# The Turkish Model for Transition to Nuclear Energy - II

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Centre for Economics and Foreign Policy Studies

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THE TURKISH MODEL FOR TRANSITION TO NUCLEAR ENERGY - II

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The Centre for Economics and Foreign Policy Studies (EDAM) is an independent think tank based in Istanbul. EDAM's focus is on economics and Turkish foreign policy. EDAM's main objective is to contribute to the public debate in Turkey and abroad on:

- Turkish foreign and security policy,
- Turkey- EU relations.
- the impact and management of globalisation,
- energy and climate change policies,

EDAM undertakes research in these areas and holds regular roundtables and conferences. EDAM also cooperates with its partner institutions in EU Member States on joint research and publication activities.

# Institutional And Legal Structure

EDAM brings together a network of members from multiple sectors of Turkish society including academia, civil society, media and business. This diversified representation enables EDAM to create a productive and effective platform through which different visions and perspectives can interact.

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EDAM accepts project-based funding, matching grants and institutional donations in order to carry out its projects. Additionally, EDAM undertakes joint projects and research with various civil society and international organizations on the basis of the principle of shared funding.

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## Sinan Ülgen

Sinan Ülgen graduated in 1987 from the University of Virginia with a double major in computer sciences and economics. He undertook graduate studies at the College of Europe in Brugge, Belgium where he received, in 1990, a masters degree in European economic integration. He then joined the Turkish Foreign Service as a career diplomat. In 1992, he was posted to the Turkish Permanent Delegation to the European Union in Brussels where he became part of the team that negotiated the Turkey-EU customs union.

Ulgen is the founder and managing partner of Istanbul Economics. The consultancy specializes in market entry strategies for international companies, political and economic risk analysis related to Turkey and regulatory affairs.

Ulgen is the chairman of the Istanbul based think tank, Center for Economics and Foreign Policy Studies (EDAM). His research and opinion pieces have been published by the Center for European Policy Studies (CEPS) in Brussels, Center for European Reform (CER) in London, the Atlantic Council in Washington DC and the World Economic Forum as well as newspapers such as Le Figaro, the Financial Times, Wall Street Journal, European Voice and the International Herald Tribune. He is also the co-author of a book on Turkey-EU relations with Kemal Dervis. Ulgen is also a visiting scholar at Carnegie Europe in Brussels.

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He graduated from Yıldız Technical University as a mathematical engineer, then completed his Master's degree at the Nuclear Energy Institute of Istanbul Technical University as a Nuclear Energy Engineer. He received his PhD degree from the École Polytechnique de Montréal. At Istanbul Technical University , he became an Assistant Professor in 1994, an Associate Professor in 1996, and a full Professor in 2002. He was Vice Chair at Istanbul Technical University, Nuclear Energy Institute in 1994–1999 and Chair and Head of Nuclear Sciences Department in 2002–2003. During this time, he was an Institute Board Member and Institute Council Member at Nuclear Energy Institute . He worked at the Turkish Atomic Energy Agency as a Commission Member and Advisory Board Member in 2003–2007. He became the Dean at Faculty of Architecture and Engineering in 2009-2010 and Vice Rector of Istanbul Aydın University and Honorary Chairman of Energy Politics and Markets Research Center (EPPAM) at Istanbul Aydin University in 2010–2011. In 2011, he was briefly the Acting Rector at Istanbul Aydın University . He has 144 publications most of them published in international peer reviewed journals and submitted in international peer reviewed conferences and these publications were cited 340 times and 254 of them are international. He is the member of Canadian Nuclear Society (CNS) and World Association of Soil and Water Conservation (WASWC).

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## Aaron Stein

Aaron Stein received a bachelor’s degree in political science from the University of San Fransisco and a graduate degree in 2010 from the Monterey Institute of International Studies. His area of expertise is non-proliferation policies. Aaron also regularly contributes to EDAM’s ongoing work on security, arms control and non-proliferation studies. Aaron is also a reporter for the web based Southeast European Times international news agency.

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Deniz Sanin is a senior at the Economics department of the Sabnaci University. She is due to receive a double major from economics and mathematics in 2013. She has been working as a research assistant since 2010 on different topics. Her current research focuses on development economics and public policies.

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# Introduction

Turkey's expected transition to nuclear power has put on the agenda the necessity of reviewing more carefully the public policies in an area that closely concerns the public. A year ago, EDAM had published its first comprehensive study examining relevant public policies in a country in the process of moving towards nuclear energy. The previous study reviewed the risks of nuclear energy, analyzed prominent nuclear accidents worldwide, undertook an economic evaluation of the electricity purchasing price stipulated in the agreement with Russia is evaluated in the light of international precedents and the developments in the Turkish electricity market, examined the investment model foreseen for the construction and operation of the Akkuyu and finally reviewed nuclear energy and security policies.

The full study can be accessed from EDAM's web site

http://www.edam.org.tr/index.php?option=com_content&view=article&id=135&Itemid=208

In this second comprehensive study prepared by EDAM, an economic analysis of the transition to nuclear power underpinned by a comparative study of the cost of other primary energy sources is undertaken. In other words, the expected cost benefits of a transition to nuclear power are investigated under different scenarios. The relationship between nuclear power and climate change policies is examined, Turkey's institutional and regulatory structure for nuclear power is considered, Turkey's policies towards one of the most critical elements of the nuclear chain namely the the fuel cycle are analyzed and finally a review of the potential for technology transfer in this sensitive field is carried out in the framework of the bilateral nuclear cooperation agreements concluded by Ankara.

This study has been prepared under the coordination of EDAM Chairman Sinan Ülgen, with the contributions of Prof. Dr. Hasan Saygın from Istanbul Aydın University, Assoc. Prof. Dr. Gürkan Kumbaroğlu from Boğaziçi University, Assoc. Prof. Dr. İzak Atiyas and Deniz Sanin from Sabancı University, Aaron Stein from EDAM and Deniz Sanin from Sabanci University. EDAM deputy secretary general Nazife Al has also contributed. This study has been financed by a grant from the Hewlett Foundation, California, USA.

Section I

# Nuclear Energy and Turkey: A Demand Analysis

# I

Gürkan Kumbaroğlu

# Executive Summary

In Europe, countries like Germany and Switzerland have announced that they will not build new nuclear energy plants once the current operational ones reach their economic lifetime. On the other hand, other European countries like France and Sweden appear to be determined to continue their nuclear programs. Likewise in Asia, the fast emerging economies of recent years such as China and South Korea do not seem to be affected by the Fukushima disaster and further their programs to install new nuclear power plants. In these countries nuclear energy is seen as a must in order to meet the fast growing energy demand and support economic growth, through low-cost production of goods and services which increases competitiveness.

With its emerging economy and rapidly growing electric energy demand, Turkey resembles more the Asian countries as opposed to European countries where the demand is matured (saturated). In Turkey, rapidly growing demand which averages 7-8% per year in the long run, brings the need for new investment and capacity additions. Per capita consumption needs to be quadrupled in order to reach the European average. Hence, despite the efforts to increase energy efficiency as well energy savings and decrease electricity losses, an economically growing Turkey will expectedly continue to have an increase in demand and additional capacity requirements in the mid and long term.

## *Electricity generation and need in Turkey*

The generation capacity projection for the period 2011-2020 utilizes the demand forecast series derived in the modeling exercise done in June 2011 by the Ministry of Energy and Natural Resources in accordance with macroeconomic targets. Two scenarios, characterized by high demand series and low demand series, were used to define the upper and lower boundaries of the evolution of demand. On average, electricity in the low demand series is forecasted to grow by %6.5 and in the high demand series by 7.5% annually. Accordingly demand would increase from 227 billion kWh in 2011 to 433.9 billion kWh in 2020. It is estimated that peak power demand in 2020 cannot be met under the current supply outlook. Furthermore, demand cannot be met already in 2016 according to figures for reliable power generation and in 2018 according to project generation figures.

## *Energy Generation Costs*

The envisaged electric energy generation capacity of the Akkuyu nuclear power plant has been calculated in the Climate Change Strategy section of this report. Accordingly, annual production will be 8,935,200 MWh in 2019, 17,870,400 MWh in 2020, 26,805,600 MWh in 2021 and 35,740,800 MWh in 2022 onwards. The median value of cost figures in the IEA report under interest rate assumptions of 5% and 10% are given, respectively, as 5.9 and 9.9 cent/kWh for nuclear plants , 8.6 and 9.2 cent/kWh for combined cycle gas plants and 6.2 and 9.0 cent/kWh for coal plants. The comparison of nuclear energy generation cost, using the figures above, with the cost of generating the same amount of electric energy by a natural gas or coal fired power plant is provided in the following Table.

Table Economic comparison, using IEA cost data, if nuclear power is substituted by natural gas or coal fired power ($ million)

| | Nuclear | | Natural Gas | | Coal | |
|---|---|---|---|---|---|---|
| | 5% Interest | 10% Interest | 5% Interest | 10% Interest | 5% Interest | 10% Interest |
| 2019 | 527 | 885 | 768 | 822 | 554 | 804 |
| 2020 | 1,054 | 1,769 | 1,537 | 1,644 | 1,108 | 1,608 |
| 2021 | 1,582 | 2,654 | 2,305 | 2,466 | 1,662 | 2,413 |
| 2022 and onwards | 2,109 | 3,538 | 3,074 | 3,288 | 2,216 | 3,217 |

Accordingly when Akkuyu nuclear power plant becomes fully operational with its full capacity of 4,800 MW, under IEA cost calculations with 5% interest rate assumption, it annually saves $ 1 billion in comparison to production from a natural gas fired plant and $ 100 million in comparison to production from a coal fired plant. On the other hand, when 10% interest rate is assumed, nuclear is found to be more expensive than both natural gas and coal by $ 250 million and $ 300 million, respectively. These calculations do not include externality costs, i.e. damage costs arising from fossil fuel based plants' greenhouse gas emissions and for nuclear plants cost from radioactive wastes and associated risks. The analysis of associated risks is done in a previous study by EDAM and the contribution of nuclear power plants to climate change has been analyzed in another section of this report.

## *The Need for Cheap Generation*

Since electrical energy is a main input in the production of goods and services across all sectors, it constitutes a major cost item in production. Therefore, high electricity prices are reflected in the prices of goods and services as a reflection of increased production cost, which in return hampers competitiveness. Particularly within the context of international trade, exporting firms of countries with low electricity prices enjoy a competitive advantage. Steering investment through financial instruments such as subsidies and taxes is vitally important for a developing country, such as Turkey, with rapidly increasing electricity demand and investment needs. If greenhouse emissions are restricted, then an electricity generation system based on fossil fuels risks incurring new costs due to the need for investing in new and expensive technologies which would increase overall costs and damage the economy at large. In short, the importance of generating cheap electricity that is ecologically and economically sustainable is abundantly clear and necessary measures should be taken to ensure sustainability. There needs to be more public debate on whether nuclear energy generation is as cheap as the IEA figures and also on issues such as waste storage, plant dismantling costs and accident risks.

### *Import dependency*

Turkey's import dependency in energy supply increased over time to reach 80% (see Figure 17). Almost half of (46% in 2010) electricity generation depends on natural gas, which exacerbate import dependency given that 98% of natural gas comes from abroad. The high level of energy import dependency feeds concern over supply security and price stability, hence increasing the importance of a wider utilization of domestic resources.

Energy imports play an important role as they hold the major share in Turkey's foreign trade deficit. The energy import bill of $ 54 billion makes up almost half of the foreign trade deficit. In order for the economy to remain healthy and sustainable, the foreign trade deficit must be decreased by increasing exports and reducing import dependency. Nuclear energy generation will create some level of foreign dependency due to the need for technology and the need for enriched uranium as a fuel. However, the small shares of fuel costs in total generation costs and the ability to acquire the long-term fuel requirements early on, reduce foreign dependency.

### *Conclusion*

Nuclear energy generation is a relatively cheap source with a high capacity factor making it a desirable energy source for many developed countries. However, on the other hand, the radioactive waste, threat of leaks and accidents make it a questionable energy alternative. The economics, technology and risks of nuclear power generation were evaluated with particular reference to the Akkuyu plant in a pioneering study (EDAM, 2011). This study complements the EDAM 2011 findings by elaborating nuclear energy within the context of increasing energy demand in Turkey from different perspectives including supply-demand projections, renewable energy potential, electricity prices, import dependency and international comparisons.

The utilization of renewable energy sources, which constitutes the largest indigenous source, should clearly be increased. However, meeting demand only by renewable energy does not seem possible because of technical and economic challenges as well as potential restrictions.

It is not realistic to expect that renewable energy can fully substitute thermal plants as long as there is not a technological revolution that will drive generation costs significantly down and render distribution networks sufficient, and as long as there no additional external financing mechanisms get available. It is important to ensure not only the technical and environmental but also economic sustainability of investments that will prevent supply shortage which may occur by 2016 according to official projections.

A further increase in electricity prices, which are already fair above the OECD average, will create a threat for international competitiveness of goods and services produced in Turkey. On the other hand, the energy import dependency of 80% threatens price stability and the fossil fuel import bill exceeding $ 50 billion threatens the balance of payments. Therefore, policy-makers aim to lower the share of imported natural gas in electricity production, which currently amounts to nearly 50% of total power generation. As an alternative to natural gas, coal and nuclear power appear as economically viable options that provide reliable production.

# 1- Introduction

In Europe, countries like Germany and Switzerland have announced that they will not build new nuclear energy plants once the current operational ones reach their economic lifetime. On the other hand, other European countries like France and Sweden appear to be determined to continue their nuclear programs. Likewise in Asia, the fast emerging economies of recent years such as China and South Korea do not seem to be affected by the Fukushima disaster and further their programs to install new nuclear power plants. In these countries nuclear energy is seen as a must in order to meet the fast growing energy demand and support economic growth, through low-cost production of goods and services which increases competitiveness.

With its emerging economy and rapidly growing electric energy demand, Turkey resembles more the Asian countries as opposed to European countries where the demand is matured (saturated). In Turkey, rapidly growing demand which averages 7-8% per year in the long run, brings the need for new investment and capacity additions. Per capita consumption needs to be quadrupled in order to reach the European average. Hence, despite the efforts to increase energy efficiency as well energy savings and decrease electricity losses, an economically growing Turkey will expectedly continue to have an increase in demand and additional capacity requirements in the mid and long term.

This study examines the role of nuclear energy within the context of increased demand for electricity in Turkey. The remaining sections include demand and supply projections, analysis of the renewable energy potential, cost comparison between different generation technologies, evolution of electricity prices in comparison to OECD countries, analysis of export dependency in energy and finally, an evaluation of the nuclear power experience of South Korea.

# 2- Electricity generation and need in Turkey

## *2.1. Electricity supply and demand forecasts*

### 2.1.1. Official demand forecasts

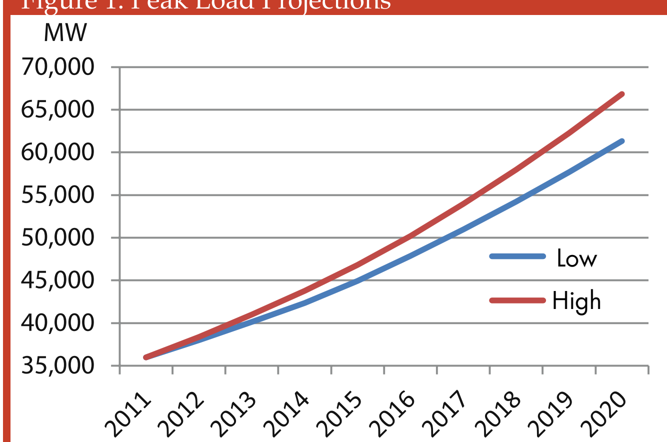
The Turkish Electric Transmission Company TEİAŞ annually publishes 10-year forecasts of production amount and capacity. The most recent study, published in November 2011, covers the period 2011-2020. This study investigates how electric energy demand will be met by taking into consideration the capacity of existing plants, facilities that are under construction and the ones, for which licenses have been granted and which are expected to be operational in the foreseeable future. In addition the analysis considers reliable capacity by taking into consideration operating reserves and reports *projected and reliable* production capacity of the above mentioned facilities.

The generation capacity projection for the period 2011-2020 utilizes the demand forecast series derived in the modeling exercise done in June 2011 by the Ministry of Energy and Natural Resources in accordance with macroeconomic targets. Two scenarios, characterized by high demand series and low demand series, were used to define the upper and lower boundaries of the evolution of demand. On average, electricity in the low demand series is forecasted to grow by %6.5 and in the high demand series by 7.5% annually. Demand forecasts are reported in gross terms excluding the inefficiencies and losses in the transmission network as well as internal usage of the facilities. In addition, peak load series are derived under the assumption that the load curve will not change its characteristics during the planning period. Peak load and annual demand projections for both scenarios are presented in Table 1. Figures 1 and 2 illustrate the evolution of the peak load and demand intervals.

