Power and Justice** p. 236.

IV. A. 3. 3. Economics

Economic strength has been one of the most prominent elements of national strength and "instrument of political power"[253] because almost everything has something to do with economic strength. For today's world, a country's economics refers especially to its industrial state because what converts natural resources into economically beneficial products is industry.[254] As being the key element of national power, economics affects a wide range of issues from military to education due to reason that every step to take in national scope has economically prices. Next topics, as being the sub-topics of "Economics", are considered to be elements of economic. That is, economy of a country is a sum of these elements.

IV. A. 3. 3. 1. Natural Resources

Element of natural resources is one of the key factors in determining the national power. For instance, possession of petroleum, major iron ores, water, coal et cetera is very important for industry, military and development but as Jablonsky points out, "physical possession of natural resources is not necessarily a source of power unless a nation can also develop those resources and maintains political control over their disposition".[255] Lack of natural resources leads country to be depended on foreign natural resources which leads national power to be mitigated; at least limited. In today's world, industry, as being the machine of economy, moreover, is depended on natural sources. Natural resources must be converted into actual national power from being potential power and this task is accomplished via industry. Importance of natural resources actually comes from their meaning for a countries economics and military power.

IV. A. 3. 3. 2. Industrial Capacity

Unless the natural sources, whether foreign or domestic, are converted into industrial goods, they will have no contribution to national power in terms of economics with the exception of feeding. That is, what turns sources into tangible power is industry.[256] For example, Japan is one of the most prominent examples to the states who suffer from lack of enough natural

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[253] Edward H. Carr. (1981). **Twenty Years' Crisis: 1919-1939**, Houndmills: Palgrave, p. 113.
[254] Tayyar, Arı. (1999), **Uluslararası İlişkiler ve Dış Politika**, 3th Ed. İstanbul: Alfa, p. 52.
[255] David Jablonsky. *National Power*, **Theory of War and Strategy**.
[256] Theodore, A. Coulombis and J.H. Wolfe. **Introduction to International Relations : Power and Justice** p. 246.

sources but as a result of advanced technology, Japan is able to recover its deficiencies. On the opposite side, most of the petroleum rich countries have not been able to strengthen their economies due to lack of sufficient industry.

IV. A. 3. 3. 3. Agriculture

Although often ignored, agriculture is an important component of national power. Countries, who suffer from inadequacy of food, face very critical problems. In general terms, children are the most important victims of food scarce because of the negative consequents of food scarce on brain and physical development.[257] When the subject is different from nourishing, excessive dependency on foreign countries does not have to have vital conclusions on population but if the subject is nourishing, excessive dependency is likely to be a matter of life and death. For instance, Canada is one of the countries who enjoy a great deal of security. So, for Canada, there is no matter of life and death unless it faces excessive nourishing problems. On the other side, Somalia has long been known as a country that faces hunger. So, as long as this situation goes on, Somalia does not have chance to be a powerful state. Issue of nourishing is vital because it is impossible to postpone it. Need for feeding has to be satisfied immediately; it is not possible to diminish the part of national income which is devoted to nourishing. So, resolution for feeding matters has to be based mostly on agriculture.

In conclusion, agriculture is the basic and indispensible supplier of national power. It is meaningless to talk about the national power of a country that suffers from hunger. It is quite clear that self-sufficiency is neither possible nor necessary for all states but dependency on foreign resources, on the subject of feeding, has to be in certain limits.

IV. A. 3. 4. Military

Military has historically been a constant component of national power. As Jablonsky points, there are lots of examples in history in which Superiority in military issues has signed decline or rise of powers.[258] Although nature of national power has been moving away from military sphere recently, it is still an important component that must be considered. As mentioned before, military power must be evaluated as an aggregation of tangible/quantitative and intangible/qualitative factors. Tangible factors are the ones that can be presented by numbers

[257] Theodore, A. Coulombis and J.H. Wolfe. **Introduction to International Relations : Power and Justice** p. 248

[258] David Jablonsky. *National Power*, **Theory of War and Strategy**.

like number of military personnel, number of tanks, number of planes, number of ships and so on. Intangible factors are the ones that cannot be presented by referring numbers but these factors affect the military power of a country deeply. For instance, acquisition high-technology weapons, brilliant commanders as being intangible actors, have enormous impact on military power. Historically, one of the most amazing examples of having a brilliant commander became visible during the Turkish independence war. Under the leadership of Mustafa Kemal, Turks were able to defeat Greek armies who had held the advantage of both technology and personnel.

Components of power listed above do not imply that they can be evaluated independently. Every component is in touch with each other and they intensely affect each other by feedbacks. For instance, a country with a weak economy would be defective in supporting national education. This probably leads lack of trained human resource, which, in turn, harms economy. Weak economy would also be insufficient to realize infrastructural and superstructure investments, to strengthen military power, to develop natural resources. Or, from the opposite view, a strong economy can provide better, more scientific and modern educational opportunities to its people. None of the components are more important than one another. Here, it must be remembered that economy has an active role. A strong economy improves ability of advancing/developing/ameliorating every other components of national power. Technology works as the most important contributor of economic development and other components. Next topic of this thesis is devoted to express relations between technology and components of national factor with special emphasis on technology and economy.

Reflections of national power on real life can be observed in the example of relations between Turkey and Greece. Greeks, unjustly, think that Turkey is a comminatory state for Greek. But, here the main point is that while Greeks find Turkey comminatory, they base their arguments upon the assumption that Turkey is superior to Greek from the points of population, geography, economic resources and military[259] which are components of national power.

[259] S. Gülden, Ayman. (2001). *Türk Yunan İlişkilerinde Güç ve Tehdit*, (In Faruk Sönmezoğlu [Ed.] **Türk Dış Politikasının Analizi**, [(2th ed.)], İstanbul: Der, p. 546.