Table 1. Peak load and demand projections *Source: TEİAŞ (2011)*

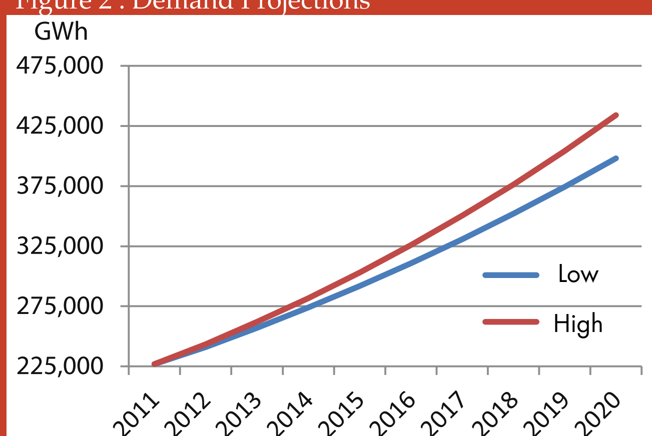
| | Low Demand Scenario | | | | High Demand Scenario | | | |
|---|---|---|---|---|---|---|---|---|
| | Peak Load MW | Change (%) | Demand GWh | Change (%) | Peak Load MW | Change (%) | Demand GWh | Change (%) |
| 2011 | 36,000 | 7.8 | 227,000 | 7.9 | 36,000 | 7.8 | 227,000 | 7.9 |
| 2012 | 38,000 | 5.6 | 241,130 | 6.2 | 38,400 | 6.7 | 243,430 | 7.2 |
| 2013 | 40,130 | 5.6 | 257,060 | 6.6 | 41,000 | 6.8 | 262,010 | 7.6 |
| 2014 | 42,360 | 5.6 | 273,900 | 6.6 | 43,800 | 6.8 | 281,850 | 7.6 |
| 2015 | 44,955 | 6.1 | 291,790 | 6.5 | 46,800 | 6.8 | 303,140 | 7.6 |
| 2016 | 47,870 | 6.5 | 310,730 | 6.5 | 50,210 | 7.3 | 325,920 | 7.5 |
| 2017 | 50,965 | 6.5 | 330,800 | 6.5 | 53,965 | 7.5 | 350,300 | 7.5 |
| 2018 | 54,230 | 6.4 | 352,010 | 6.4 | 57,980 | 7.4 | 376,350 | 7.4 |
| 2019 | 57,685 | 6.4 | 374,430 | 6.4 | 62,265 | 7.4 | 404,160 | 7.4 |
| 2020 | 61,340 | 6.3 | 398,160 | 6.3 | 66,845 | 7.4 | 433,900 | 7.4 |

Figure 1: Peak Load Projections




*Source: TEİAŞ (2011)*

Figure 2 : Demand Projections




*Source: TEİAŞ (2011)*

Additional demand, in accordance with TEİAŞ projections, given by the difference between demands of two consecutive years until 2020 is shown in Table 2 below.

Table 2. Yearly additional demand

| | Low Demand GWh | High Demand GWh |
|---|---|---|
| 2012 | 14,130 | 16,430 |
| 2013 | 15,930 | 18,580 |
| 2014 | 16,840 | 19,840 |
| 2015 | 17,890 | 21,290 |
| 2016 | 18,940 | 22,780 |
| 2017 | 20,070 | 24,380 |
| 2018 | 21,210 | 26,050 |
| 2019 | 22,420 | 27,810 |
| 2020 | 23,730 | 29,740 |

## 2.1.2. Generation capacity under construction

In the TEİAŞ study, generation capacity projections are established by taking into account various types of facilities in the Turkish Electrical System including existing plants, facilities that are under construction and the ones that are expected to be operational in the foreseeable future for which licenses have been granted. The study contains detailed information on the facilities that are under construction. Installed capacity levels, project and reliable generation amounts of the facilities under construction that are granted licenses by the end of 2010 and private production facilities which will be operational in the planning horizon, are calculated by taking into consideration the year in which these facilities will become operational and under two different scenarios based on the assumptions noted below as put forward by the Energy Market Regulatory Authority.

Under scenario 1, the operationality date was deemed uncertain for those projects with a progress rate below 10% and for those where information on progress is undisclosed. Projects with a progress rate 70% or above were assumed to become operational in 2011. In addition, for projects with a progress rate between 35%- 70% the following assumptions, contingent on the capacity of the facility, were applied for date of operationality:

- Below 100 MW year 2012,
- Between 100 MW – 1000 MW year 2013,
- Above 1000 MW year 2014

Finally, for projects with a progress rate between 10% and 35%, one year was added to the foreseen completion date.

Scenario 2 follows the same methodology as scenario 1 with the replacement of 10%, 15% and 35% thresholds with 40%, 70% and 80% respectively.

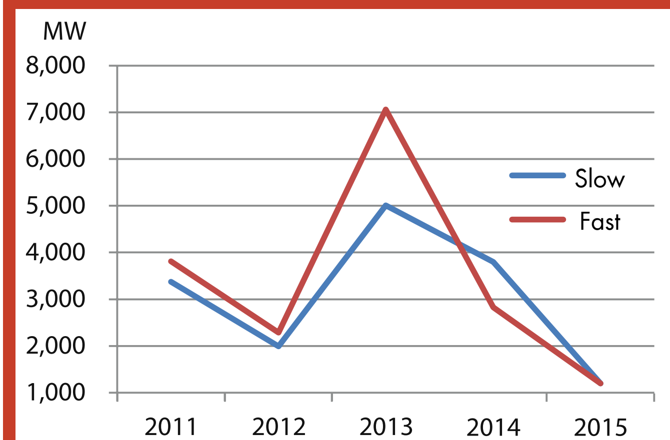
The amount of electric energy that will be produced by each facility is calculated, within two scenarios (projec and reliable generation levels) by evaluating for each year the periodic maintenance, down time, hydrologic and rehabilitation conditions of the plants. Table 3 shows the additional installed capacity, under both scenarios, that is expected to be available once facilities under construction become operational.

Table 3. Distribution of production facilities *Source: TEİAŞ (2011)*

| | Slow Progress Scenario | | | Fast Progress Scenario | | |
|---|---|---|---|---|---|---|
| | Installed Capacity MW | Project Generation GWh | Reliable Generation GWh | Installed Capacity MW | Project Generation GWh | Reliable Generation GWh |
| 2011 | 3,372 | 7,641 | 6,180 | 3,811 | 8,532 | 6,709 |
| 2012 | 1,991 | 11,333 | 8,426 | 2,287 | 12,841 | 9,584 |
| 2013 | 5,006 | 19,013 | 15,400 | 7,058 | 25,216 | 21,058 |
| 2014 | 3,801 | 20,226 | 17,241 | 2,827 | 24,096 | 20,812 |
| 2015 | 1,200 | 13,787 | 11,587 | 1,200 | 12,070 | 10,130 |

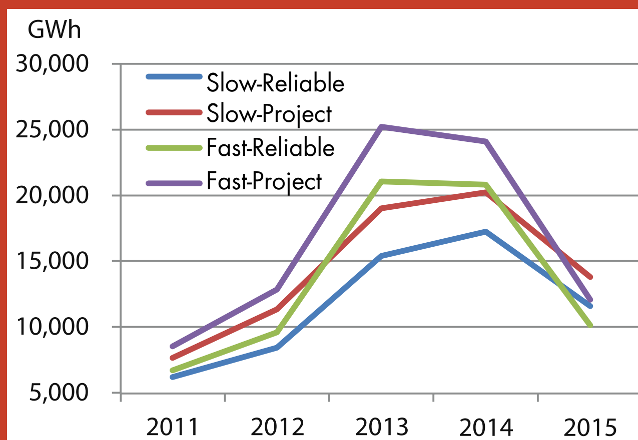
As seen in Figure 3, additional capacity that will be operational in 2014 and 2015 is higher under the slow paced construction scenario in comparison to the scenario with fast paced construction. This is due to the fact that facilities with fast progressing constructions become operational in previous years.

Figure 3. Additional Capacity Projections




*Source: TEİAŞ (2011)*

Figure 4. Additional Generation Projections



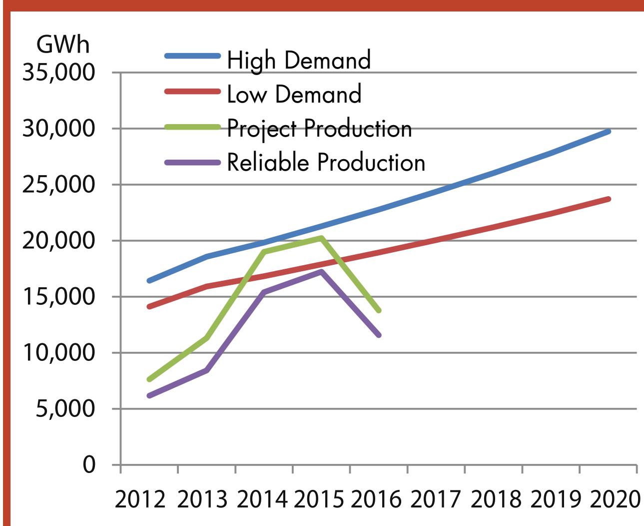

*Source TEİAŞ (2011)*

### 2.1.3. The Need for Additional Capacity

The TEİAŞ study reports on how a demand increase from 227 billion kWh in 2011 to 433.9 billion kWh in 2020 (in accordance with the high demand series determined in the modeling exercise of the Ministry of Energy and National Resources) would be met given the supply outlook given in the previous section and presents implications for supply-demand balance. It is found that peak power demand in 2020 cannot be met under the current supply outlook. Furthermore, demand cannot be met already in 2016 according to figures for reliable power generation and in 2018 according to project generation figures.

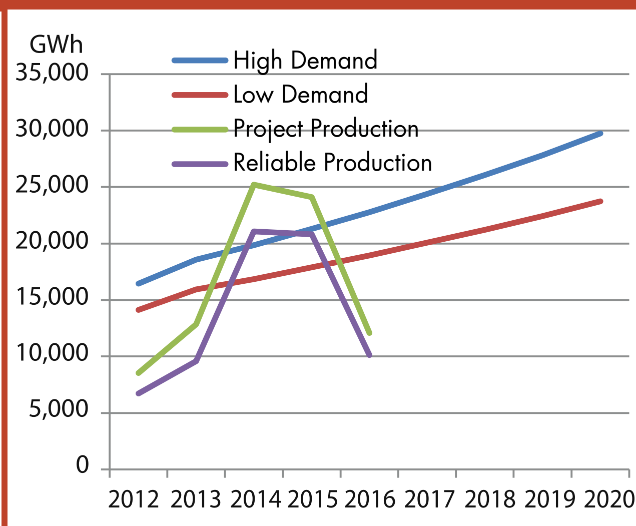
The demand projections and additional generation forecasts reported previously are illustrated in Figures 5 and 6. As can be seen in Figure 5, if the progress of plants under construction continues in slow pace, the reliable production figures of these plants will not be enough to meet additional demand. On the other hand, while projected productions are sufficient to meet low demand scenarios in 2014 and 2015, they fall short of high demand projections. Figure 6 shows that if the progress of plants under construction continues in fast pace, then additional demand in 2014 and 2015 could be met; however, still there is unmet additional demand in preceeding and succeeding periods.

Figure 5: Suppply and demand – Slow growth




*Source: TEİAŞ (2011)*

Figure 6. Suppply and demand – Fast growth




*Source: TEİAŞ (2011)*

Table 4 shows the production of public and private plants, both operational and under construction, as a percentage of total demand. As illustrated, the reserve production nearing 30% at times plunges to negative values between 2016-2019 depending on the scenario, making evident the need for additional production facilities beginning 2016. A similar situation is observed for installed capacity backup to meet peak power demand.

Table 4 .The production of public and private plants, both operational and under construction, as a percentage of total demand

| | Low Demand | | | | High Demand | | | |
|---|---|---|---|---|---|---|---|---|
| | Project Generation | | Reliable Generation | | Project Generation | | Reliable Generation | |
| | Fast Progress | Slow Progress | Fast Progress | Slow Progress | Fast Progress | Slow Progress | Fast Progress | Slow Progress |
| 2011 | 30,3 | 29,9 | 11,8 | 11,6 | 30,3 | 29,9 | 11,8 | 11,6 |
| 2012 | 28,1 | 27,1 | 10,6 | 9,9 | 26,9 | 25,9 | 9,6 | 8,9 |
| 2013 | 29,8 | 26,4 | 13,0 | 10,2 | 27,3 | 24,1 | 10,9 | 8,1 |
| 2014 | 30,0 | 25,5 | 14,2 | 10,2 | 26,4 | 21,9 | 10,9 | 7,1 |
| 2015 | 26,5 | 22,8 | 11,3 | 8,1 | 21,7 | 18,2 | 7,2 | 4,0 |
| 2016 | 19,3 | 15,9 | 4,9 | 1,9 | 13,8 | 10,5 | 0,0 | -2,9 |
| 2017 | 11,7 | 8,5 | -1,6 | -4,5 | 5,5 | 2,5 | -7,1 | -9,8 |
| 2018 | 5,2 | 2,2 | -7,5 | -10,2 | -1,6 | -4,4 | -13,5 | -16,0 |
| 2019 | -1,1 | -4,0 | -13,0 | -15,5 | -8,4 | -11,1 | -19,4 | -21,8 |
| 2020 | -7,0 | -9,7 | -18,2 | -20,6 | -14,7 | -17,2 | -24,9 | -27,1 |

*Source: TEİAŞ (2011)*

## *2.2. Technological Foresight*

### 2.2.1. Energy Strategy and Technological Preferences

According to the "Electric Energy Market and Supply Security Strategy Paper" in force since 2009, the goals for year 2023 are set as follows: the share of renewable sources in electricity generation is targeted to be at least 30% whereas it is aimed that the share of natural gas gets reduced to less than 30% of total generation; the share of nuclear energy is planned to be 5%. Furthermore, it is envisaged that the installed capacity of wind power will increase to 20,000 MW and all 600 MW of geothermal potential as well as all of hydroelectric power potential will be operational by 2023. Finally, the strategy paper targets widening the use of solar power in the generation of electricity in order to fully benefit from its potential. The increased share of renewables in electricity generation will decrease the share of fossil fuels, and particularly of imported energy sources. It is also mentioned that proven lignite and hardcoal reserves will be depleted until 2023 and plants dependent on imported coal will be operational.

### 2.2.2. Renewable Energy Potential

The Wind Power Potential Map of Turkey (REPA) along with the Solar Energy Potential Map (GEPA) are published on the website of the General Directorate for Renewable Energy under the auspices of the Ministry of Energy and Natural Resources. The regional wind speed and capacity factors as well as solar radiation levels are reported in both maps. Figures prove Turkey to be in a vantage point with respect to majority of European countries in both sources of energy. "The

Ministry of Energy and Natural Resources and Affiliates' Targets and Activities" report of 2011, also known as the "Blue Book", quantifies the REPA figures of installed capacity. Accordingly, the potential of wind power is given to be 47,849 MW (see Table 5). But in view of the conversion efficiency of wind power, this capacity corresponds to an electricity generation potential of approximately 33 billion kWh. In addition according to TEIAS at present only 33 billion kWh of wind power can be connected the transmission network. Whereas compared to the reference year of 2011, the increase in yearly demand is estimated to be between 170 and 207 billion kWh.

Table 5. Total Wind Power Potential of Turkey *Source: Blue Book (2011)*

| Wind Speed (m/s) | Wind Power (W/m$^2$) | Total Area (km$^2$) | Percentage of Land With Wind | Total Installed Capacity (MW) |
|---|---|---|---|---|
| 7.5- 8 | 400-500 | 5.851,87 | 0.8 | 29.259,36 |
| 8-8.5 | 500-600 | 2.598,86 | 0.4 | 12.994,32 |
| 8.5-9 | 600-800 | 1.079,98 | 0.1 | 5.399,92 |
| >9 | >800 | 39,17 | 0 | 195,84 |
| | | 9.569,89 | 1,3 | 47.849,44 |

According to the State Hydraulic Works (DSI), Turkey's theoretical hydropower potential amounts to 433 billion kWh whereas the recoverable technical potential is computed as 216 billion kWh. DSI data indicates that Turkey's hydropower potential utilization rate is quite low when compared to developed countries and there is a potential of 20,000 MW capacity whose construction has not started.

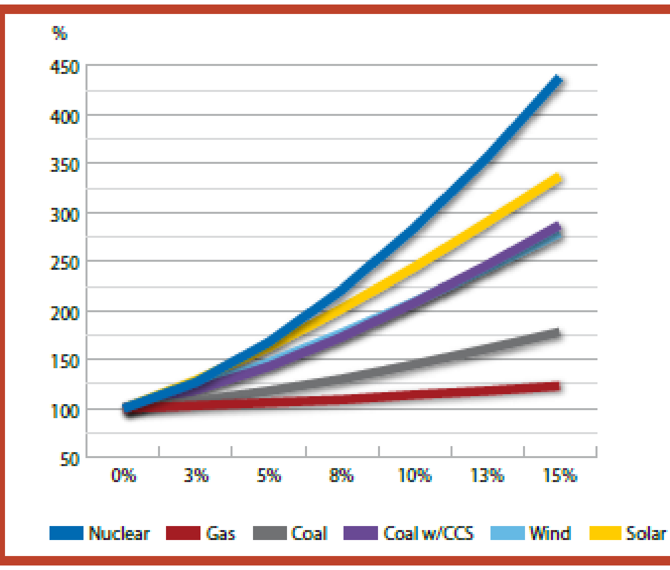
It is evident in GEPA that Turkey is located on a solar belt and has a significant solar energy potential . Whilst some of this potential is used in hot water generation, its use for electricity generation is virtually non-existent. Due to the fact that electricity generation from solar energy is more expensive with respect to other renewable sources such as wind and hydro, no quantified data in terms of installed capacity is available for solar power. Nonetheless, it is worthwhile to note that Germany with a solar potential less than the worst performing region of Turkey, the Black Sea region, has more than 20,000 MW installed solar power capacity.

## 2.3. Generation Costs

### 2.3.1. Energy Generation Costs

The study "Projected Costs of Generating Electricity" published by the International Energy Agency (IEA) in 2010 presents production costs of various technologies. It reports from 21 countries capturing data from a total of 190 plants of which 48 are coal (34 with Carbon Capture and Storage (CCS) technology and 13 without CCS), 27 are natural gas, 20 are nuclear, 26 are wind (18 on land and 8 on water), 17 are solar, 14 are hydroelectric, 20 are co-generation and 18 are other types. The evaluation of data from these plants is done under a common methodology and assumptions, providing for a chance to compare. The calculated figures represent the net production cost excluding transmission and distribution costs. The cost forecasts of the study include an endogenized cost of 30 USD/ton $CO_2$. According to the IEA study, nuclear, coal and natural gas plants are relatively cheaper alternatives in Europe. While the assumptions of the study are presented in the report, it is underlined that cost calculations are particularly sensitive to the interest rate. As seen in Figure 7 below, the cost of nuclear power technology is significantly affected by the interest rate assumption.

Figure 7. The impact of interest rate assumption on cost calculations




*(Source: IEA, 2010)*

Figures 8 and 9 show regional costs under two different interest rate scenarios

Figure 8. Electricity generation costs under 5% interest rate assumption *(Source: IEA, 2010)*

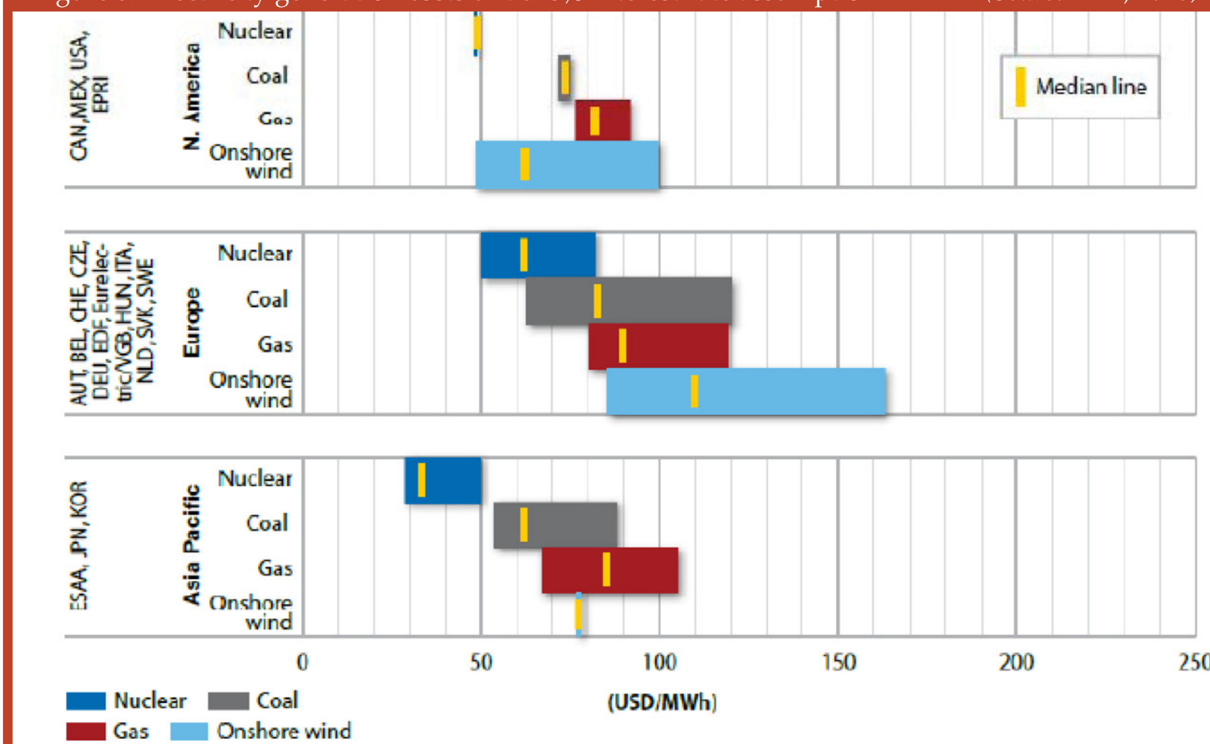
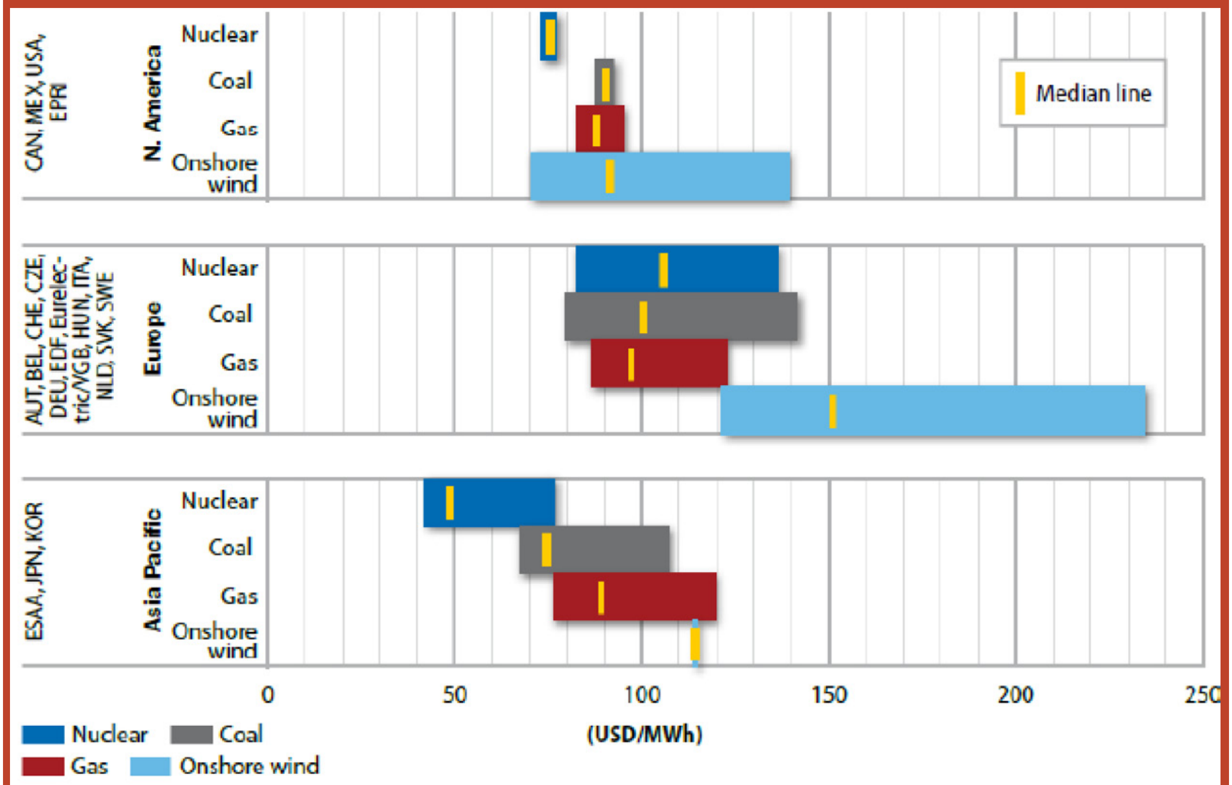


Figure 9. Electricity generation costs under 10% interest rate assumption *(Source: IEA, 2010)*



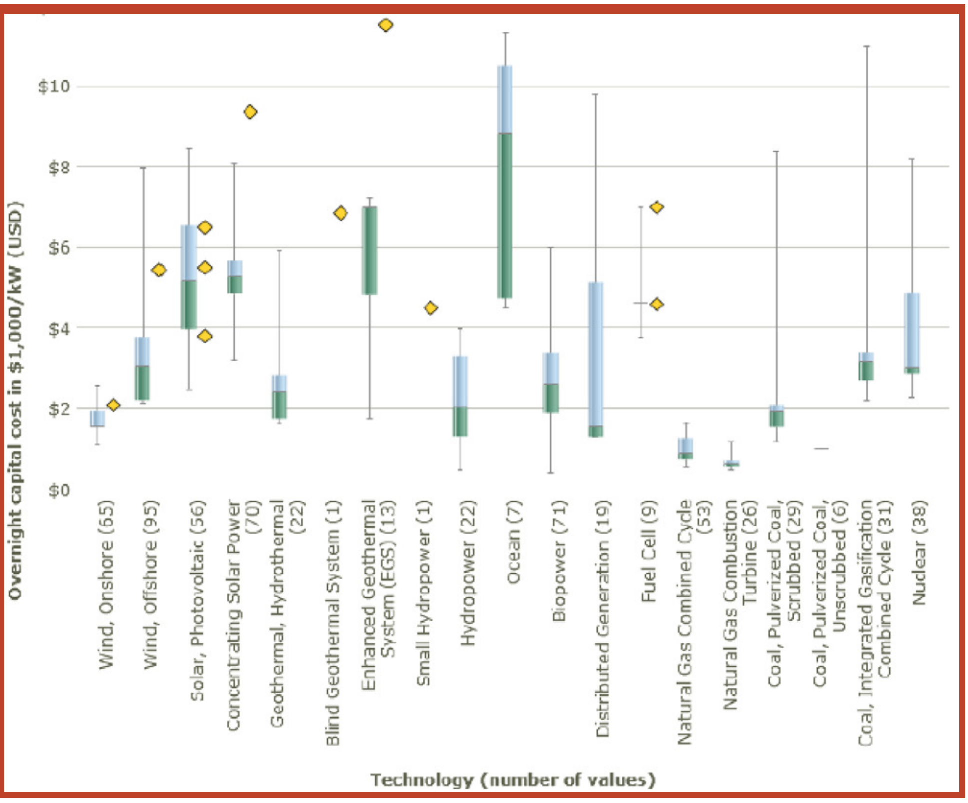

The IEA regional cost figures presented above take into consideration only onshore wind power from among the renewable power generation technologies. Among these, only some wind power plants in the USA are able to compete with nuclear power plants in terms of generation cost. A more comprehensive and up to date cost analysis is available at the U.S. National Renewable Energy Lab (NREL) database. Figures 10 through 13 show the cost range based on the data from various plants between 2008 and 2012. Accordingly, due to relatively higher investment costs and relatively lower production costs, total costs remain low for nuclear power plants. However, unlike the IEA results, NREL results provide similar production costs for nuclear power and wind power. This outcome stems from the fact that, under suitable weather conditions, wind power can compete with nuclear power in terms of cost. It must be noted, however, that discontinuity of suitable wind conditions limit wind power plants' ability to meet the demand throughout a year and the issue of reliability, further discussed in the following section, becomes relevant.

The envisaged electric energy generation capacity of the Akkuyu nuclear power plant has been calculated in the Climate Change Strategy section of this report. Accordingly, annual production will be 8,935,200 MWh in 2019, 17,870,400 MWh in 2020, 26,805,600 MWh in 2021 and 35,740,800 MWh in 2022 onwards. The median value of cost figures in the IEA report under interest rate assumptions of 5% and 10% are given, respectively, as 5.9 and 9.9 cent/kWh for nuclear plants, 8.6 and 9.2 cent/kWh for combined cycle gas plants and 6.2 and 9.0 cent/kWh for coal plants. The comparison of nuclear energy generation cost, using the figures above, with the cost of generating the same amount of electric energy by a natural gas or coal fired power plant is provided in Table 6. Table 6 shows that when Akkuyu nuclear power plant becomes fully operational, envisaged to be 4,800 MW, under IEA cost calculations with 5% interest rate assumption, it annually saves $ 1 billion in comparison to production from a natural gas fired plant and $ 100 million in comparison to production from a coal fired plant. On the other hand, when 10% interest rate is assumed, nuclear is found to be more expensive than both natural gas and coal by $ 250 million and $ 300 million, respectively. These calculations do not include externality costs, i.e. damage costs arising from fossil fuel based plants' greenhouse gas emissions and for nuclear plants cost from radioactive wastes and associated risks. The analysis of associated risks is done in a previous study (EDAM, 2011) and the contribution of nuclear power plants to climate change has been analyzed in the following section of this report.

Table 6. Economic comparison, using IEA cost data, if nuclear power is substituted by natural gas or coal fired power ($ million)

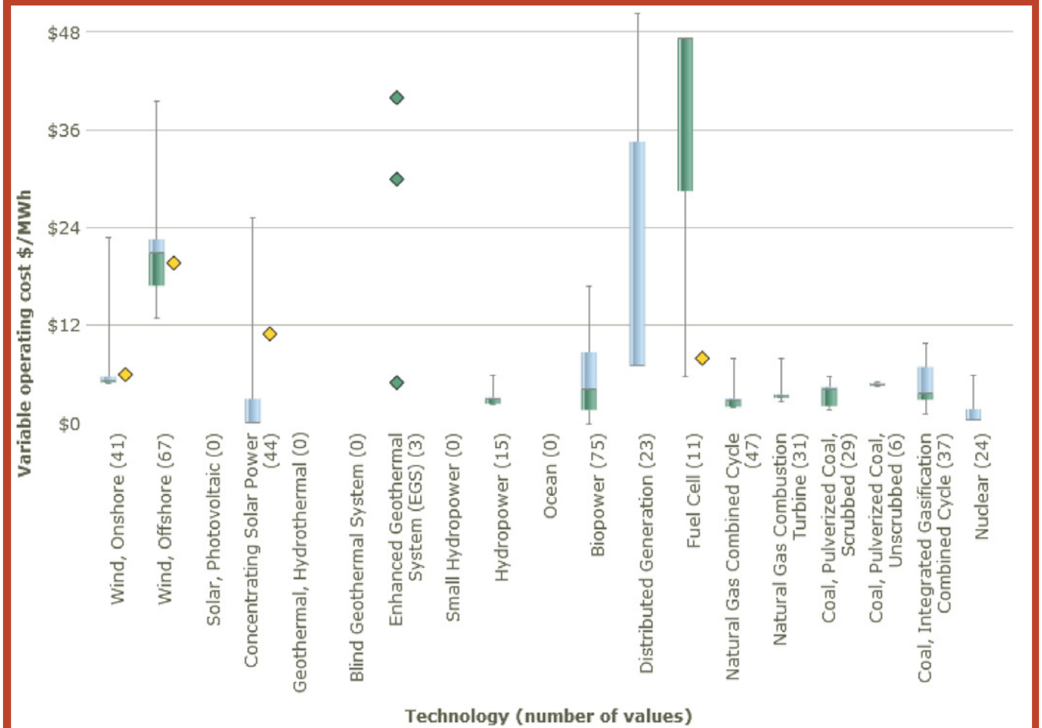
| | Nuclear | | Natural Gas | | Coal | |
|---|---|---|---|---|---|---|
| | 5% Interest | 10% Interest | 5% Interest | 10% Interest | 5% Interest | 10% Interest |
| 2019 | 527 | 885 | 768 | 822 | 554 | 804 |
| 2020 | 1,054 | 1,769 | 1,537 | 1,644 | 1,108 | 1,608 |
| 2021 | 1,582 | 2,654 | 2,305 | 2,466 | 1,662 | 2,413 |
| 2022 and onwards | 2,109 | 3,538 | 3,074 | 3,288 | 2,216 | 3,217 |

Figure 10. Cost of electricity generation technologies in the US between 2008 and 2012



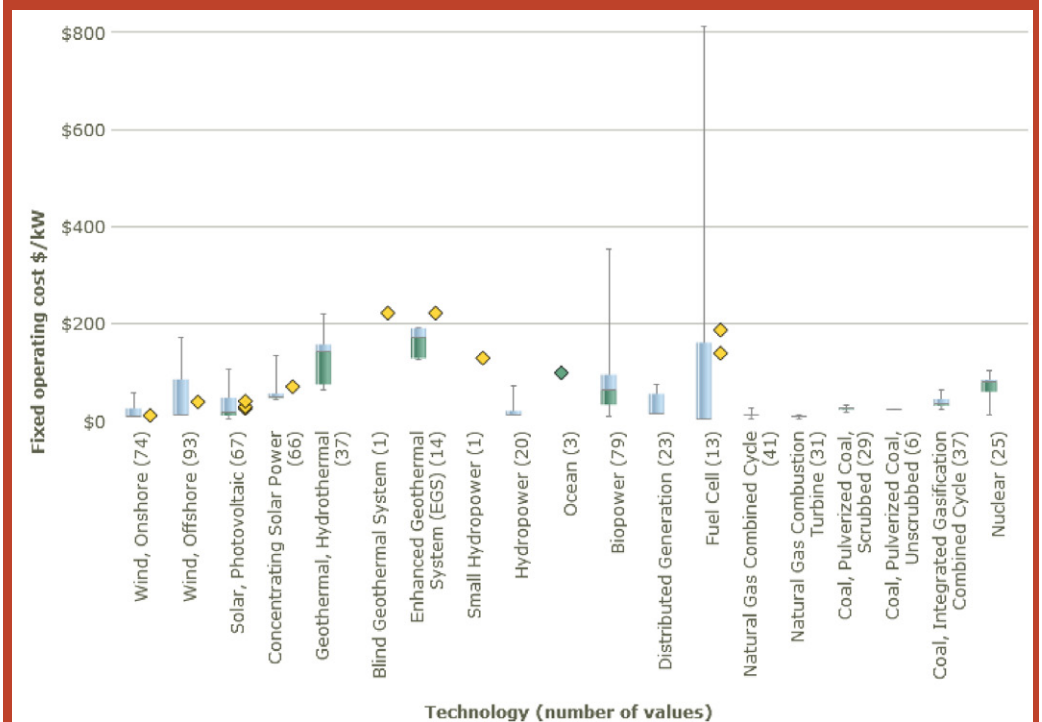

*(Source: NREL, 2012)*

Figure 11. Variable operational costs of electricity generation technologies in the U.S. between 2008 and 2012




*(Source: NREL, 2012)*

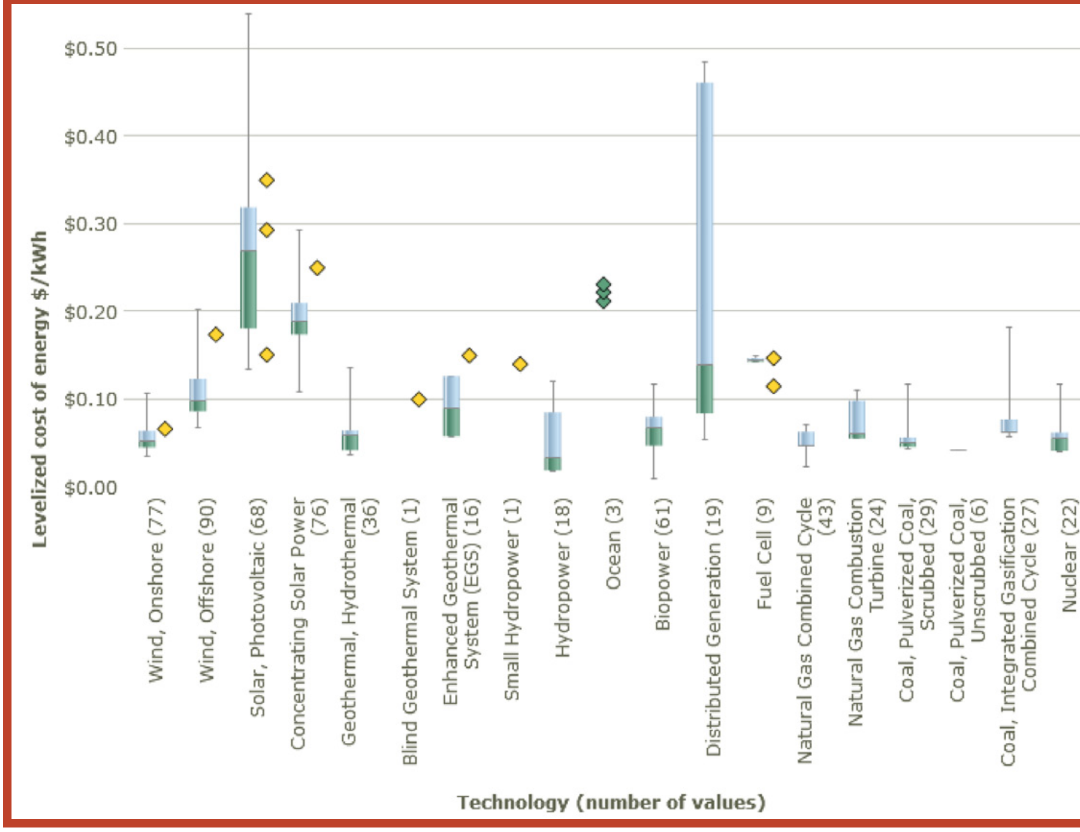
Figure 12. Fixed operational cost of electricity generation technologies in the U.S.