IV. B. Technology and National Power

IV. B. 1. Does Technology Affect International Affairs?

Technology has always been at the top of the most effective and decisive factors in shaping the world history and politics. Although history of technology is as old as history of humanity, history of technological development is not within the boundaries of this thesis, so instead, it is preferred to put forward stupendous effects of technology on the history of world with references to some drastic developments. It is not claimed that every single technological development led extensive alterations on political history or technology is the only reason of developments for international affairs but rather, it is claimed that the most important reason of the rise and fall of powers, including great powers, stemmed from the determinative effects of technology. Here, there is a vital point that must be clarified. In this thesis, technology is not considered as an element of national power but rather it is claimed to have leverage effect, directly or indirectly, on every elements of national power.

Technological developments are the primary elements that determined leading powers in world politics. For instance, “heavy plough” has been considered to be at the root of the evolution of “West” into a hegemonic power.[260] Actually, it was invented almost two centuries ago but widespread use of heavy plough started in X-XI centuries and invention of heavy plough resolved the problem of drainage which remained unsolved until X-XI centuries.[261] Resolution of drainage problem led agricultural areas to be widened and so much more people were fed which in turn led population to increase. Here, of course, heavy plough is not claimed to be the only factor, but it is claimed to be one of the most important factors which constitute the corner stone of the rise of the West.

Another example can be given on the subject of sea power which has long been a significant propulsive force of being world power. By the beginning of the XVI century, Europeans were able to build stronger, bigger ships that are more able-bodied against cannon’s recoils[262]; that is, these ships were technologically more advanced. These developments in European seafaring terminated other naval warfare methods and opened way for Europeans to be an unrivaled sea power[263]

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[260] Oral, Sander. (1998). **Siyasi Tarih: İlkçağlardan 1918’e**, (6th ed), Ankara: İmge, p. 63.
[261] Ibid.
[262] William, H. McNeill. (2002). **Dünya tarihi,** (Translated by Alaeddin Şenel, 6th ed), Ankara: İmge, p. 467.
[263] William, H. McNeill, **Dünya tarihi**, p. 468.

One more striking example was given by Selim Somçağ. He reveals that, basic reason of the fall of Ottoman Empire was the using of rifle as standard infantryman gun by the European states while the soldiers of the Ottoman Empire were still fighting with traditional armaments.[264] This event declared the beginning of the fall for Ottoman's who was one of the most important actors of international affairs in new age.

On the other side, as Sencer İmer pointed in his article, England turned 19th Century into an English century by inventing the mass steel production and industrial revolution.[265] Both mass steel production and industry revolution are the results of technological advances and led England to be indisputable leading power of the world politics. Mass steal production is still one of the most crucial indicators of national power.

Another example which interested international affairs deeply can be given from a closer history. When Soviet Russia was able to send Sputnik to an orbit of the world on October 4.1957, United States of America felt herself under a big danger because Soviet Russia had got the advantage of accession between continents which America lagged. Meaning of this success in international arena was clear. Strategic balances were changed in favor of Soviet Russia because although Russia had captured nuclear bomb's secrets, it was not able to throw the bomb on America's territory but now Russian could overcome this task easily.[266] Oral Sander asserts that this state of imbalance between these states became evident in during the second Berlin crisis in 1958 in which Soviet Russia's attitude was harsher than before.[267]

It is possible to give numerous of examples that changed the nature of international relations. One of them is the invention of compass which made it possible to reach transoceanic places and so changed the channels of commerce. Another one is the invention of printing press which is asserted as one of the accelerating power of enlightenment.

In conclusion, international affairs are deeply and intensely shaped by technological advancements. As pointed in Jared Diamond's book, weapons and transportation technologies

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[264] Selim, Somçağ. (2008). **Osmanlı ve Batı**, *(*Extended 2[th] ed), İstanbul: Bengi, p. 33.
[265] Sencer, İmer. (2003). *Yirmi Birinci Yüzyılda Dünya ve Türkiye'de Muhtemel Gelişmeler*, (In Erdinç Yazıcı [Ed.]), **Yirminci Yüzyıldan Yirmi Birinci Yüzyıla Türkiye ve Dünya**, Ankara: İlke Emek, p. 189-207.
[266] Oral, Sander. (1998). **Siyasi Tarih: 1918-1994**, (6th Ed), Ankara: İmge, p. 280.
[267] Ibid.

reveal the main reasons of history's basic course.[268] Communities, empires national states or republics; whoever got the highest technology of the era they belong, they actually got the most important advantage of being the leading power of the region or of the world. Of course, technology alone cannot transform a state into a leading power. As mentioned above, national power is consisting of some components. Unless all these components are obtained at the same time, being a leading power is not possible. Technology works as the propulsive force behind these components.

IV. B. 2. Nuclear Technology and National Power: Should Turkey Adopt Nuclear Technology?

Components of national power are permanently in coactions and within these components, economy's affects on every aspects of national power is drastic. Economy of a country has always been important but beginning with the industrial revolution, relative weight of economics has grown steadily.[269] Jablonsky points that; strong domestic economies can produce nonmilitary national power in international arena.[270] "Leading industrial nations have all techniques available for exercising power, including rewards or punishment by means of foreign trade, foreign aid and investment and loans, as well as the mere consequences their domestic policies can have on the global economy."[271] As declared under the topics of natural resources and industrial capacity, natural resources, to some extent, must be converted into industrial goods to meet nations' needs. As Holsti pointed in his book, "needs that cannot be filled within national frontiers help create dependencies on the other state."[272] This reality poses a bigger danger for weak national economies that are vulnerable to external developments. So, a strong economy is among the key elements which allow states to avoid from being subject of economical coercions.

Industrial capacity is the locomotive of the economical development. As Halil Seyidoğlu asserts there is a strong positive relationship between industrialization and development.[273] According to conclusions of numerous applied surveys, increase in "real income per head" in

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[268] Jared Diamond, (2004), **Tüfek, Mikrop ve Çelik**, (10th ed., Translated by Ülker İnce), Ankara: Tübitak, p 309.
[269] Theodore, A. Coulombis and J.H. Wolfe. **Introduction to International Relations : Power and Justice** p. 242.
[270] David Jablonsky, *National Power*, **Theory of War and Strategy**, p. 151.
[271] Ibid. 151.
[272] Kalevi, J. Holsti, (1967), **International Plolitics: A Framework for Analysis**, New Jersey, Prentice-Hall, Inc., Englewood Cliffs, p. 240.
[273] Halil Seyidoğlu, (2001), **Uluslararası İktisat**, İstanbul: Güzem, p. 608.

developed countries, mostly stem from technological progress.[274] This assignation clearly shows that progress in technology issues is the key element of industrialization and industrialization is the key element of economic development. This determination is also put forward by Sencer İmer's assertion that, "a healthy economy relies on industrial production; especially on high-tech industrial goods. For example, 40% of Taiwan's national income is acquired from high-tech industrial goods.[275]

Nuclear power plants' contribution to industrial capacity is asserted to be outstanding. Osman Kemal Kadiroğlu says that "All products that are used in nuclear plants have to have very high quality assurance and control. Manufacturing for nuclear industry enforces quality assurance and control which will be the driving force for a national system of quality assurance and control. With better quality in manufacturing, a country can easily obtain a higher level in the competitive world trade."[276] Moreover, steel industry occupies a very strategic part in countries' overall economy. Steel is converted into infrastructure and industrial goods and then is dispersed in world markets. "If we sum all metals up, steel constitutes more than 90% of all metals; that is, we are still living in the era of iron."[277] Okan Zabunoğlu points that, "nuclear technology forces a country advance almost all kinds of engineering. For instance, as being one of the most important inputs of economic development, it is important to produce qualified steel. At the top of this quality, there is nuclear quality steel that we cannot produce yet."[278]

Moreover, Sencer İmer's evolution on this issue is also vital. He says "Making headway in technology is about advancing in three fields; first is material science, second one is construction and the third one is control systems. Due to reason that Turkey is not dealing with nuclear technology, it is backward and has to overcome this issue. To reach developed countries, Turkey must remedy to these problems, must be able to produce new materials, must be able to design new kinds of materials but Turkey cannot do these now. Because Turkey is not striving to do overcome these tasks and so cannot get over. For example, as an aim, Turkey must develop radiation-resistant materials. How will we realize this if we do not struggle to solve this kind of problem? It is impossible. If we can improve this material, we

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[274] Halil Seyidoğlu, **Uluslararası İktisat**, p. 103.
[275] Interview with Sencer İmer.
[276] Interview with Osman Kemal Kadiroğlu.
[277] Sencer, İmer. *Türkiye'nin Demir-Çelik Sanayinin Durumu ve Geleceği*, Cumhuriyet, Strateji, Vol 27, 03.01.2008, p. 3-5.
[278] Personal Interview with Okan Zabunoğlu.

can build nuclear-powered submarine which is very important for Turkey; or ships like this too. Then, we can capture a very important position in the world in this sector like Chine, England, Japan, America, Russia… If we capture this technology we can be like advanced countries in medical sciences, space technology and so on. Developed countries are developed because they have these technologies. If we can succeed these tasks, we can be among the major powers of the world. Otherwise, Turkey becomes a state, which serves them or mostly a state that read their science magazines, under their hegemony. The one who knows also realizes; the one who realizes also knows".[279]

Prof. Dr. Sümer Şahin from Gazi University also declares that nuclear power plants will be exceedingly helpful for our technological advancement. He says that "… when Turkey starts to build nuclear power plants, it compulsorily will increase its local contribution in those power plants. This means that Turkey will experience a great technologic development in a wide variety of fields. It also will increase Turkey's national income…"[280]

In addition to these subjects, agricultural capacity of a country also implies a very important side of national power. Here, the primary question to deal with is whether or not a country can sufficiently provide its domestic needs. Morgenthau claims that countries that can feed themselves have a great priority over other countries that are not able to feed themselves.[281] Morgenthau also adds that a country, which suffers permanently from food deficiency, always remains weak in international politics.[282] He thinks that the best examples of this reality are the fall of Middle East and North Africa form being centers of power as a result of extinction of irrigation systems[283] Moreover, fall of Spain is considered to be the same. Morgenthau asserts that Spain fell because wide territories became steppes and loss of forests due to bad using.[284] Wide agricultural areas became deserts.[285]

Applications of nuclear technology in agriculture is wide and very fertilizer. For instance, it is determined in IAEA's Nuclear Technology Review 2008 that nuclear technology has allowed induced crop mutations to become the method of choice for developing crop varieties,

[279] Interview with Sencer İmer.
[280] Interview with Sümer Şahin.
[281] Hans Morgenthau. **Politics Among Nations: The Struggle for Power and Peace**, p. 145.
[282] Hans Morgenthau. **Politics Among Nations: The Struggle for Power and Peace**, p. 146.
[283] Ibid.
[284] Hans Morgenthau. **Politics Among Nations: The Struggle for Power and Peace**, p. 147.
[285] Ibid.

resulting in the official release for cultivation of approximately 3000 mutant varieties.[286] Via recently added two mutant crop varieties, namely "Clearwater" and "Herald", farmers are making significant savings by avoiding the need to purchase expensive dietary supplements to counter the effects of phytic acid.[287] Also, in the same review, it is mentioned that a variety called Sakukei has led farmers to make substantial savings.[288]

Improving livestock productivity and health is another subject observed in the same review. It is asserted that "nuclear technology applications that were developed to fulfill specific and unique requirements increasingly used to obtain more and better livestock and livestock products"[289] "Current trends indicate that the techniques will play important roles in the improvement of animal nutrition reproduction and health"[290]

Food irradiation is also a vital theme to deal with. IAEA's same report says that food losses caused by pest, contamination and spoilage are enormous and it is estimated that 42% of the production of the eight major food and cash crops of the world are lost to pests with post harvest losses adding further 10%.[291] According to scientists, irradiation of food is a valuable tool to address the reduction of losses due to food spoilage and deterioration, the control of microbes and other organisms.[292]