*(Source: NREL, 2012)*

Figure 13. Cost of electricity generation technologies in the US between 2008 and 2012 under 7% interest rate assumption

*(Source: NREL, 2012)*




## *2.4. The Need for Reliable Generation*

Two main pillars of ensuring reliable supply are reduction of export dependency and diversification. According to the long term targets provided in the "Electricity Energy Market and Supply Security Strategy Paper", the use of domestic coal, hydraulic, wind and geothermal energy potentials in electricity generation will be increased until 2023 while nuclear energy will account for 5% of total electricity generation. The first target of the strategic theme "Energy Supply Security" of the 2010-2014 Strategic Plan published by the Ministry of Energy and Natural Resources is defined as "Prioritization of Domestic Supply and Supply Diversification". In order to reach this target, it is envisaged that nuclear energy plant construction will commence before 2014.

The study of Kumbaroğlu et al. (2008a) provides a comparative analysis of various production technologies' capacity factors and availabilities. While the capacity factor of a nuclear energy plant is above 90%, it is between 60% and 80% for plants using fossil fuels. In the renewable energy category, the capacity factor for geothermal and biomass is 90%, while for others it is 50%. Nuclear energy and geothermal energy become viable options for supply in regard of security; their capacity factor over 90% plays an important role in the uninterrupted supply for baseload generation. Capacity factors of U.S. plants between 2008 and 2012 are given in Figure 14. These results are similar to those provided in Kumbaroğlu et al. (2008a).

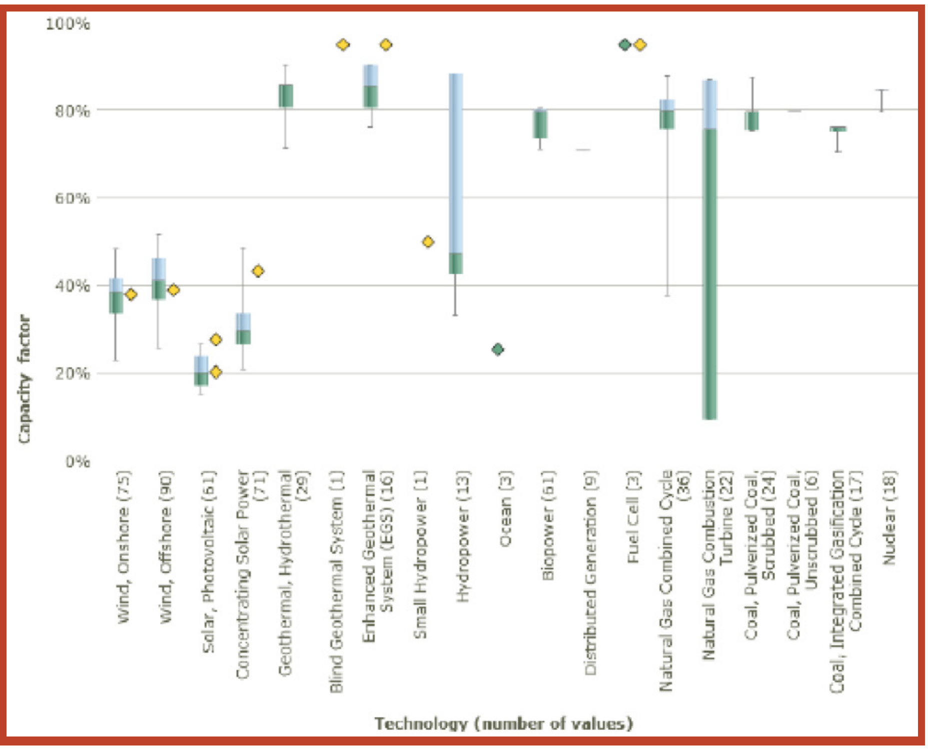



Figure 14. Capacity factors of U.S. plants between 2008 and 2012

*(Source: NREL, 2012)*

## *2.5. Evolution of electricity prices*

According to the IEA data, both domestic and industrial electricity prices in Turkey are fair above the OECD average. Data of the last 15 years reveals that historically prices in Turkey have been well above (twice or even more at times) the OECD (see Table 7).

Table 7. Evolution of average end-user electricity prices in Turkey and OECD (USD/kWh)

| | Industry | | Domestic | |
|---|---|---|---|---|
| | Turkey | OECD | Turkey | OECD |
| 1997 | 0.154 | 0.064 | 0.159 | 0.106 |
| 1998 | 0.150 | 0.063 | 0.157 | 0.105 |
| 1999 | 0.165 | 0.060 | 0.173 | 0.105 |
| 2000 | 0.177 | 0.063 | 0.187 | 0.105 |
| 2001 | 0.228 | 0.069 | 0.240 | 0.109 |
| 2002 | 0.232 | 0.069 | 0.245 | 0.110 |
| 2003 | 0.193 | 0.073 | 0.205 | 0.112 |
| 2004 | 0.176 | 0.074 | 0.195 | 0.115 |
| 2005 | 0.172 | 0.080 | 0.191 | 0.121 |
| 2006 | 0.168 | 0.089 | 0.187 | 0.132 |
| 2007 | 0.164 | 0.093 | 0.183 | 0.136 |
| 2008 | 0.202 | 0.106 | 0.239 | 0.147 |
| 2009 | 0.229 | 0.107 | 0.274 | 0.151 |
| 2010 | 0.229 | 0.107 | 0.279 | 0.150 |

As seen in Figures 15 & 16, average electricity prices of OECD countries exhibit a smooth slowly increasing trend whereas there are sharp fluctuations around the increasing trend in Turkey. The main reason for the high volatility of prices is due to the changes observed in natural gas prices and currency, which is an outcome of the country's high energy import dependency.

Figure 15. Industrial electricity prices

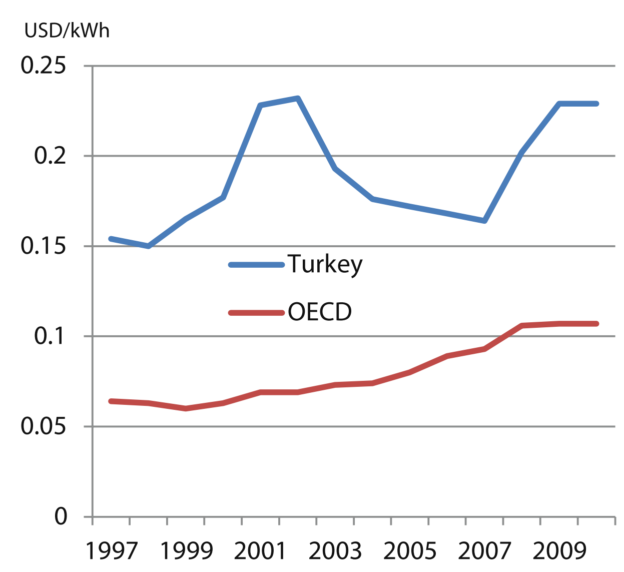
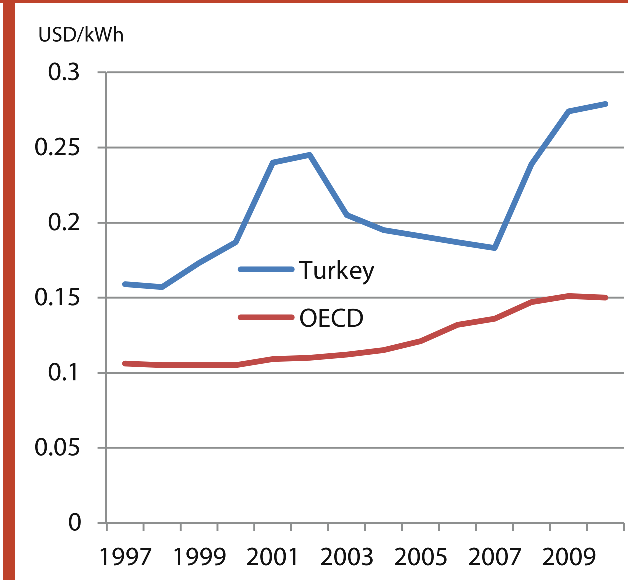



Figure 16. Domestic electricity prices




*Data Source: International Energy Agency (IEA)*

## *2.6. Renewable Energy Subsidies*

According to the subsidy programme introduced by law number 5346 of 10 May 2005 on The Usage of Renewable Energy Sources for Electric Energy Generation and law number 6094 of 29 December 2010, licensed suppliers with a "Renewable Energy Supply Document", are guaranteed the following prices per kWh for a 10-year period:

– Hydroelectric generation facility:$ 7.3 cents

– Wind energy generation facility: $ 7.3 cents

– Geothermal energy generation facility: $ 10.5 cents

– Biomass generation facility (including landfill gas): $ 13.3 cents

– Solar energy generation facility: $ 13.3 cents

Kumbaroğlu et al.'s (2008a) modeling study revealed that the law of 2005 would not be enough for proliferation of renewable energy technologies and that there needs to be higher incentive that is specific to different technologies. It is believed that the new incentive figures announced at the end of 2010 as presented above, albeit being low in comparison to European countries, in addition with subsidies for domestic generation technologies can help the development of renewable energy technologies in regions where there is high potential. Furthermore, more investors might be drawn to these technologies by carbon tax or emission caps. However, the fact that renewable sources are not continuous requires high planning in the production system to ensure supply security. This planning includes on the one hand meeting the increasing back-up capacity needs and on the other hand more investment on improvement of distribution networks to make them sufficient. However, as shown in the previous section, any investment that will increase the above OECD average electricity prices should be avoided unless outside financing options arise. Within the context of Turkey's sustainable development move, there is an increased demand particularly due to the energy sector. Directing all investment needed to meet this energy demand to renewable sources of energy emerges as an expensive option. However, Turkey has a greater renewable energy potential, which is under-utilized when compared to most European countries. The need for increased use of renewable energy technologies in Turkey is beyond any doubt. At the same time, however, there is need for cheap and reliable supply to meet the rapidly increasing demand.

## *2.7. The Need for Cheap Generation*

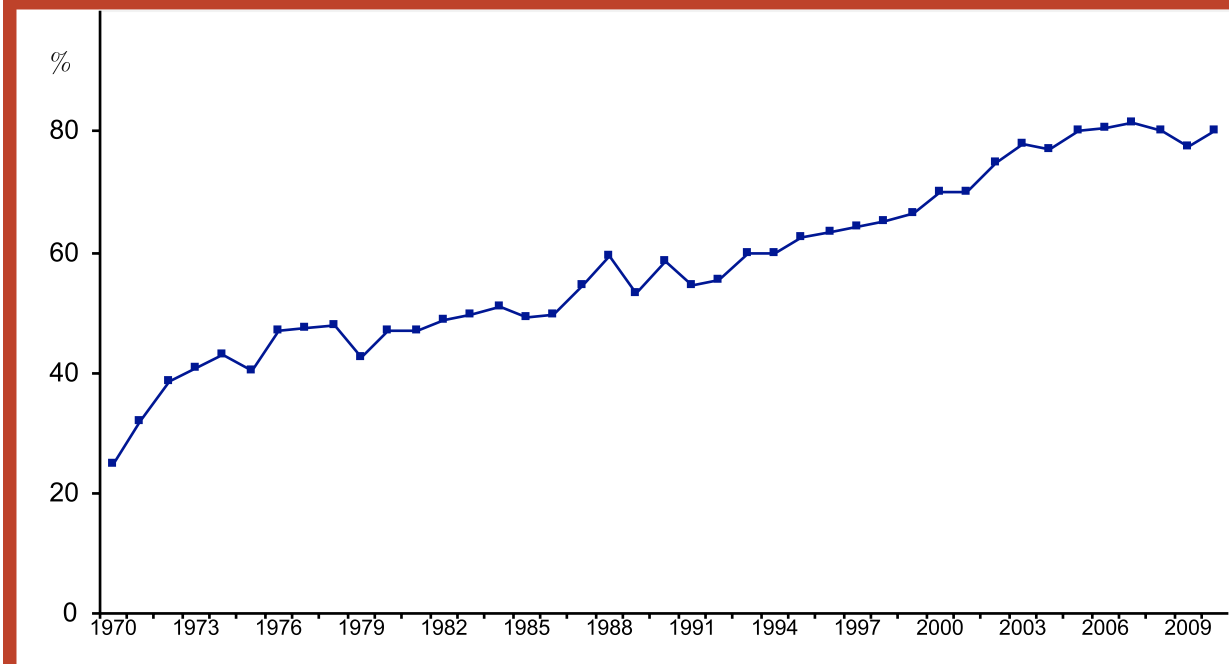
Since electrical energy is a main input in the production of goods and services across all sectors, it constitutes a major cost item in production. Therefore, high electricity prices are reflected in the prices of goods and services as a reflection of increased production cost, which in return hampers competitiveness. Particularly within the context of international trade, exporting firms of countries with low electricity prices enjoy a competitive advantage. There are numerous scientific studies that investigate the relation between energy prices and macroeconomic indicators (e.g. Akkemik 2011, Kumbaroğlu et al., 2008). Therefore, cheap electrical energy is important for the macroeconomy. Steering investment through financial instruments such as subsidies and taxes is vitally important for a developing country, such as Turkey, with rapidly increasing electricity demand and investment needs. If greenhouse emissions are restricted, then an electricity generation system based on fossil fuels risks incurring new costs due to the need for investing in new and expensive technologies which would increase overall costs and damage the economy at large. Technology renewal does not necessarily imply foregoing fossil fuels, since as mentioned earlier, under the IEA scenarios with endogenized carbon tax, natural gas and coal preserve their relative low cost levels. However, there is a possibility of cleaner and more efficient technology renewal. For example, carbon capture and storage (CCS) and gasification are widely used technologies in coal fired power plants. In short, the importance of generating cheap electricity that is ecologically and economically sustainable is abundantly clear and necessary measures should be taken to ensure sustainability. There needs to be more public debate on whether nuclear energy generation is as cheap as the IEA figures and also on issues such as waste storage, plant dismantling costs and accident risks. With regard to these issues, the first comprehensive and, still, the only independent and scientific study was published by EDAM in 2011 on the Akkuyu nuclear power and its comparison with other plants in the world.

## *2.8. Import dependency*

### 2.8.1. Import of primary energy supply

Turkey's import dependency in energy supply increased over time to reach 80% (see Figure 17). Almost half of (46% in 2010) electricity generation depends on natural gas, which exacerbate import dependency given that 98% of natural gas comes from abroad. The high level of energy import dependency feeds concern over supply security and price stability, hence increasing the importance of a wider utilization of domestic resources.

Figure 17. Evolution of Energy Import Dependency




*(Data Source: World Energy Council Turkish National Committee)*

### 2.8.2. Cost of imported energy

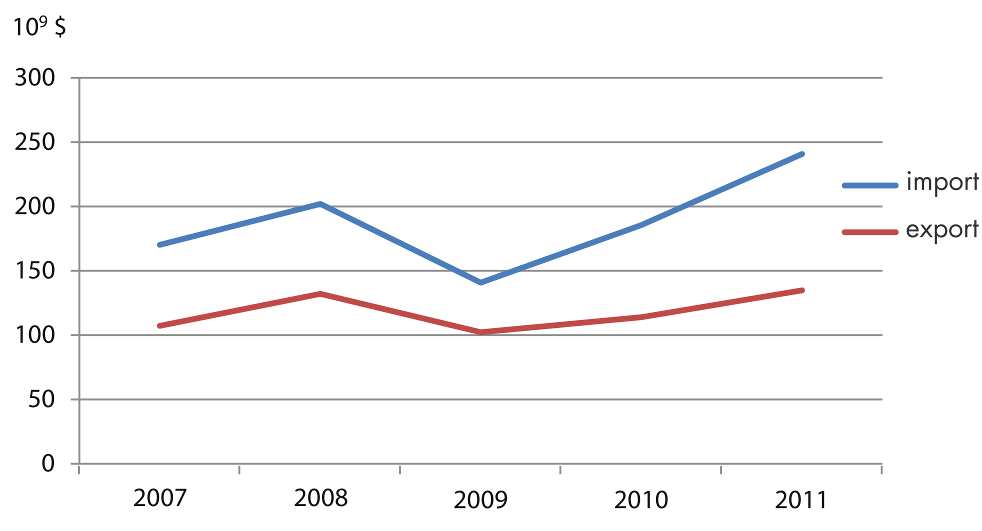
Turkey's import of mineral oil and fuels in 2009 was $ 38.5 billion and $ 54.1 billion in 2011. Although import statistics with respect to items is not available (probably due to confidentiality clauses of international agreements), it is known that oil and natural gas imports constituted the main cost items. The sectoral distribution of statistics reveals that imports of coke coal and refined oil products were $10.4 billion in 2009, $13.8 billion in 2010 and $18.3 billion in 2011. In the mining and quarrying sector, the value of imports listed as "confidential" was $18.3 billion in 2009, $23.5 billion in 2010 and $34.4 billion in 2011. Therefore, the sum of confidential data imports and imports of coal and oil products make up 98% of imports of oil and fuels and quantify the total energy source imports. It corresponds to approximately 21% of Turkey's total imports. In short, it is evident that the $ 54 billion worth energy imports as of 2011 constitute a major burden on the Turkish economy.

### 2.8.3. The need for reducing import dependency

Short term and long-medium term foreign debt stock of Turkey was, respectively, $ 78.2 billion and $ 211.8 billion in 2010. Foreign currency inflow is needed in order to pay the debt back. However, as illustrated in Figure 18, Turkey's imports surpass the exports causing a current accounts deficit and preventing net foreign currency inflow. The energy import bill of $ 54 billion makes up almost half of the foreign trade deficit. In order for the economy to remain healthy and sustainable, the foreign trade deficit must be decreased by increasing exports and reducing import dependency. Energy imports play an important role as they hold the major share in Turkey's foreign trade deficit.

Nuclear energy generation will create some level of foreign dependency due to the need for technology and the need for enriched uranium as a fuel. However, the small shares of fuel costs in total generation costs and the ability to acquire the long-term fuel requirements early on, reduce foreign dependency.

Figure 18. Turkish import expenditures and export revenues




*(Source: Main Economic Indicators 2012, Ministry of Development)*

# 3- A new technology with possible side benefits for high technology industrial development. The example of South Korea.

The inception of South Korea's nuclear program can be traced back to 1956 when the South Korean Ministry of Education and Science Technology established the Atomic Energy Department. Their first research reactor began operating in 1962. Today, the total electrical generation capacity of the nuclear power plants in South Korea amounts to 20.5 GW from 23 reactors. This corresponds to nearly 30% of South Korea's total installed capacity and about 45% of total generation. Eleven more nuclear reactors are scheduled for construction until 2021, adding 13.8 GW capacity in total.

A study (Valentine/Sovacool, 2010) analyzing the socio-cultural, political and economic conditions prevalent during the inception of nuclear power programs in Japan and South Korea identifies six common factors as having a clear influence on supporting nuclear power development: (1) strong state involvement in guiding economic development; (2) centralization of national energy policymaking and planning; (3) campaigns to link technological progress with national revitalization; (4) influence of technocratic ideology on policy decisions; (5) subordination of challenges to political authority, and (6) low levels of civic activism.

Transparency and public acceptance is key to the success of the South Korean nuclear program as argued by Kim/Chang (2012a). The South Korean Ministry of Education and Science Technology has established the CNEPP (Comprehensive Nuclear Energy Promotion Plan) to systematically implement the national nuclear energy policy in accordance with the Atomic Energy Act. All five years revisited, the 4th CNEPP has been developing a concrete implementation plan for the 2012-2017 period. Six promotion areas were set in the 4th CNEPP as nuclear utilization, sustainability, export/growth force, radiation, safety/public acceptance, and infra/international cooperation. It will be discussed by various social, economic, political, cultural, and technical professionals to harmonize with the national vision for the future, short- and long-term plans. By doing this, it will help to improve the nuclear safety, transparency, and effectiveness in the promotion of national nuclear technology.

Kim/Chang (2012b) argue that Korea has to transform to a carbon-neutral economy and that it is compulsory to rely more on alternative energy sources.

However, as the economies of scale for renewable energy are highly dependent on location-specific conditions (natural resources, societal perceptions, etc.) beyond market and policy, their research results suggest that nuclear should serve as the main substitute for fossil fuels in Korea.

South Korea will host the top two global energy events in 2013: the 22nd World Energy Congress and the 36th IAEE International Conference, both in Daegu. These organizations provide an excellent opportunity for energy executives, researchers, policy-makers and experts from Turkey to discuss these issues with their Korean counterparts in particular and other international participants in general.

# 4- Conclusions

Nuclear energy generation is a relatively cheap source with a high capacity factor making it a desirable energy source for many developed countries. However, on the other hand, the radioactive waste, threat of leaks and accidents make it a questionable energy alternative. The economics, technology and risks of nuclear power generation were evaluated with particular reference to the Akkuyu plant in a pioneering study (EDAM, 2011). This study complements the EDAM 2011 findings by elaborating nuclear energy within the context of increasing energy demand in Turkey from different perspectives including supply-demand projections, renewable energy potential, electricity prices, import dependency and international comparisons.

The utilization of renewable energy sources, which constitutes the largest indigenous source, should clearly be increased. However, meeting demand only by renewable energy does not seem possible because of technical and economic challenges as well as potential restrictions.

It is not realistic to expect that renewable energy can fully substitute thermal plants as long as there is not a technological revolution that will drive generation costs significantly down and render distribution networks sufficient, and as long as there no additional external financing mechanisms get available. It is important to ensure not only the technical and environmental but also economic sustainability of investments that will prevent supply shortage which may occur by 2016 according to official projections.

A further increase in electricity prices, which are already fair above the OECD average, will create a threat for international competitiveness of goods and services produced in Turkey. On the other hand, the energy import dependency of 80% threatens price stability and the fossil fuel import bill exceeding $50 billion threatens the balance of payments. Therefore, policy-makers aim to lower the share of imported natural gas in electricity production, which currently amounts to nearly 50% of total power generation. As an alternative to natural gas, coal and nuclear power appear as economically viable options that provide reliable production.

In Europe, an example for a country which makes extensive use of both coal and nuclear power is Germany: as of 2011, coal has the lion's share of 43% in electricity generation and nuclear is on the third rank with a share of 18%. Following the Fukishima incident Germany decided to shut down the nuclear plants that were constructed before 1980 (despite deciding, shortly before Fukishima to prolong their lifetimes). In addition, it was decided that once the operational ones complete their lifetimes, they will be shut down and will not be substituted by new nuclear plants. This decision was influenced by the strong public opposition to nuclear energy, which gained momentum after the Fukishima accident. However, criticism was also voiced in the press (Financial Times Deutschland, 2011) criticizing the decision to phase out nuclear as not being sustainable and as posing a threat to the German economy. Besides coal and nuclear power Germany makes also exyensive use of renewable energy technologies (much more extensive than Turkey despite a much lower potential). As of 2011, renewable energy sources account for the second largest share in total electricity generation in Germany with 20% and it is aimed to increase this share to substitute for the decrease that will be caused by phasing out nuclear power. The developments in Germany show the impact of public opinion on energy policy and the dilemma between the economic advantages of nuclear energy and its risks. As such a dilemma is valid for any country in general, what differentiates Germany from Turkey is that in Germany the demand for electricity has reached saturation and is not increasing.

With a rapidly increasing demand for electricity, Asian countries like China and South Korea exhibit a similar trend to Turkey. Attempts to increase use of nuclear energy in China continue with a target of 40 GW installed capacity by 2020 while opinions are voiced claiming that nuclear energy is the only 'sustainable' alternative for the country (China Daily, 2012). Similarly, studies to increase the use of nuclear power are well underway in South Korea where construction of two new reactors began in 2012. The South Korean Prime Minister was quoted saying that nuclear energy is not a choice but it is a must for the country and the only alternative to fossil fuels (The Korea Herald, 2012). A transparent process along with a healthy institutional system enabled public trust and support to nuclear energy generation growing rapidly after the construction of the first nuclear power plant in 1962. The fact that construction of two new reactors started in the eve of the elections of December 2012, which indicates that the positive public perception continues.

After shutting down all its nuclear plants for inspection following Fukishima, Japan re-opened its first nuclear plant in July, 2012. The Japanese prime minister stated that the living standards of the people could not be sustained without nuclear energy (The Independent, 2012). A worldwide opposition to nuclear energy has been on the rise particularly in the aftermath of Fukushima. However, the need for nuclear energy in developing countries is voiced ever louder in several countries. Opposing opinions and considerations are being discussed by experts in independent international platforms, e.g. set up by the World Energy Council and the International Association for Energy Economics. It would contribute to establish a productive discussion environment and broaden the perspective of interested people from Turkey, where a phase-in program for nuclear energy has been announced, if they participate in such platforms and listen to the views and evaluations of international experts.

Following the decision to phase-in nuclear energy, the related debate in Turkey so far remains shallow, mostly based on ideological differences, and void of scientific studies. In an attempt to remedy this situation, the current study presents a framework to feature accurate analysis to be made when considering the need for nuclear energy in Turkey for which this section provides the necessary backroung to evaluatie supply-demand projections, renewable energy potential, electricity generation costs, electricity prices and import dependency.

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Section II

# Nuclear Power in Turkey's Climate Change Strategy

# II

Gürkan Kumbaroğlu

# Executive Summary

In May 2010, Turkey released its National Climate Change Strategy Document, and, in July of the same year, adopted – by passing law number 6007 - an agreement regarding the establisment and operation of a nuclear power plant in Akkuyu. Although these two developments took place two months apart and independently of each other, there is an indirect interplay in place: as it is known, nuclear power plants do not release greenhouse gases during operation, and, for this reason, reducing green house gas emissions becomes possible to the extent the nuclear generation replaces electricity generated from fossil fuels.. In order to determine how effective a nuclear power plant would be in reducing gree house gas emissions in Turkey, firstly, the national emission factor (the amount of emission per unit electricity generation) caused by electricity generation needs to be calculated in compliance with the international methodology.

## *Greenhouse Gas Emissions from Power Generation*

CO2 emissions resulting from fossil fuel use for electricity generation have caused this sector to have the fastest emission growth rate, which was 252.3 per cent in the period 1990-2010. While the accelerated growth of CO2 emissions resulting from electricity generation is in correlation with the increase in supply created to meet the increasing electricity demands, the actual determining factor is the composition of the production of the supply: meaning, the high carbon intensity of electricity generation. While CO2 emissions in electricity generation result from thermal plants, there is no CO2 emission during generating electricity from renewable energy sources such as wind and hydropower. Hence, changes in the technological composition of electricity supply have great impact on emissions. Between the years 1990-2010, while the share of hydroelectric energy in total electricity generation decreased from 40 percent to 25 percent, the share of the thermal plants rised from 60 to 74 percent; and wind power obtained a 1 percent share. Although the share of hydropower decreased, its installed capacity level increased by 2.3 times and rised to 15,831 MW from 6,764 MW in 20 years. However, the installed capacity level of thermal power plants during the same period also increased by 3.4 times, rising from 9,536 MW to 32,279 MW. These developments were effective on CO2 emission growth resulting from electricity generation.

## *The Effect of Nuclear Power on Greenhouse Gas Emissions*

The Akkuyu nuclear power plant is expected to be a four-unit plant with a total installed capacity of 4,800 MW. It is observed that the assumption of a capacity factor of 85 per cent, which was put forth in the economics of nuclear energy section of a previous study (EDAM, 2011), in which the nuclear power adoption model of Turkey was examined, can be accepted as a realistic estimate. With that assumption, the total electricity power that the Akkuyu nuclear power plant is expected to generate in a year is calculated as 35,740,800 MWh/year.

The reduction of emissions, which is calculated by multiplying the emission factor calculated as 0.5459 tCO2/MWh and the generation value of the nuclear plants.

Table The Amount of $CO_2$ Emission Reduction Enabled by the Akkuyu Nuclear Power Plant

| Year | $CO_2$ Emission Reduction Amount |
|---|---|
| 2019 | 8,935,200 MWh x 0.5459 $tCO_2$/MWh = 4,877,726 $tCO_2$ |
| 2020 | 17,870,400 MWh x 0.5459 $tCO_2$/MWh = 9,755,451 $tCO_2$ |
| 2021 | 26,805,600 MWh x 0.5459 $tCO_2$/MWh = 14,633,177 $tCO_2$ |
| 2022 | 35,740,800 MWh x 0.5459 $tCO_2$/MWh =19,510,903 $tCO_2$ |
| 2023 and onward | 19,510,903 $tCO_2$/ year |

The Akkuyu nuclear power plant will enable nearly 6.6-7.5 percent reduction in emissions resulting from electricity generation by the year 2023. In case of an establishment of two other plants with equal power to Akkuyu plant, these ratios will triple; and, assuming that the carbon intensity in electricity generation remains constant, there will be a nearly 20 per cent reduction in emissions resulting from electricity generation.

## *Conclusion*

It has been determined that once the Akkuyu nuclear power plant is in operation with all of its units, it will enable a nearly 19.5 Mton ton savings in $CO_2$ emissions. And, it is calculated that this value will equal to nearly seven pe cent of the emissions resulting from electricity generation. As it has been presented in this study, considering that the ratio of emissions resulting from electricity generation stands as the sector with the highest share, which is 40 percent of Turkey's total emissions volume, it is understood that the savings from emissions that will be possible corresponds to a significant amount.

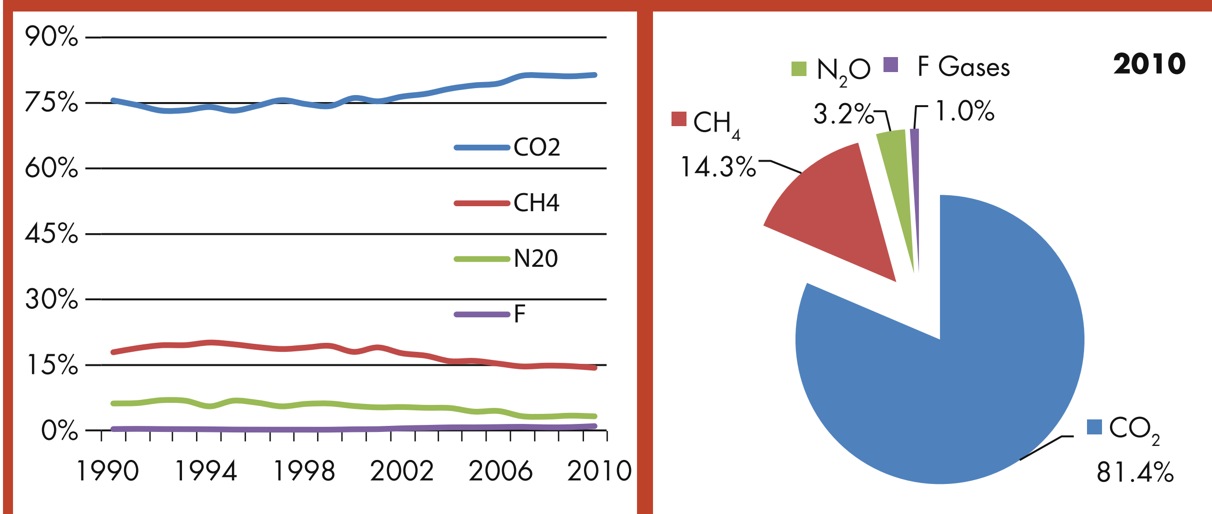
Although emission reductions that are enabled through the usage of nuclear energy are not taken into account under the Kyoto Protocol Flexibility Mechanisms, it nevertheless will be effective in limiting the increase of emissions in Turkey by reducing the carbon intensity of electricity generation.

# 1. Introduction

In May 2010, Turkey released its National Climate Change Strategy Document, and, in July of the same year, adopted – by passing law number 6007 - an agreement regarding the establisment and operation of a nuclear power plant in Akkuyu. Although these two developments took place two months apart and independently of each other, there is an indirect interplay in place: as it is known, nuclear power plants do not release greenhouse gases during operation, and, for this reason, reducing green house gas emissions becomes possible to the extent the nuclear generation replaces electricity generated from fossil fuels.. In order to determine how effective a nuclear power plant would be in reducing gree house gas emissions in Turkey, firstly, the national emission factor (the amount of emission per unit electricity generation) caused by electricity generation needs to be calculated in compliance with the international methodology. Since the level of greenhouse gas emissions other than carbon dioxide ($CO_2$), such as $CH_4$ and $N_2O$, is negligibly small, computations are focused on $CO_2$ emission reduction.

The composition of Turkish greenhouse gas emissions is presented in Figure 1 together with the historical development. In 2010, $CO_2$ emissions had the lion's share of 81.4 percent, followed by $CH_4$ emissions with 14.3 percent These are followed by $N_2O$ emissions, with 3.2 percent, and F-gas emissions with 1.0 percent. In recent years, emissions of $CO_2$ have followed a trend of increase from 75.6 percent in 1990, which is taken as reference in national submissions under the United Nations Framework Convention on Climate Change (UNFCCC).