Moreover identification of the sources of the pollutions has been an important subject. IAEA's 2007 nuclear technology preview report exposes that isotopic and nuclear techniques play an important role in identifying the sources of pollutants.[293] As pointed in the same report, application of nuclear technologies to agriculture helps develop strategies for optimum feed utilization and leads overall production system to be more efficient and sustainable.[294]. On the other side, nuclear technologies are used for efficient water management which is important for sustainable and integrated management for water resources. For instance,

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[286] International Energy Agency. (2008). *Nuclear Technology Review 2008*, available at: http://www.iaea.org/About/Policy/GC/GC52/GC52InfDocuments/English/gc52inf-3_en.pdf, available on: 12.01.2008, p. 19.
[287] Ibid. 19.
[288] International Energy Agency. *Nuclear Technology Review 2008*, p. 20.
[289] Ibid.
[290] Ibid.
[291] International Energy Agency, *Nuclear Technology Review 2007*, p. 22.
[292] International Energy Agency, *Nuclear Technology Review 2007*, p. 23.
[293] International Energy Agency, *Nuclear Technology Review 2007*, p. 33.
[294] International Energy Agency, *Nuclear Technology Review 2007*, p. 34.

groundwater dating techniques can be used by states to assess their groundwater resources.[295] For instance, recently developed isotope Helium-3 allows states to date their groundwater from variety of sources more accurately.[296]

These attainments clarify that nuclear technologies has been and will be an indispensable contributor for agriculture and so, for national power. As Turkey provides food variation, healthier food and as Turkey gets more self-sufficient on food, it will also experience the strategic contributions of agriculture to national power.

Furthermore, military power is affected widely by technological advancement too. First of all, military is the world's largest single economic consumer.[297] Today, developed countries devote immense amount of money for military expenditures but less developed countries too, devote immense percent of their GDP. For instance, Turkey devotes 5.30% of its GDP for military expenditures which is pretty high.[298] Diminishing this percent would be helpful in constituting a strong economy for Turkey. To reach such a goal, Turkey has to advance its technological capacity, which in turn leads to decrease dependency on foreign sources in military issues. Because, as declared before, military power, as being a component of national power, is deeply affected by technological advancements in a positive way. On the other side, high-tech military equipment requires educated and well trained troops that have ability to use and maintain complex weapon systems.[299] This is also a strong factor to improve the overall quality of military power. As Turkey gains its independence in military issues and owns better educated military personnel, it will be able to guarantee its national security better than today and to help its national economy.

Beyond the application fields of nuclear technology mentioned in this study, there is a wide variety of application fields such as genomics, biochips, medical applications, gene therapy and so on. Technology is something that advances altogether because technology give birth to

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[295] International Energy Agency. (2006). *Annual Report 2006,* available at: http://www.iaea.org/Publications/Reports/Anrep2006/anrep2006_full.pdf, available on: 13.01.2008, p. 36

[296] Ibid.

[297] Theodore, A. Coulombis and J.H. Wolfe. **Introduction to International Relations : Power and Justice,** p 249.

[298] CIA, *World Factbook,* available at https://www.cia.gov/library/publications/the-world-factbook/, available on: 13.01.2009.

[299] Theodore, A. Coulombis and J.H. Wolfe. **Introduction to International Relations : Power and Justice**, p.251.

technology and furthermore it is a process which accelerates itself.[300] So, Turkey has to obtain every technology as much as possible and has to further its own technological development which leads its economical welfare to be improved, industrial capacity to be progressed, agricultural independence and self sufficiency to be increased, military power to be enhanced and so in turn its national power to be greater. Nuclear is one of the most revolutionary high-tech and added-value creator technologies. If Turkey wants to be one of the first class countries of the world, it has to obtain nuclear technology because countries become first class countries only if they could take a step to high technology.[301] "Power resources are raw materials out of which power relationships are forged"[302] Turkey, from this point of view, has to produce its own contribution to nuclear technology and this aim can be achieved only if it could experience it. As Atatürk pointed, "Science does not develop by translation, it develops with experience".

IV. B. 3. How Will Nuclear Technology Affect Turkish Foreign Policy?

Goal of this thesis is to state how building a nuclear power plant probably would affect Turkish foreign policy. This goal is not going to be worked out by furnishing references to case studies but rather a main inference will take place. As a result of overall study of this thesis, it is figured out that nuclear power plants are safe, stable, reliable and fertile facilities to operate. This conclusion is actually put forward by the experts of nuclear energy.

On the other side, Turkey has long been having problems stemming from energy issues. In Turkey, although it has always been set forth that Turkey was at the edge of an energy crisis, nation and industry rarely experienced electricity cut offs. But, as Okan Zabunoğlu says, a careful survey exposes the sad reality. He says; "Turkey would probably have had a big energy crisis near the turn of the century if natural gas had not been started being imported. Share of imported natural gas in electricity production gradually increased, and today 55 % of our electricity comes from burning natural gas. Unfortunately, nearly all of it is import."[303] Turkey did not experience an energy crisis but had a very crooked energy structure. Furthermore Turkey does not have an energy policy because depending on imported energy

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[300] Jared Diamond, **Tüfek Mikrop ve Çelik**, p. 315-332.
[301] Ömer Ersun, (2008), *Türkiye'nin Nükleer Reaktörlere İhtiyacı Var mı?*, Stratejik Analiz,, No. 93, Ocak, p. 40.
[302] David, A. Baldwin, (2002). *Power and International Relations*, (In Walter Carlnaes, Thomas Risse and Beth A. Simmons, [Ed]) **Handbook of International Relations**, London: Sage p. 180.
[303] Interview with Okan Zabunoğlu.

resources to meet energy needs and ignoring domestic resources, ignoring making long term plans cannot be considered as energy policies. With this unsustainable and unreliable structure, it is unrealistic to expect to develop. As Turkey ensures its access to reliable and continuous energy, suitable ground for economic development will occur in respect of energy. Under Turkey's circumstances, nuclear energy's probable contribution to electricity generation, so to economic development is not something negligible. This would lead Turkey's national power to be enhanced.