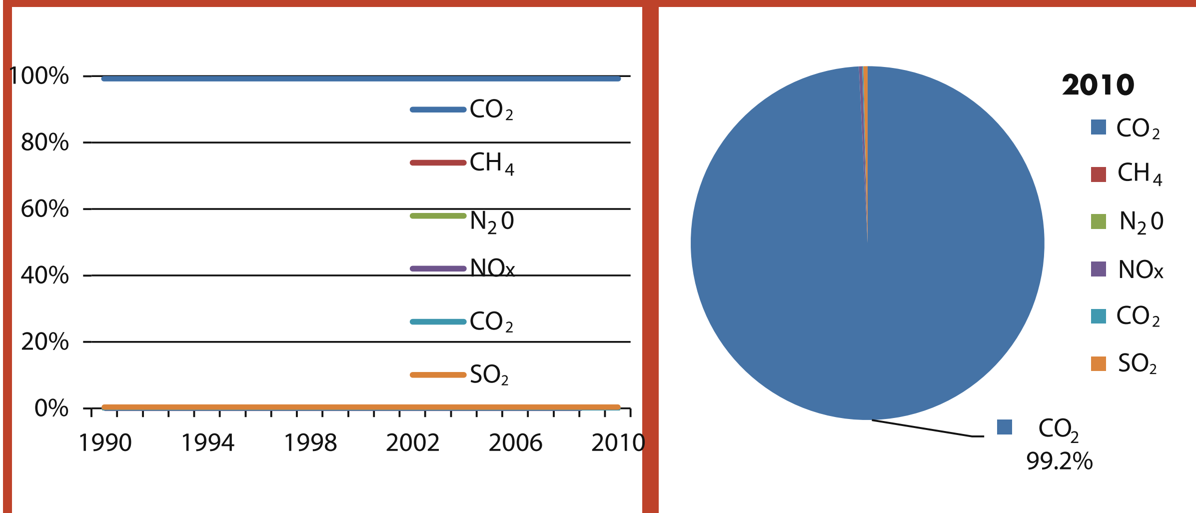
Figure 1. Composition of Greenhouse Gases in Turkey from 1990 to 2010




*(Data Source: National Greenhouse Gas Inventory Report, 2012)*

On the other hand, as can be seen in Figure 2, among the gases emitted during electricity generation, the percentage of $CO_2$ is 99.2 percent in year 2010 and has remained about the same since 1990, while all other greenhouse gasses had a share of less than one percent.

**Figure 2. Composition of Greenhouse Gases Resulting from Electricity Generation in Turkey from 1990 to 2010**




*(Data Source: National Greenhouse Gas Inventory Report, 2012)*

While $CO_2$ stands out with its highest share among all greenhouse gases, as can be is seen in Table 1, it also has, by far, the greatest atmospheric concentration and radiative forcing level. Due to its longevity and high level of concentration in the athmosphere, the $CO_2$ gas' radiative forcing value is by far the highest among all other greenhouse gases. For this reason, in efforts to confront climate change, the reduction of emissions of $CO_2$ gas is especially focused on.

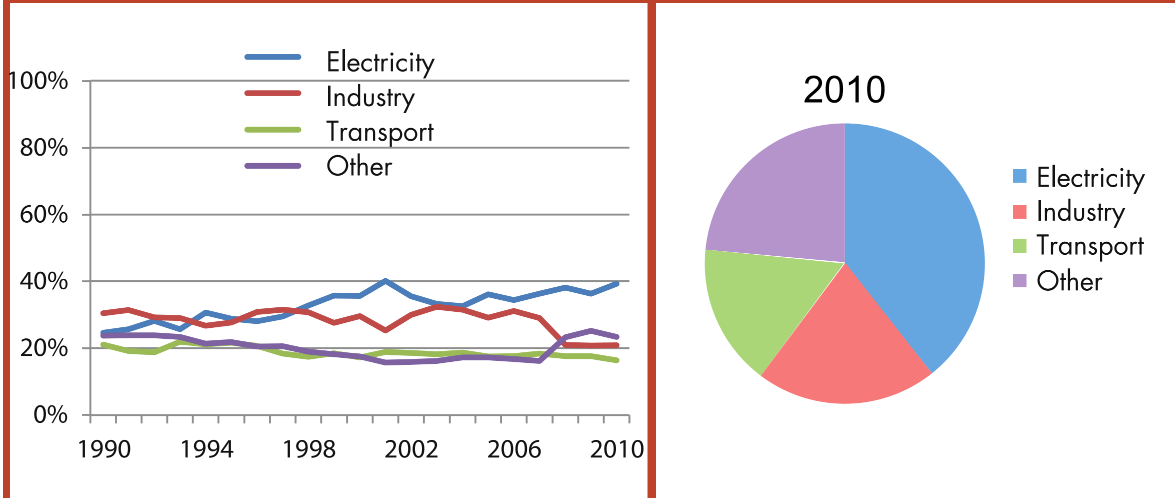
**Table 1. Greenhouse Gases, Atmospheric Concentrations and Radiative Forcing Values**

| | Concentration (One in a million) | Increase during 1998-2005 | Radiative Forcing ($W/m^2$) | Change during 1998-2005 (%) |
|---|---|---|---|---|
| $CO_2$ | 379 ± 0.65 (One in a million) | + 13 (One in a million) | 1.66 | +%13 |
| $CH_4$ | 1774 ± 1.8 (One in a billion) | +11 (One in a billion) | 0.48 | - |
| $N_2O$ | 319 ± 0. 12 (One in a billion) | +5 (One in a billion) | 0.16 | +%11 |

*(Data Source: Intergovernmental Panel on Climate Change Fourth Assessment Report, Climate Change 2007: The Physical Science Basis, 2007)*

The main source of emission of $CO_2$ is the usage of fossil fuels: according to the latest data (2010), in Turkey, 85 per cent of $CO_2$ emissions results from energy usage and 39.3 per cent of this share results from electricity generation. As it is observable in Figure 3, in sectoral ratios of $CO_2$ emissions, electricity generation has the highest share of increase throughout years.

**Figure 3.** Sectoral Share of $CO_2$ Emissions Resulting from Energy Usage in 2010




*(Data Source: National Greenhouse Gas Inventory Report, 2012)*

Since electrification (such as, increase in usage of electrical vehicles in transportation, and spread of automation and informatics technologies in industrial and services sectors, etc.) is expected to rise in all sectors, it could be predicted that the importance and share of the electricity sector in national climate change strategy will rise. In this regard, determining the scope of the contribution of nuclear energy, as an electricity generation technology without $CO_2$ emissions, to the national climate change strategy through lowering the emissions and emission intensity from electricity generation becomes significant.

The Climate Change Strategy of Turkey, with its historical development and expectations for the future, are covered in the next section. In the subsequent section, $CO_2$ emissions in Turkey resulting from electricity generation are examined and the emission factor is calculated according to the international methodology. Afterwards, the impact of energy production from nuclear power plants on lowering $CO_2$ emissions, based on the calculated emission factor, is shown.

# 2. Turkey's Climate Change Strategy

## 2.1. *Historical Developments*

Turkey, as a member of OECD, was placed in the developed country annexes (Annex I and Annex II) of the UNFCCC; and, with the reasoning that it would not be possible to meet the obligations this would bring along, it did not ratify the convention when it was approved on 21 March 1994. According to the agreement, while the countries listed under Annex I were expected to take preventive measures to limit greenhouse gas emissions, countries in Annex II were anticipated to also provide developing countries with financial assistance. While Turkey was making attempts to withdraw from these annexes, in 1997, parties to the UNFCCC agreed upon the Kyoto Protocol, which set forth committments on Annex I countries to reduce emissions to specific levels. The Protocol was entered into force eight years later, on 16 February 2005, when Russia's ratification set the emission volume of Annex I parties to the required threshold level of 55 percent. Meanwhile, the status of Turkey as a developed country under the UNFCCC had changed in 2001: according to decision 26/CP.7 taken at the 7th UNFCCC Conference of Parties (COP7), Turkey was moved out from Annex II; it was agreed on with consensus that Turkey's circumstances were different than the other countries in Annex I and parties to the convention were called upon to recognize Turkey's special position. Decision 26/CP.7 came into effect on 28 June 2008. As Turkey was removed from the list in Annex II, its obligations to provide developing countries with new and additional financial support in accordance with article 4.3, to adjust to climate change in accordance with article 4.4, and to transfer technology in accordance with article 4.5 of the UNFCCC were also removed and Turkey a became party to the UNFCCC on 24 May 2004 and also to the Kyoto Protocol, as a non-Annex B country (not having an obligation of emission reduction), on 26 August 2009.

Following Turkey's joining the UNFCCC in 2004, a Coordination Board on Climate Change was established the same year. The Coordination Board, under the authority of the Minister of Environment and Forestry, is composed of

- Undersecretary of the Ministry of Foreign Affairs
- Undersecretary of the Ministry of Public Works and Settlement
- Undersecretary of the Ministry of Transport
- Undersecretary of the Ministry of Agriculture and Rural Affairs
- Undersecretary of the Ministry of Industry and Trade
- Undersecretary of the Ministry of Energy and Natural Resources
- Undersecretary of the Ministry of Environment and Forestry
- Undersecretary of the State Planning Office
- The President of the Union of Chambers and Commodity Exchanges of Turkey.

The Board carries activities on 'Reduction,' 'Conformity,' 'Technology Transfer,' and 'Finance,' which were designated as building blocks at the COP13 Conference of Parties held in the Bali island of Indonesia in 2007 and given the name 'Bali Road Map'.

On the other hand, it was agreed during the Board Meeting 2009/2, which took place on 28 July 2009, that there would be an effort to realize an 11 percent reduction of the greenhouse gas emissions projected for 2020, which was stated in the 1st National Communication sent to the UNFCCC in 2007. According to the projections stated in the 1st National Communication, $CO_2$ emissions in Turkey would increase from 240.7 million tons in 2005 to 604.6 million tons in 2020; and, in this regard, according to the adopted emission reduction goal, the emission rise in Turkey between 2005 and 2020 is anticipated to remain at 124 percent instead of 151 percent.

With the start of a series of workshops under the coordination of the Ministry of Environment and Forestry on 28 February 2009 in Abant, Bolu, relevant institutions and organizations discussed rational strategies to be included in the 'National Climate Change Strategy Document', which was proposed to the Prime Ministry High Planning Council after having been discussed on the Board, and was released on May 2010. In the Turkey's National Climate Change Strategy Document for 2010-2020, prodding of nuclear energy as a zero emission technology is placed among the mid-term activities to reduce greenhouse gas emissions. Additionally, the prodding of nuclear energy is also included in Turkey's Climate Change National Action Plan for 2011-2023, which was released in July 2011.

## *2.2. Future Expectations*

The 17th Conference of the Parties to UNFCCC (COP17) held on December 2011 in Durban, South Africa and the 7th Meeting of the Parties of the Kyoto Protocol (COP/MOP7) shed a little light into the future. The main output of these meetings is the decision on determining the second liability term as the years 2013-2017. In addition to this, establishment of a new working group, named the Durban Platform, and preparation of an official text by this group for a new agreement were agreed upon.  It is expected of this group, which will start its initial meetings on May 2012, to complete the preparations of a new agreement at the latest by 2015.

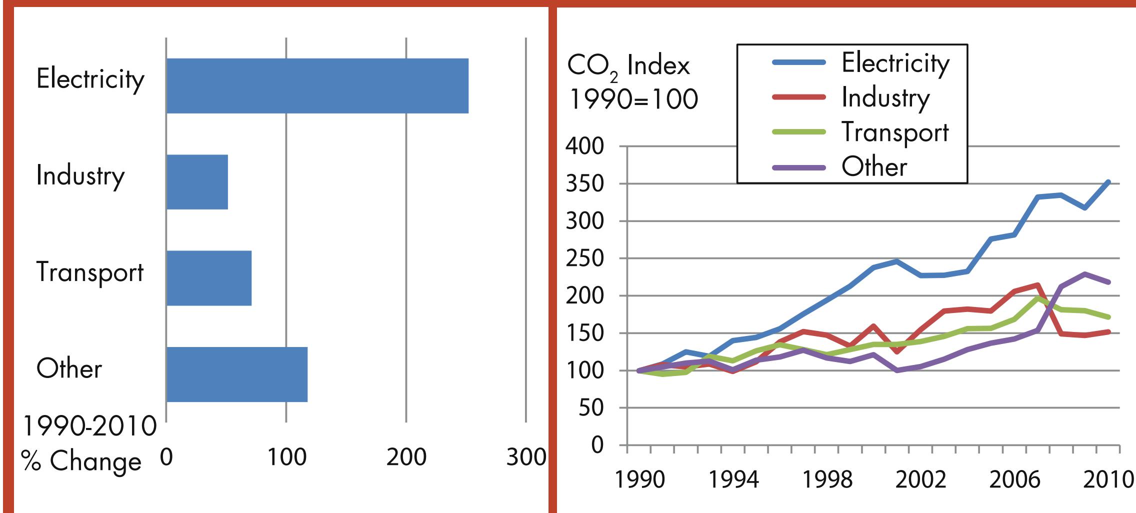
Although there is a bit of uncertainty about the future due to the situation Turkey is in, because of its EU candidacy on the one hand and its incomplete conditions as a designated country (26/CP.7 and 1/CP.16 decisions) and ongoing capacity building on the other, along with the changing dynamics of the negotiations on a new agreement, it could still be anticipated that Turkey will be in a sustainable development process in which the concentration of emissions would decrease in accordance with the National Climate Change Strategy Document and National Action Plan. It is aimed by decision-makers that the usage of nuclear energy, in accordance with the National Strategy Document, in electricity generation would be effective in lowering greenhouse gas emission intensities.

# 3- Turkey's Contribution to Climate Change

## *3.1. Greenhouse Gas Emissions from Power Generation*

$CO_2$ emissions resulting from fossil fuel use for electricity generation have caused this sector to have the fastest emission growth rate, which was 252.3 per cent in the period 1990-2010 (See Figure 4).

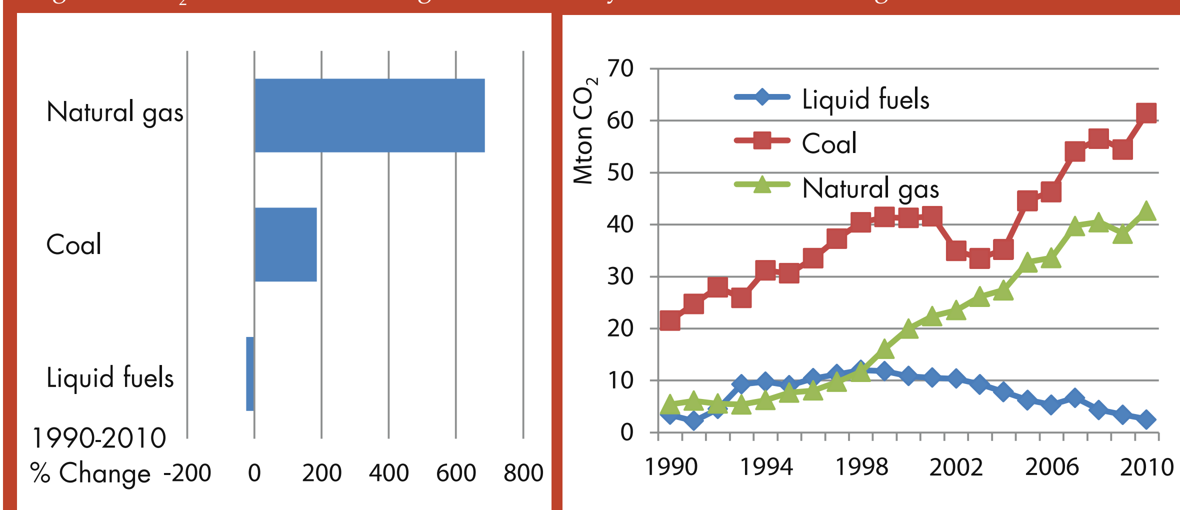
Figure 4. Sectoral Development of $CO_2$ Emissions Resulting from Energy Use




*(Data Source: National Greenhouse Gas Inventory Report, 2012)*

While the accelerated growth of $CO_2$ emissions resulting from electricity generation is in correlation with the increase in supply created to meet the increasing electricity demands, the actual determining factor is the composition of the production of the supply: meaning, the high carbon intensity of electricity generation. While $CO_2$ emissions in electricity generation result from thermal plants, there is no $CO_2$ emission during generating electricity from renewable energy sources such as wind and hydropower. Hence, changes in the technological composition of electricity supply have great impact on emissions. Between the years 1990-2010, while the share of hydroelectric energy in total electricity generation decreased from 40 percent to 25 percent, the share of the thermal plants rised from 60 to 74 percent; and wind power obtained a 1 percent share. Although the share of hydropower decreased, its installed capacity level increased by 2.3 times and rised to 15,831 MW from 6,764 MW in 20 years. However, the installed capacity level of thermal power plants during the same period also increased by 3.4 times, rising from 9,536 MW to 32,279 MW. These developments were effective on $CO_2$ emission growth resulting from electricity generation.

Figure 5. $CO_2$ Emissions Resulting from Electricity Generation According to Source 1990-2010




*(Data Source: National Greenhouse Gas Inventory Report, 2012)*

## *3.2. Turkey's Emission Factor for Electricity Generation*

Turkey's emission factor for electricity generation has been calculated on the basis of the UNFCCC's latest methodological tool "Tool to Calculate the Emission Factor for an Electricity System" (UNFCCC, 2011). The Turkish transmission system is interconnected, which defines the relevant electricity system to determinde Turkey's emission factor for electricity generation. Hence, the estimation of OM (Operating Margin) and BM (Built Margin) emission factors are based on the definition of the Turkish electricity network as one single interconnected system and grid power plants serving the system.

### 3.2.1. The Operating Margin Emission Factor

According to the "Tool to calculate the emission factor for an electricity system", four alternative methods are available to calculate the OM emission factor:

(a) Simple OM; Basit or

(b) Simple adjusted OM; or

(c) Dispatch data analysis OM; or

(d) Average OM.

In choosing the right method for the calculation of OM, "Simple adjusted OM", "Dispatch data analysis OM" and "Average OM" methods can be eliminated as all of these methods require plant-specific information of power plants which are connected to the grid, but there is no plant-specific data publicly available.

Accordingly, the "Simple OM" method is adopted in the calculations, based on the total net electricity generation of all power plants serving the system. This method is applicable when low cost and/or must run resources constitute, as an average of the five most recent years, less than 50 percent of the total generation for the grid. Nevertheless, the only major low operating cost and must run resource in Turkey is hydropower because the share of all other renewable resources is negligibly small. As can be seen in Table 2, the share of low-cost/must run sources does not exceed 50% for the most recent 5 years.

**Table 2.** Share of hydroelectric production in Turkey, 2006 – 2010

| | 2006 | 2007 | 2008 | 2009 | 2010 |
|---|---|---|---|---|---|
| Turkey's Gross Electricity Production (GWh) | 176,300 | 191,558 | 198,418 | 194,813 | 211,208 |
| Electricity Production from Hydro (GWh) | 44,244 | 35,851 | 33,270 | 35,958 | 51,796 |
| Total Share of Hydro (%) | 25% | 19% | 17% | 18% | 25% |

The Simple Operating Margin Emission Factor is calculated as the generation-weighted average $CO_2$ emissions per unit net electricity generation ($tCO_2$/MWh) of all generating power plants serving the system, not including low-cost/must run power plants/units.

According to the "Tool to calculate the emission factor for an electricity system", the formula given below is applied for computing $EF_{grid, OMsimple, y}$.

$$EF_{grid,OMsimple,y} = \frac{\sum_i FC_{i,y} \times NCV_{i,y} \times EF_{CO_2,i,y}}{EG_y}$$

where

| | | |
|---|---|---|
| $EF_{grid,OMsimple,y}$ | = | Simple operating margin $CO_2$ emission factor in year y (t $CO_2$/MWh) |
| $FC_{i,y}$ | = | Amount of fossil fuel type i consumed in the project electricity system in year y (mass or volume unit) |
| $NCV_{i,y}$ | = | Net calorific value (energy content) of fossil fuel type i in year y (GJ / mass or volume unit) |
| $EF_{CO2,i,y}$ | = | $CO_2$ emission factor of fossil fuel type i in year y (t$CO_2$/GJ) |
| EGy | = | Net electricity generated and delivered to the grid by all power sources serving the system, not including low-cost / must-run power plants / units, in year y (MWh) |
| i | = | All fossil fuel types combusted in power sources in the project electricity system in year y |
| y | = | Either the three most recent years for which data is available at the time of submission of the CDM-PDD to the DOE for validation (ex ante option) or the applicable year during monitoring (ex post option), following the guidance on data vintage in step 2 |

In order to calculate fuel-specific emissions, the IPCC emission factors shown in Table 3 were used..

To be on the conservative side, the minimum values are used in the OM calculations. Based on these values, $CO_2$ emissions from electricity generation in Turkey are computed as shown in Table 4.

Table 3. IPCC Emission factors

| | kg $CO_2$/GJ | | | Default Carbon Oxidation Factor |
|---|---|---|---|---|
| | min | mid | max | |
| Hard coal | 92,8 | 96,1 | 100,0 | 1,0 |
| Lignite | 90,9 | 101,0 | 115,0 | 1,0 |
| Fuel oil | 75,5 | 77,4 | 78,8 | 1,0 |
| Diesel oil | 72,6 | 74,1 | 74,8 | 1,0 |
| Natural gas | 54,3 | 56,1 | 58,3 | 1,0 |
| LPG | 61,6 | 63,1 | 65,6 | 1,0 |
| Naphta | 69,3 | 73,3 | 76,3 | 1,0 |

*(Data Source: 2006 IPCC Guidelines for National Greenhouse Gas Inventories)*

Table 4. Annual $CO_2$ Emissions from Electricity Production

| | 2008 | 2009 | 2010 |
|---|---|---|---|
| $CO_2$ Emissions from Electricity Production (tons) | 104,062,368 | 98,532,497 | 99,128,859 |

The calculation of net electricity production is demonstrated in Table 5. As the efficiency factor from gross to net electricity for thermal resources is not known, the overall relation between overall gross and net electricity production is assumed to be the same for thermal production.

**Table 5.** Net Electricity Production from Thermal Sources

| | 2008 | 2009 | 2010 |
|---|---|---|---|
| Gross Electricity Production [GWh] (a) | 198,418 | 194,813 | 211,208 |
| Net Electricity Production [GWh] (b) | 189,762 | 186,619 | 203,046 |
| Net/Gross (c=a/b) | 0.956 | 0.958 | 0.961 |
| Gross Electricity Production from Thermal Sources [GWh] (d) | 163,919 | 156,583 | 155,370 |
| Net Electricity Production from Thermal Sources [GWh] (cxd) | 156,768 | 149,998 | 149,366 |

Using the same relation for both overall electricity production and thermal production is an approximation based on a rough assumption. Yet, obviously, such an assumption results in a conservative estimation because the efficiency of thermal plants is typically much lower than other plants. The OM emission factors are calculated by dividing total emissions by net electricity production from thermal sources as shown in Table 6.

**Table 6.** OM Emission Factor for 2008 – 2010

| | 2008 | 2009 | 2010 |
|---|---|---|---|
| $EF_{Grid,\ OM,\ simple}$ [$tCO_2$/MWh] | 0.6638 | 0.6569 | 0.6637 |

As the generation-weighted average of the figures between 2008 and 2010, Turkey's OM emission factor is computed as **0.6603 $tCO_2$ / MWh**.

## 3.2.2. The Build Margin (BM) Emission Factor

Computing the BM is based on the sample of plants, in either of two proposed ways:

(a) The set of five power units that have been built most recently, or

(b) The set of power capacity additions in the electricity system that comprise 20% of the system generation (in MWh) and that have been built most recently.

Among these two options, the sample group that comprises the larger annual generation should be used. The data for recently built power plants is available in TEİAŞ's capacity projection reports documenting capacity, type of utility, fuel type and date of commissioning. According to the data:

- The total annual generation of the five plants that have been built most recently is 5,271 GWh. This represents approximately 2.7% of the overall electricity generation capacity in Turkey. Obviously, it is far below the 20 percent threshold proposed by the methodology.
- The most recent capacity additions that comprise the 20% of the total system generation corresponds to 42.1 TWh.

According to the methodology, the Build Margin (BM) Emission Factor $EF_{BM}$ is calculated as the generation-weighted average emission factor of a sample of power plants m for a specific year, as follows:

$$EF_{grid,BM,y} = \frac{\sum_{i,m} EG_{m,y} \times EF_{EL,m,y}}{\sum_{m} EG_{m,y}}$$

where:

| | |
|---|---|
| $EF_{grid,\ BM,\ y}$ | Build margin $CO_2$ emission factor in year y ( $tCO_2 / MWh$ ); |
| $EG_{m,y}$ | Net quantity of electricity generated and delivered to the grid by power unit m in year y (MWh) |
| $EF_{EL,m,y}$ | $CO_2$ emission factor of power unit m in year y ($tCO_2$/MWh) m |
| m | Power units included in the build margin |
| y | Most recent historical year for which power generation data is available |

As electricity production figures of some small facilities were not available, annual electricity productions of these plants have been calculated as

$EG_{m,y}$= Full Load Working Hours × Installed Capacity

In the calculation of $EF_{grid,\ BM,\ y}$, first $EF_{EL,m,y}$ values are computed by using the formula

$$EF_{EL,m,y} = \frac{EF_{CO_2,m,i,y} \times 3.6}{\eta_{m,y}}$$

where

| | |
|---|---|
| $EF_{EL,\ m,\ y}$ | $CO_2$ emission factor of power unit *m* in year y ( $tCO_2 / MWh$ ); |
| $EF_{CO_2,m,i,y}$ | Average net energy conversion efficiency of power unit m in year y ( $tCO_2 / GJ$ ) |
| $\eta_{m,y}$ | Average net energy conversion efficiency of power unit m in year y (ratio) |
| m | All power units serving the grid in year y except low-cost/must-run power units |
| y | The relevant year as per the data vintage chosen |

For this computation, the default efficiency values shown in Table 7 were used.

Table 7. Default Efficiency Factors for power plants

| | Grid power plants | |
|---|---|---|
| Generation Technology | Old units (before and in 2000) | New units (after 2000) |
| Coal | - | - |
| Subcritical | 37% | 39% |
| Supercritical | - | 45% |
| Ultra-supercritical | - | 50% |
| IGCC | - | 50% |
| FBS | 35.5 % | - |
| CFBS | 36.5 % | 40% |
| PFBS | - | 41.5 % |
| Oil | - | - |
| Steam turbine | 37.5 % | 39% |
| Open cycle | 30% | 39.5% |
| Combined cycle | 46% | 46% |
| Natural gas | - | - |
| Steam turbine | 37.5 % | 37.5 % |
| Open cycle | 30% | 39.5 % |
| Combined cycle | 46% | 60% |

*Source: "Tool to calculate the emission factor for an electricity system" (UNFCCC, 2011)*

Accordingly, the Build Margin emission factor is calculated as **0.4315 $tCO_2$/MWh**.

## 3.2.3. The Combined Margin Emission Factor

The combined margin emissions factor is calculated as follows:

$$\mathbf{EF_{grid, CM, y} = EF_{grid, OM, y} \times w_{OM} + EF_{grid, BM, y} \times w_{BM}}$$

where

$EF_{grid,BM,y}$ = Build margin $CO_2$ emission factor in year y ($tCO_2$/MWh)

$EF_{grid,OM,y}$ = Operating margin $CO_2$ emission factor in year y ($tCO_2$/MWh)

$w_{OM}$ = Weighting of operating margin emissions factor (%)

$w_{BM}$ = Weighting of build margin emissions factor (%)

The methodological tool "Tool to calculate the emission factor for an electricity system" recommends equal weighting for electricity generation projects other than wind and solar power. Hence, equal weighting is used implying

$$\mathbf{EF_{grid, CM, y} = 0.6603 \times 0.5 + 0.4315 \times 0.5}$$

The resulting : $EF_{grid,CM,y}$ is **0.5459 $tCO_2$/MWh**

# 4- The Effect of Nuclear Power on Greenhouse Gas Emissions

Following the agreement between the government of the Russian Federation and the government of the Republic of Turkey on cooperation in relation to the construction and operation of a nuclear power plant at the Akkuyu site in the Republic of Turkey, Turkey has started a serious of negotiations with China, South Korea, Japan, and Canada for a second nuclear power plant to be built in Sinop. According to the statements made by the officials of the Ministry of Energy and Natural Resources, for energy diversification and security of supply, operation of three nuclear plants with a total capacity of 15,000 MW is aimed to be realized until 2023. However, since the only project on which there has been a signed agreement so far is the plant in Akkuyu, the effect of the plant to be built in Akkuyu on greenhouse gas emissions has been made the focus of this working paper.

The Akkuyu nuclear power plant is expected to be a four-unit plant with a total installed capacity of 4,800 MW. It is observed that the assumption of a capacity factor of 85 per cent, which was put forth in the economics of nuclear energy section of a previous study (EDAM, 2011), in which the nuclear power adoption model of Turkey was examined, can be accepted as a realistic estimate. With that assumption, the total electricity power that the Akkuyu nuclear power plant is expected to generate in a year is calculated as shown below.

The amount of generation that will take place when the four-unit Akkuyu nuclear power plant will be in operation is calculated as:

= 4,800 MW × 8,760 hours/year × 0.85 = 35,740,800 MWh/year

[1] It is expected that the first of the four units, which will each have a power capacity of 1,200 MW, will start generation in 2019, and the other three will enter commercial operation every other following year. The anticipated value of generation expected to be obtained from the Akkuyu plant in accordance with this plan is shown in Table 8.

Table 8. Akkuyu Nuclear Power Plant Electricity Generation Amounts

| Year | Generation Amount |
|---|---|
| 2019 | 1200 MW x 8760 hour x 0.85 = 8,935,200 MWh |
| 2020 | 2400 MW x 8760 hour x 0.85 = 17,870,400 MWh |
| 2021 | 3600 MW x 8760 hour x 0.85 = 26,805,600 MWh |
| 2022 | 4800 MW x 8760 hour x 0.85 = 35,740,800 MWh |
| 2023 and onwards | 35,740,800 MWh/year |

1_ According to the agreement between Turkey and Russian Federation, signed on 12 May 2010, regarding cooperation on the establishment and operation of a nuclear power plant in Akkuyu, once all of the necessary documents, permissions, licenses, and approvals are ready for starting the building of the plant, the first unit shall be entered into commercial operation within the next seven years, and the other three units every other following year.

The emission reduction values of today which correspond to the generation values shown in Table 8 can be calculated by using Turkey's average electricity generation emission factor calculated in the previous section. However, in this calculation of emission amounts, the technological composition of electricity generation is assumed to remain unchanged. Nevertheless, when the long-term projections such as the Electricity Market and Supply Security Strategy Paper, which was approved in May 2009, are taken into consideration, it is expected that the use of renewable energy resources will be on the rise. Accordingly, until year 2023, it is aimed that the domestic coal and hydroelectric potential will be used up entirely; the wind power capacity will be increased to 20,000 MW and geothermal power to 600 MW; and the share of natural gas in production will be reduced to under 30 percent. According to the report 'Turkey's 10 Year Electricity Generation Capacity Projections (2011-2020)' published by TEİAŞ in November 2011 (TEİAŞ, 2011), under the assumptions that change based on projects and the level of reliable generation of power plants, the composition of generation is expected to be, by 2020, in ranges shown below. It is observed that the composition in year 2010 also falls under these ranges.[2] In light of this comparison shown in Table 9, and by assuming that the projections of TEİAŞ are reliable and also taking into account the fact that hydroelectric power plants, like other renewable ones, do not release greenhouse gas during electricity generation, it is concluded that the average emission factor calculated for the year 2010 can also be applied to 2020.

Table 9. Turkey's Electricity Generation Composition (%)

| | 2010 | 2020 Projections (TEİAŞ) |
|---|---|---|
| Thermal Power Plants | % 74 | %73 - %80 |
| Hydroelectric Power Plants | % 24 | %16 - %23 |
| Other Renewables | % 2 | %4 |

In the TEİAŞ report, which includes capacity projections until 2020 for each technology, the operation of a nuclear power plant is also considered to start. In this report, the demand ranges calculated by the Ministry of Energy and Natural Resources are used; and, accordingly, the demand in 2020, presented in two different scenarios of low and high range, is anticipated to be 398,160 GWh – 433,900 GWh. According to these demand values, the amount of generation that the two units of the Akkuyu nuclear plant, which is expected to be operating by that time, will meet nearly four percent of Turkey's total demand in that year. With the other two units also starting to operate, this ratio would double and reach eight percent.

2_ It should be noted that the public plants under construction and those private plants that had received licenses and are expected to operate on determined dates are taken into account while no predictions have been made on license applications that would be made in the following years; therefore, TEİAŞ projections do not match with the Supply Security Strategy Document. For example, while the projections regarding wind power in the report of TEİAŞ is stated as 3.3 GW installed capacity for the year 2020, in the Supply Security Strategy Document, it is aimed to be 20 GW by the year 2023.

The reduction of emissions, which is calculated by multiplying the emission factor calculated in the previous section and the generation value of the nuclear plants, is as shown in Table 10.

Table 10. The Amount of $CO_2$ Emission Reduction Enabled by the Akkuyu Nuclear Power Plant

| Year | $CO_2$ Emission Reduction Amount |
|---|---|
| 2019 | 8,935,200 MWh x 0.5459 $tCO_2$/MWh = 4,877,726 $tCO_2$ |
| 2020 | 17,870,400 MWh x 0.5459 $tCO_2$/MWh = 9,755,451 $tCO_2$ |
| 2021 | 26,805,600 MWh x 0.5459 $tCO_2$/MWh = 14,633,177 $tCO_2$ |
| 2022 | 35,740,800 MWh x 0.5459 $tCO_2$/MWh =19,510,903 $tCO_2$ |
| 2023 and onward | 19,510,903 $tCO_2$/yıl |

Since the estimation of the range of demand for the year 2020 is 398,160 GWh – 433,900 GWh and the emission factor of 0.5459 $tCO_2$ / MWh is used on that range, the interval of total $CO_2$ emissions due to electricity generation is calculated to be 217,355,544 – 236,866,010 $tCO_2$ / year. In the demand estimation study by the Ministry of Energy and Natural Resources, the growth rate of low demand in recent years has been accepted as 6.3 percent per year, while the high demand growth rate appears as 7.4 percent. When these projections for the year 2020 are expanded to 2023 by using the mentioned growth rates, the estimated demand is computed as 478,253 GWh – 537,529 GWh. The total $CO_2$ emissions resulting from electricity generation, calculated according to that range, account to 261,078,313 – 293,437,081 $tCO_2$ / year for the year 2023. When evaluated in terms of ratio, it is seen that the Akkuyu nuclear power plant will enable nearly 6.6-7.5 percent reduction in emissions resulting from electricity generation by the year 2023. [3]In case of an establishment of two other plants with equal power to Akkuyu plant, these ratios will triple; and, assuming that the carbon intensity in electricity generation remains constant, there will be a nearly 20 per cent reduction in emissions resulting from electricity generation.

3_ The amount of emission percentage reduction and the share of nuclear energy within total electric energy are the same because both the total electricity generation amount used in calculating the emission volume and the nuclear energy generation amount are multiplied by the same emission factor.