As declared under the topics of components of national power, nuclear power plants' meaning is not limited with energy issues. The main point of building a nuclear power plant is to acquire and adopt nuclear technology. Building a nuclear power plant without obtaining nuclear technology would have important but relatively very limited affects on national power because nuclear technology helps lots of kinds of technologies to progress too. If Turkey could obtain nuclear technology, there will be a technological take off which in turn enhance national power.

What does it mean for Turkey's foreign policy? Sencer İmer asserts this issue as follows: "If we perceive this issue as just buying a nuclear power plant, everybody would try to sell it but if we consider this issue as a whole technology transfer, no one would like a new competitor to exist. It is very clear. Turkey has to aim at reaching developed countries' level. This must be a goal. If Turkey endeavors to reach developed countries' level rationally, they will try to prevent Turkey from obtaining this technology. And these countries will be the ones that seem our allies. They do not want this but Turkey has to resist against them and act in accordance with its own national interests. Also, because nuclear power plants will diminish energy costs of Turkey and increase competition power, especially European countries with which Turkey has intense trading relations, will be disturbed. On the other side, some of them will decide to benefit from cheap energy costs, educated work force and qualified production ability which Turkey will obtain by nuclear technology. Then, investor probably comes to Turkey. This situation would fasten Turkey's development and strengthen its relationships with major powers (countries). Turkey may experience some resistance during this process but when it overcomes, will be accepted as developed country".[304]

[304] Interview with Sencer İmer.

The relationship between Turkey's foreign policy and nuclear technology is asserted by Mete Göknel as follows; "Having nuclear technology in this region is strategically very important. For instance, historically, there has always been a competition between Turkey and Iran. This competition comes to order and disappears between whiles. Iran never wants Turkey to get nuclear technology not because they are afraid of nuclear attack from Turkey, but because of the power nuclear technology brings. This is about being a regional power.

Ömer Ersun's evolution in this context is as follow; "It won't have direct effect on foreign policy. Nuclear industry means wider resource diversity and so better energy security. If you do not make a grave strategic mistake like ordering a turn-key reactor and if you make sure increasing technology transfer day by day with a serious bargain, perception of outer world about you changes. For example, let's imagine that Turkey could reach the level of South Korea in nuclear industry within the next fifteen- twenty years. Turkey would be accepted to major states club not only with words but really. Because we had a long imperial history and democratic, secular heritage of Atatürk, we would be respected even if all other Muslim communities were suspected; we would become a player whose words are listened in the world scene."[305]

Soner Aksoy says about this issue that "It will affect us in a positive way. We will be more satiated consumer in commercial relations with them. Decrease in dependency on their energy sources will render us more powerful. We will be more coquettish consumer but because it does not mean that we will completely be independent in respect of external oil and natural gas sources, we will be able to apply a more balanced win-win policy. Also, other countries will be more respectful to you when they know that you have nuclear power plants"[306]

Associated Prof. Dr. Mustafa Kibaroğlu from Bilkent University has a different assertion on this subject. He says that "nuclear technology becomes subject of international relations only if it is observed in the light of nuclear weapons. It is not a matter of foreign policy that which technology is acquired by states. Nuclear technology is the technology of 1940s, 50s, 60s. Turkey should invest in future technologies like nano-technology, molecular biology. Will not Turkey be respectable country if it cannot get nuclear technology? If respectability and

[305] Interview with Ömer Ersun.
[306] Interview with Soner Aksoy.

prestige are important, then Turkey must invest in future's technologies. I do not think there is something missing in Turkey due to lack of nuclear technology; it is a political decision."[307]

In the context of national power, the most important thing a more powerful Turkey would experience is actually a major alteration in the nature of its foreign relations. By saying nature of foreign relations, the situation of conflict or collaboration is meant. Today, nature of Turkey's foreign relations, in general terms, reflects the situation of conflict. Turkey has long been in a dispute with Greece because of the continental shelf of the Greece islands in Aegean Sea. On the other side, Cyprus also is one of the controversial subjects of Turkey-Greece relations. Moreover there is a political tension between Turkey and Armenia stemming from so called Armenian genocide. A staminal foreign problem Turkey has to solve is formation of a Kurdish state at Iraq's north which is deeply in transverse with Turkey's national interests. Especially, since the 1979 revolution, relations between Turkey and Iran has been bumpy and although long term interests of both side prevents relations come to dead end, it seems there will no long term amelioration too.[308]

To change the controversial nature of foreign relations into collaborator nature, Turkey has to impose other states that being in controversial relations with Turkey is costly and being in amicable relations with Turkey is beneficial. Once this image is obtained, a stronger Turkey would be able to pursue its foreign policy objectives more actively and more effectively. In Turkey's history, there are some experiments that expose how national power is exercised in real situation. For instance, when Republic of Cyprus demolished by Greeks from 1963 on, Turkey had decided intervene the island but, in 1964, U.S.A opposed to this decision. In his letter, U.S.A's President Johnson told Turkey not to realize this act with very harsh expressions and said that U. S.A would not consent military equipment to be used by Turkish state for this intervention.[309] In the letter, Johnson also added that in the event of intervention, U.S.A would not help Turkey if Soviet Russia had intervened Turkey.[310] So, Turkey had to abandoned intervention. Although this strife with U.S.A., Turkey realized an air strike to Cyprus in 06.08.1964 because of the skirmishes lived in Erenköy. Here, we come across the main point. In 06.08.1964, Turkey realized intervention to Cyprus from air not because it preferred to do so but because Turkey did not have troopships for landing its troops. And

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[307] Interview with Mustafa Kibaroğlu.
[308] Gökhan, Çetinsaya. (2002), *Rafsancani'den Hatemi'ye İran Dış Politikasına Bakışlar*, (In Mustafa Türkeş, İlhan Uzgel[Ed]), **Türkiye'nin Komşuları**, Ankara: İmge, p. 324.
[309] Sibel, Gülcan. (2004), *Kıbrıs: Doğu Akdeniz'de Egemenlik Mücadelesi*, (In Kemal İnat, Burhanettin Duran, Muhittin Ataman[Ed]), **Dünya Çatışma Bölgeleri**, Ankara: Nobel, p. 143.
[310] Ibid.

moreover necessary troopships were not given to Turkey by other states[311]. Following the foundation of Erdemir Steel Fabrics, Turkey could produce necessary flat steel and built its own troopships with them; in turn Turkey realized intervention in 1974 via these ships.[312] As a matter of fact, Turkey relatively became stronger when it was able to produce its own flat steel and troopships. This strength proved itself in 1974 with Cyprus Peace Act. If Turkey was strong enough to act in accordance with its national interests at the beginning of 1960s, it may forestall the violence before happened. Moreover, a stronger Turkey could also discourage Greeks to resort to violence. Because it is clear that there is a dichotomy between Turkey and Greece and what determine the characteristics of the dichotomy is power relations and moreover, perceptions and thoughts on power relations effects and determines the strategies of opposing sides towards each other.[313] This example shows how important for a country to be nationally strong because as Mehmet Gönlübol pointed, external dependency of a country increases as that country remains incapable to meet its own needs.[314]

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[311] Sencer, İmer. *Türkiye'nin Demir-Çelik Sanayinin Durumu ve Geleceği*, p. 3-5.
[312] Ibid.
[313] S. Gülde Ayman, *Türk Yunan İlişkilerinde Güç ve Tehdit*.
[314] Mehmet, Gönlübol. (1993), **Uluslararası Politika**, (4th Edition), Ankara: Attila, p. 145.

CONCLUSION

There is a tendency to see nuclear issues from the window of energy but although nuclear energy, of course, is an important part of this subject, the main point is obtaining nuclear technology via nuclear power plants which is crucial for advancement of lots of other technology fields. Because, once this technology is acquired, the level that was acquired in other fields of technology also advances. The leading parts of these advancements are seen in subjects of material issues, construction issues and automatisation/command issues.

There are some biases which assert nuclear power plants as fatal facilities but the fact is much different than this. Technical specifications of NPPs were observed in the first part of this study and from that data, it can be concluded that NPPs are harmful neither for the environment nor for the people. Also it can be added that there are countries that operate tens of nuclear power plants at the same time like France, U.S.A, Japan, Germany, England and so on. If these facilities were something fatal, then these countries, who are also among the most developed countries –including human rights- of the world, would never apply this technology in their own territories. Moreover, as Yalçın Sanalan points, if there are people who should afraid from nuclear power plants and radiation, it must be Japanese people; not Turks.[315]

With all these knowledge, it can be concluded that nuclear power plants are not harmful and that it is completely suitable and necessary for Turkey. As mentioned earlier in this study, expecting to acquire nuclear technology without having nuclear power plant is completely absurd. Turkey must never be contended with electricity gaining of nuclear power plant but also it has to transfer the nuclear technology.

What is emphasized and mainly inferred from this study is that, if Turkey could acquire nuclear power plant and nuclear technology, its national power will enhance. From the respect of technology, one of the pre-conditions of being a major power of the world is to be owner of nuclear technology. If Turkey could transfer nuclear technology, it would be one of its huge steps to be a regional power. Also, Turkey's dependency on foreign technology aid would diminish. By asserting this subject from this respect, there occurs one more vital point to pay attention.

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[315] Interview with Yalçın Sanalan.

States, that have high technology and scientific capacity to produce high technology, do not interest only in their own problems, they are also strong enough to intervene regional and global political issues.[316] It is obvious that dioristic constituent of this power is science and technology. States that show ability to advance scientific knowledge-based technology capture dominancy in every field. This dominancy does not remain limited to science and technology; it manifests itself not only politically and militarily but also in efforts to possession of world's resources. If Turkey can acquire this technology, it will be a cornerstone for Turkey to be a country which has ability to shape the political development at least in its region also in the world.

Suggestions for the Future Work

Turkey, for its own sake and future must realize this task as soon as possible. The way to realize this task will be by participation of the state in the every aspect of nuclear power plant project, not by models like build-operate-transfer. Turkey had experienced that the model of build-operate-transfer failed. So, it is not advisable to follow this method. All states, who acquired nuclear technology, were able to do it by participation of states and Turkey also has to adopt this way. Unless Turkey, as a state, participates in economical side of this issue and undertakes the risks of this process, there seems no way to success such a vital issue. The recent competition to build Nuclear Power Plant in Turkey ended with a price offer of 15 cents by Russian Atomstroyexport and Turkish Park consortium; the expensive offer Turkey had to face with is due to the uncertainties, risks and high capital cost that the consortium had to take into account. Turkey has to diminish those risks to realize this task; otherwise cost cannot be decreased. The role of state in nuclear power plant projects must be investigated and advantages and historical data on state's role in such a project must be taken into account.

To determine a healthy way for transferring this technology, Turkey must observe the experiments of the countries that transferred this technology accomplishedly before Turkey. South Korea and Taiwan are two of very suitable examples for this kind of work because they both transferred this technology afterward. Turkey can overcome this issue by following the

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[316] Turan, Güven. (2003), *Yirmi Birinci Yüzyılda Türk Bilim ve Teknoloji Politikası: Zihniyet Yaklaşımı*, (In Erdinç Yazıcı [Ed]), **Yirminci Yüzyıldan Yirmi Birinci Yüzyıla Türkiye ve Dünya**, Ankara: İlke Emek, p. 79.

way that those countries used. During such an observation, Turkey has to pay attention especially on the role of state in these countries.

One more deficiency in Turkey is the unconsciousness of its people about technological issues; especially about nuclear technology. There should be a serious effort to enlighten the people in Turkey which in turn leads public opinion to be in favor of nuclear technology. It does not mean that there is no way to succeed such a task without the support of people but support of people is important and positive opinion of people on this issue facilitates the process.

In addition to this element, another important mistake that Turkey suffers from is the lack of a program which guides Turkey for this goal. Turkey needs a serious program that must be planned comprehensively at every stage from beginning to end like human resource analysis or transmission investment which will be required once nuclear power plant is established.

In the future, while Turkey is going through the nuclear technology transfer, using Thorium in the breeder reactors to produce Uranium-233 must be carefully taken into account. Turkey is presented as Thorium rich country[317]. So this should be carefully analyzed and utilized in a country developing nuclear technology.

[317] K.M.V. Jayaram. *An Overview of World Thorium Resources, Incentives for Further Explorationand Forcast for Thorium Requirements in the Near Future*, Available at: http://www.iaea.org/inisnkm/nkm/aws/fnss/fulltext/0412_1.pdf, available on: 05.05.2009.

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Interview with Ömer Ersun, Ankara, 31.07 2008

Interview with Sencer İmer, Ankara, 09.01.2009

Interview with Sümer Şahin, Ankara, 22.06.2008

Interview with Soner Aksoy, Ankara, 31.07.2008

Interview with Yalçın Sanalan, Ankara, 22.10.2008

Appendix 1. World Nuclear Power Reactors 2007-09 and Uranium Requirements

5 January 2009

This table includes only those future reactors envisaged in specific plans and proposals and expected to be operating by 2030. Longer-range estimates based on national strategies, capabilities and needs may be found in the WNA Nuclear Century Outlook. The WNA country papers linked to this table cover both areas: near-term developments and the prospective long-term role for nuclear power in national energy policies.

COUNTRY (Click name for Country Profile)	NUCLEAR ELECTRICITY GENERATION 2007		REACTORS OPERABLE 1 Jan 2009		REACTORS UNDER CONSTRUCTION 1 Jan 2009		REACTORS PLANNED Jan 2009		REACTORS PROPOSED Jan 2009		URANIUM REQUIRED 2008
	billion kWh	% e	No.	MWe	No.	MWe	No.	MWe	No.	MWe	tonnes U
Argentina	6.7	6.2	2	935	1	692	1	740	1	740	123
Armenia	2.35	43.5	1	376	0	0	0	0	1	1000	51
Bangladesh	0	0	0	0	0	0	0	0	2	2000	0
Belarus	0	0	0	0	0	0	2	2000	2	2000	0
Belgium	46	54	7	5728	0	0	0	0	0	0	1011
Brazil	11.7	2.8	2	1901	0	0	1	1245	4	4000	303
Bulgaria	13.7	32	2	1906	0	0	2	1900	0	0	261
Canada	88.2	14.7	18	12652	2	1500	3	3300	6	6600	1665
China	59.3	1.9	11	8587	11	11000	26	27560	72	58400	1396
Czech Republic	24.6	30.3	6	3472	0	0	0	0	2	3400	619
Egypt	0	0	0	0	0	0	1	1000	1	1000	0
Finland	22.5	29	4	2696	1	1600	0	0	1	1000	1051
France	420.1	77	59	63473	1	1630	0	0	1	1600	10527
Germany	133.2	26	17	20339	0	0	0	0	0	0	3332
Hungary	13.9	37	4	1826	0	0	0	0	2	2000	271
India	15.8	2.5	17	3779	6	2976	10	9760	15	11200	978
Indonesia	0	0	0	0	0	0	2	2000	4	4000	0
Iran	0	0	0	0	1	915	2	1900	1	300	143
Israel	0	0	0	0	0	0	0	0	1	1200	0
Italy	0	0	0	0	0	0	0	0	10	17000	0
Japan	267	27.5	53	46236	2	2285	11	14945	1	1100	7569
Kazakhstan	0	0	0	0	0	0	2	600	2	600	0
Korea DPR (North)	0	0	0	0	0	0	1	950	0	0	0
Korea RO (South)	136.6	35.3	20	17716	5	5350	3	4050	2	2700	3109
Lithuania	9.1	64.4	1	1185	0	0	0	0	2	3400	225
Mexico	9.95	4.6	2	1310	0	0	0	0	2	2000	246
Netherlands	4.0	4.1	1	485	0	0	0	0	0	0	98
Pakistan	2.3	2.34	2	400	1	300	2	600	2	2000	65
Poland	0	0	0	0	0	0	0	0	5	10000	0
Romania	7.1	13	2	1310	0	0	2	1310	1	655	174
Russia	148	16	31	21743	8	5980	11	12870	25	22280	3365
Slovakia	14.2	54	4	1686	2	840	0	0	1	1200	313
Slovenia	5.4	42	1	696	0	0	0	0	1	1000	141
South Africa	12.6	5.5	2	1842	0	0	3	3565	24	4000	303

COUNTRY (Click name for Country Profile)	NUCLEAR ELECTRICITY GENERATION 2007		REACTORS OPERABLE 1 Jan 2009		REACTORS UNDER CONSTRUCTION 1 Jan 2009		REACTORS PLANNED Jan 2009		REACTORS PROPOSED Jan 2009		URANIUM REQUIRED 2008
	billion kWh	% e	No.	MWe	No.	MWe	No.	MWe	No.	MWe	tonnes U
Spain	52.7	17.4	8	7448	0	0	0	0	0	0	1398
Sweden	64.3	46	10	9016	0	0	0	0	0	0	1418
Switzerland	26.5	43	5	3220	0	0	0	0	3	4000	537
Thailand	0	0	0	0	0	0	2	2000	4	4000	0
Turkey	0	0	0	0	0	0	2	2400	1	1200	0
Ukraine	87.2	48	15	13168	0	0	2	1900	20	27000	1974
UAE	0	0	0	0	0	0	3	4500	11	15500	0
United Kingdom	57.5	15	19	11035	0	0	0	0	6	9600	2199
USA	806.6	19.4	104	100845	0	0	12	15000	20	26000	18918
Vietnam	0	0	0	0	0	0	2	2000	8	8000	0
WORLD**	**2608**	**15**	**436**	**371,927**	**43**	**37,668**	**106**	**118,095**	**266**	**262,075**	**64,615**
	billion kWh	**% e**	**No.**	**MWe**	**No.**	**MWe**	**No.**	**MWe**	**No.**	**MWe**	**tonnes U**
	NUCLEAR ELECTRICITY GENERATION 2007		REACTORS OPERATING		REACTORS BUILDING		ON ORDER or PLANNED		PROPOSED		URANIUM REQUIRED

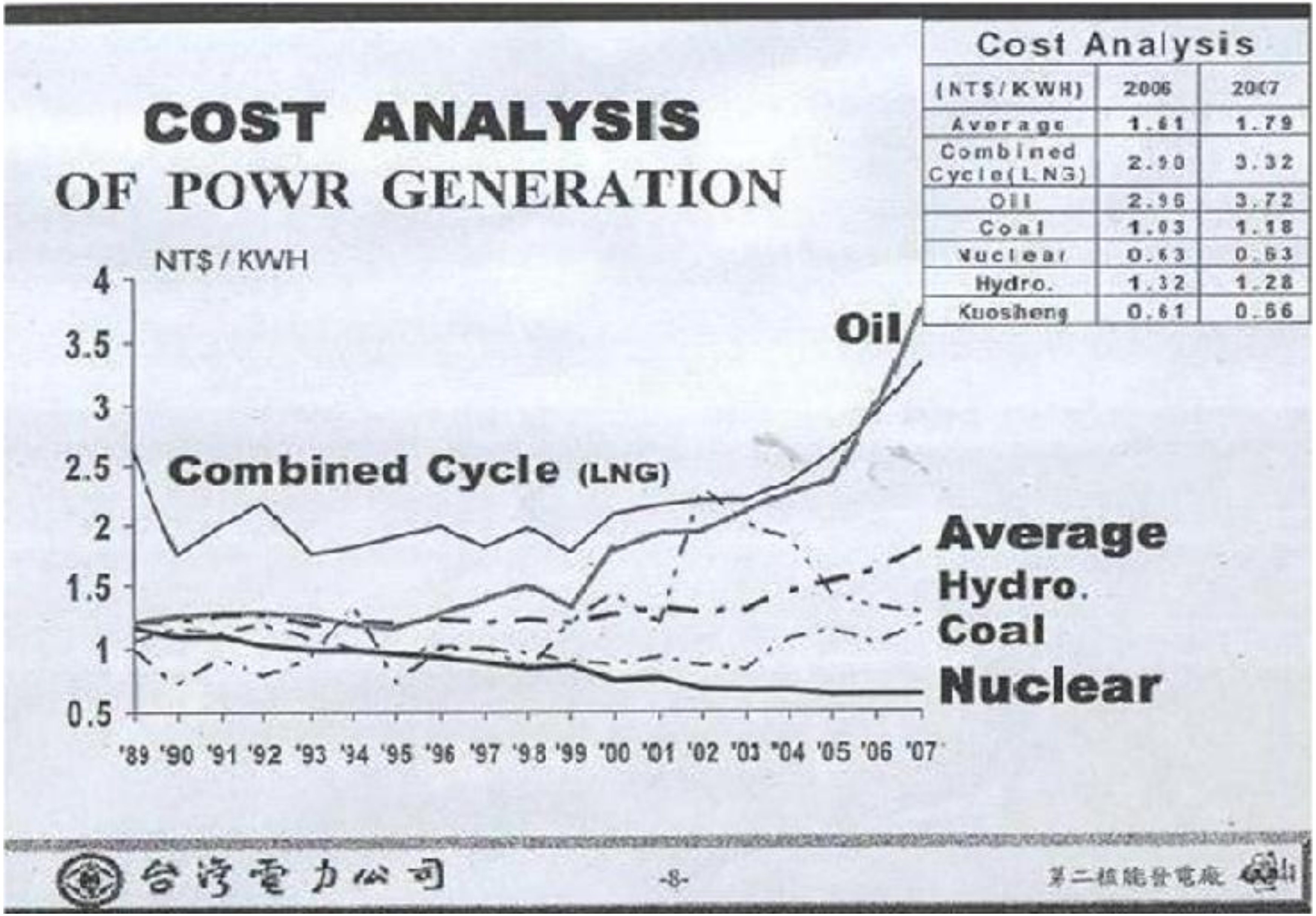
Sources:
Reactor data: WNA to 1/1/09
IAEA- for nuclear electricity production & percentage of electricity (% e) 5/08.
WNA: Global Nuclear Fuel Market (reference scenario) - for U.

Operating = Connected to the grid;
Building/Construction = first concrete for reactor poured, or major refurbishment under way;
Planned = Approvals, funding or major commitment in place, mostly expected in operation within 8 years, or construction well advanced but suspended indefinitely;
Proposed = Specific program or site proposals, expected operation within 20 years. Planned and Proposed are generally gross MWe;
TWh = Terawatt-hours (billion kilowatt-hours), MWe = Megawatt net (electrical as distinct from thermal), kWh = kilowatt-hour.

64,615 tU = 76,200 t U_3O_8

** The world total includes 6 reactors operating on Taiwan with a combined capacity of 4916 MWe, which generated a total of 39 billion kWh in 2007 (accounting for 19.3% of Taiwan's total electricity generation). Taiwan has two reactors under construction with a combined capacity of 2600 MWe.

Appendix 2. Costs of Electricity Production in Taiwan



Cost Analysis

(NT$/KWH)	2006	2007
Average	1.61	1.79
Combined Cycle(LNG)	2.90	3.32
Oil	2.95	3.72
Coal	1.03	1.18
Nuclear	0.63	0.63
Hydro.	1.32	1.28
Kuosheng	0.61	0.56