# 5- Conclusions

In this study, Turkey's electricity generation emission factor has been calculated in accordance with the methodology published by the UNFCCC to provide a guideline for the evaluation of projects aiming to reduce $CO_2$ emissions from electricity generation and trading emission certificates within the framework of the Kyoto Protocol's flexibility mechanisms. The calculated emission factor is multiplied by the amount of electrical energy that the Akkuyu nuclear power plant will produce, and hence the implied emission reduction is determined. It should be noted here that the emission reduction due to nuclear power generation cannot be certified and traded under the Kyoto Protocol Flexibility Mechanisms. It is stated in decision 17/CP7, which was taken at the $17^{th}$ Meeting of the Parties in 2001 in Marakkesh where the implementation rules on the mechanisms were determined, that the emission reductions from nuclear power generation cannot be certified and traded in order to be used in reaching the emission reduction goals of the Annex-1 countries. Aside from this, it is seen that there is neither any positive nor negative evaluation within the frameworks of the UNFCCC and the Kyoto Protocol regarding nuclear power; rather, an objective approach is preferred.

It has been determined that once the Akkuyu nuclear power plant is in operation with all of its units, it will enable a nearly 19.5 Mton ton savings in $CO_2$ emissions. And, it is calculated that this value will equal to nearly seven pe cent of the emissions resulting from electricity generation. As it has been presented in this study, considering that the ratio of emissions resulting from electricity generation stands as the sector with the highest share, which is 40 percent of Turkey's total emissions volume, it is understood that the savings from emissions that will be possible corresponds to a significant amount.

Although emission reductions that are enabled through the usage of nuclear energy are not taken into account under the Kyoto Protocol Flexibility Mechanisms, it nevertheless will be effective in limiting the increase of emissions in Turkey by reducing the carbon intensity of electricity generation.

# Section III

# Efforts to Control the Atom and the Transfer of Nuclear Technology: An Evaluation from Turkey's Perspective

# III

Sinan Ülgen – Aaron Stein

# Executive Summary

Intent on overcoming its dependency on imported energy, Turkey has been pursuing nuclear reactors for decades. Initially lured by the promise nuclear power as a panacea for its chronic energy problems, Ankara began to put in place the necessary legislative infrastructure to accommodate the sale of nuclear power reactors in the late 1950s. In tandem, successive governments have solicited bids for the construction of reactors on the Mediterranean and Black Sea coasts. Ankara's prolonged interest in developing a nuclear energy program has drawn the interest of numerous foreign suppliers, but progress to date has been slowed by a combination of internal problems and disagreements about financing.

Beginning in the 1980s, Turkey's nuclear energy acquisition efforts accelerated. Ankara ratified the Treaty on the Nonproliferation of Nuclear Weapons (NPT), concluded a full scope safeguards agreement with the International Atomic Energy Agency (IAEA), and began to aggressively solicit bids for the construction of nuclear reactors. As the negotiations progressed, Turkey and potential suppliers busily began negotiating nuclear cooperation agreements. The agreements are the legal basis for the transfer of nuclear technology and specify the terms and conditions for cooperation and technology use. To date, Turkey has signed and ratified nuclear cooperation agreements with Canada, Argentina, South Korea, France, the United States, and Russia. Ankara has also concluded agreements with Germany, Jordan, and China but they have not been ratified.

Turkey's current government has reiterated the country's desire to develop nuclear power through partnerships with foreign suppliers and continued to seek out foreign suppliers to supply Turkey with reactors. Given the current state of its nuclear industry, Turkey is likely to remain dependent on foreign suppliers for the foreseeable future. Thus, Ankara's future development of nuclear power will be contingent on technology transfers, which are governed by the multilateral export control guidelines and framed by the conditions in state-to-state nuclear cooperation agreements. To better gauge the possibilities for Turkey's future nuclear program, and the facilities likely to be transferred, it is important to examine the origins of current nonproliferation norms and the emerging supplier consensus on limiting the spread of enrichment and reprocessing technologies.

## *Turkey and Nuclear Negotiations*

Turkey's numerous nuclear cooperation agreement all share similar provisions about the scale and scope of peaceful nuclear cooperation. All outline a desire to cooperate on nuclear power and research reactor maintenance, operation, decommission and safety, the mining of uranium and thorium, and provide the legal authority to transfer nuclear reactor technology. All agreements specify using scientific exchanges and material transfers to help bolster Turkey's radioisotope production and research. In all cases, the parties agreed to exchange data and scientific personnel, hold regular symposiums and meetings, and collaborate on joint projects. These provisions are emblematic of NPT Article IV and help shed

some light on how the suppliers envision their NPT obligations.

The agreements are also written to make extremely difficult the misuse or diversion of foreign origin fissile material for nuclear weapons production. All specifically mention that none of the material or technology will be used for non-peaceful uses. In all but one of the agreements, there are specific provisions against the enrichment of uranium above 20 percent and the reprocessing of spent fuel. These provisions are emblematic of NSG guidelines. Notably, in all but one of the agreements, the suppliers do not specify the extent to which they are willing to transfer E&R technologies. Instead, vague language referring to elements of the fuel cycle is used.

The one exception is the Turkish – Argentinian nuclear cooperation agreement. The agreement was signed before Argentina joined the NSG and reversed many of its decades old nuclear policies. While little progress was made in implementing the deal, the agreement specified cooperation on the front end of the fuel cycle, and the production of small reactors that had questionable value for large-scale electricity production. Nevertheless, the agreement still had specific provisions relating to the non-diversion of fissile material, and an explicit clause barring the manufacture of nuclear weapons. However, the terms of the agreement were not in line with the NSG and established nonproliferation norms.

In all cases, the IAEA is counted on to ensure that material is not being used for non-peaceful uses. The agreements specifically reference Turkey's 1981 full scope safeguards agreement as the main enforcement mechanism, and have separate provisions that call for the conclusion of a bilateral safeguards agreement if it is found that the IAEA cannot perform its duties. In addition, Turkey's decision to sign the additional protocol, which allows the IAEA far greater authority and powers to inspect nuclear and nuclear related facilities, makes even more remote the idea that Ankara could or would divert material for weapons production.

### *Conclusion and recommendations*

Turkey should expect to continue to receive lots of interest from foreign companies eager to sell Ankara power reactors. However, it is unlikely that supplier states will agree to sell Turkey E&R facilities. Therefore, Ankara should seek to find a middle ground between its position that all countries in good standing with the IAEA should retain their right to pursue E&R, and the prospect that the supplier states aren't likely to break with the established norms of discouraging the sale of sensitive fuel cycle facilities. If one uses Turkey's nuclear negotiations with Russia as a baseline, it appears that Ankara has unofficially been pursuing a policy of relying on fuel guarantees and take back provisions. While not willing to acquiesce to UAE style provisions, Turkey could help alleviate some lingering concerns about its nuclear intentions by clarifying its future fuel cycle intentions. Ankara should release a comprehensive strategy paper detailing Turkey's nuclear ambitions, how it plans to fuel those reactors, the current plans for dealing with waste and spent fuel, and the conditions in which Turkey would consider pursuing E&R.

Ankara should match these efforts with a more proactive effort to negotiate bilateral agreements for the exchange of experts and the training of students in nuclear sciences. Ankara should also strive to ensure that future reactor sales are not "black boxed" so as to ensure that technology transfer will "spill over" and have residual effects on Turkey's current nuclear industry.

However, these efforts appear to be complicated by the decision to accept the BOO arrangement for reactor sales. According to the Turkish-Russian agreement, the reactor that will be built in Turkey will be owned and operated by Russian personnel. Even if a Turkish company were to acquire a percentage of the company operating the reactor, it is unclear whether or not they will receive access to the design information for reactor technology. Moreover, it is unclear what role the Turkish students currently being trained in Moscow will have at the reactor site. While there are certainly some safety reasons for the Turkish decision, a clearer sense about a gradual transition to Turkish operation would help clarify some of the benefits that Turkey will receive from the technology transfer. In particular the uncertainties related to whether in the middle or long run, a Turkish company will end up taking part in the operation of the Akkuyu power plant clouds the technology benefits that Turkey could derive from this large investment.

In addition, the government should begin a concerted effort to explain how and why nuclear energy benefits Turkey as a whole. These efforts should not only be limited to the benefits of power rectors, but how the technology transferred and the skills gained from dual operation can help Turkey further develop its nuclear medicine and agricultural sectors. These initiatives should be coupled with a state led effort to bring a clearer sense of how Turkey intends to utilize the skills learned to benefit society.

# 1- Introduction

Intent on overcoming its dependency on imported energy, Turkey has been pursuing nuclear reactors for decades. Initially lured by the promise nuclear power as a panacea for its chronic energy problems, Ankara began to put in place the necessary legislative infrastructure to accommodate the sale of nuclear power reactors in the late 1950s. In tandem, successive governments have solicited bids for the construction of reactors on the Mediterranean and Black Sea coasts. Ankara's prolonged interest in developing a nuclear energy program has drawn the interest of numerous foreign suppliers, but progress to date has been slowed by a combination of internal problems and disagreements about financing.

Beginning in the 1980s, Turkey's nuclear energy acquisition efforts accelerated. Ankara ratified the Treaty on the Nonproliferation of Nuclear Weapons (NPT), concluded a full scope safeguards agreement with the International Atomic Energy Agency (IAEA), and began to aggressively solicit bids for the construction of nuclear reactors. As the negotiations progressed, Turkey and potential suppliers busily began negotiating nuclear cooperation agreements. The agreements are the legal basis for the transfer of nuclear technology and specify the terms and conditions for cooperation and technology use. To date, Turkey has signed and ratified nuclear cooperation agreements with Canada, Argentina, South Korea, France, the United States, and Russia. Ankara has also concluded agreements with Germany, Jordan, and China but they have not been ratified.

Turkey's current government has reiterated the country's desire to develop nuclear power through partnerships with foreign suppliers and continued to seek out foreign suppliers to supply Turkey with reactors. Given the current state of its nuclear industry, Turkey is likely to remain dependent on foreign suppliers for the foreseeable future. Thus, Ankara's future development of nuclear power will be contingent on technology transfers, which are governed by the multilateral export control guidelines and framed by the conditions in state-to-state nuclear cooperation agreements. To better gauge the possibilities for Turkey's future nuclear program, and the facilities likely to be transferred, it is important to examine the origins of current nonproliferation norms and the emerging supplier consensus on limiting the spread of enrichment and reprocessing technologies. In order to do so, this report will analyze the evolution of nonproliferation agreements and multi-lateral export control guidelines in order to get a better sense of the limits and opportunities for Turkey's future nuclear development. In addition on the basis of a review of past nuclear cooperation agreements, a set of recommendations will be provided to enhance Turkey's capacity for additional nuclear technology transfers through bilateral agreements.

# 2. The Commercialization of Atomic Power and the Evolution of the Nonproliferation Regime: From the Manhattan Project to the NPT

The origins of Turkey's nuclear program are rooted in the debates taking place during the 1940s and the 1950s about how best to control the spread of nuclear technology. The backdrop for these debates was the Cold War and the evolving super power dynamic. Shortly after the end of World War II, many of the Manhattan project scientists argued that the destructive power of Atomic bombs and the inevitable spread of nuclear weapons/energy facilities necessitated American disarmament and the establishment of an international agency tasked with ownership of critical nuclear facilities. However, as the early proposals made their way through the American bureaucracy, the United States eventually settled on a policy of national ownership of nuclear materials and facilities. The decision to nationalize nuclear facilities set in motion the current system of national ownership and state-to-state cooperation, in exchange for international inspections and declarations of peaceful intent.

Initially, the United States, Canada and the United Kingdom concluded an Agreed Declaration that supported policies to promote atomic energy for peaceful purposes.[1] President Truman appointed a committee to prepare a report that looked into how to implement the themes and statements in the Agreed Declaration. After deliberating for two months, the expert panel produced the Acheson-Lilienthal report. The author's made clear that the recommendations were intended to be the "foundation" for a concrete proposal to control the spread of atomic energy. The report called for ceding the control and operation of sensitive fuel cycle activities to an international atomic energy commission.[2] Notably, the plan did not include any provisions for enforcement other than a proposal calling for the geographical dispersal of the fuel cycle facilities. The report emphasized that if nuclear facilities remained under national control, "rivalries" would likely spur interest in nuclear weapons. While unstated, the Acheson-Lilienthal plan advocated for American nuclear disarmament.

As the final touches were being put on the report, U.S. President Truman appointed a conservative delegation headed by financier Bernard Baruch to present the report to the international community. After reading the report, Baruch quickly moved

1_ Richard Rhodes, *Dark Sun: The Making of the Hydrogen Bomb* (New York: Simon and Schuster, 1995), pg. 229.

2_ The Acheson-Lilienthal Report on the International Control of Atomic Energy, Prepared for the Secretary of State's Committee on Atomic Energy, 16 March 1946, http://www.fissilematerials.org/ipfm/site_down/ach46.pdf.

to change some of the earlier proposals. Importantly, the Baruch plan dropped the idea of international ownership, in favor of national facilities, inspections, and sanctions to punish states that were caught pursuing nuclear weapons.[3] The Baruch plan also insisted that the decision to impose sanctions could not be vetoed by the permanent members of the United Nations Security Council. The plan also advocated for American disarmament, but only after the inspection regime had been put in place and the international community had acquiesced to the American plan.[4]

The American move to nationalize nuclear facilities was codified even before the Baruch plan was presented to the United Nations. The 1946 Atomic Energy Act gave the U.S. government the authority to own nuclear materials, imposed classification and secrecy rules on atomic research, and created the civilian Atomic Energy Commission to oversee civilian and military research and development.[5]

The Soviet Union – which had not developed its own nuclear weapons yet – rejected the U.S. approach and presented a plan calling for universal disarmament without inspection. The failure of the earlier proposals changed the tone of the earlier efforts to control the spread of nuclear technology and eventually led to President Eisenhower's Atoms for Peace speech. Eisenhower's landmark speech contained a proposal for the creation of an international agency responsible for the supply of nuclear fuel and ensuring peaceful use.[6] The IAEA was established in 1957, but the fuel bank proposal never materialized. The Atoms for Peace was a compromise between those advocating for international control of nuclear facilities and those that were adamant that the United States should implement policies to classify nuclear technology.

To facilitate nuclear cooperation, the U.S. Congress amended the 1946 Atomic Energy Act. The Atomic Energy Act of 1954 lessened nuclear secrecy, allowed for the private ownership of nuclear facilities, and bilateral nuclear cooperation[7] in accordance with section 123. Technology transfers were conditioned on the following conditions:

1. A guarantee by the cooperating party that safeguards will apply to all transferred material and be in place as long as the facilities and materials are under the jurisdiction of the recipient state
2. In the case of non-nuclear-weapon states, a requirement that IAEA safeguards be maintained with respect to all nuclear materials in all peaceful nuclear activities within the territory of the recipient state

3_ The Baruch Plan, Presented to the United Nations Atomic Energy Commission, 14 June 1946, http://streitcouncil.org/uploads/PDF/The%20Baruch%20Plan.pdf.

4_ Ibid

5_ Atomic Energy Act of 1946, Public Law 585, 79th Congress, Excerpted from Legislative History of the Atomic Energy Act of 1946, http://www.osti.gov/atomicenergyact.pdf.

6_ Address by Mr. Dwight D. Eisenhower, President of the United States of America, to the 470th Plenary Meeting of the United Nations General Assembly, 8 December 1953, The International Atomic Energy Agency, http://www.iaea.org/About/history_speech.html.

7_ United States National Security Council, "Cooperation with other nations in the uses of peaceful of atomic energy," 13 August 1954, Dwight D. Eisenhower Library. White House Office of the Special Assistant for National Security Affairs. NSC Series. Policy Series Subseries. Box 12. NSC 5431/1

3. A guarantee that material and facilities will not be retransferred to third parties and that recipient state will not use special nuclear material produced for any nuclear explosive device, or for research on or development of any nuclear explosive device, or for any other military purpose
4. Except in the case of . . . cooperation with nuclear-weapon states, a stipulation that the United States shall have the right to require the return of any nuclear materials and equipment transferred if special nuclear material produced through the use U.S. origin technologies are used in the detonation of a nuclear explosive device or terminates or if the recipient state abrogates its IAEA safeguards agreement
5. A guarantee by the cooperating party that any material or any Restricted Data transferred pursuant to the agreement for cooperation will not be transferred to unauthorized persons or beyond the jurisdiction or control of the cooperating party without the consent of the United States
6. A guarantee that adequate physical security will be maintained with respect to any nuclear material transferred pursuant to such agreement and with respect to any special nuclear material used in or produced through the use of any material, production facility, or utilization facility transferred pursuant to such agreement
7. A guarantee that no material transferred pursuant to the agreement for cooperation and no material used in or produced through the use of any material, production facility, or utilization facility transferred pursuant to the agreement for cooperation will be reprocessed, enriched or (in the case of plutonium, uranium 233, or uranium enriched to greater than twenty percent) otherwise altered in form or content without the prior approval of the United States
8. A guarantee that no plutonium, no uranium 233, and no uranium enriched to greater than twenty percent, transferred pursuant to the agreement for cooperation, or recovered from any source or special nuclear material so transferred will be stored in any facility that has not been approved in advance by the United States
9. A guarantee that any special nuclear material, production facility, or utilization facility produced or constructed under the jurisdiction of the cooperating party by or through the use of any sensitive nuclear technology transferred be subject to all the requirements specified in this subsection.[8]

After the change in American attitudes, the United States and the Soviet Union began to sign multiyear nuclear cooperation agreements and to subsidize the building of research reactors in a number of foreign countries. The competition to export research reactors was tied to the overall effort by both sides to establish influence around the world. The Soviet Union's nuclear export policy was highly

8_ The Atomic Energy Act of 1954 (P.L. 83-703) in Nuclear Regulatory Legislation, Office of the General Counsel, Nuclear Regulatory Commission, 111th Congress, 2nd Session, vol. 1, no. 9, January 2011, pp. 7-231, http://www.nrc.gov/reading-rm/doc-collections/nuregs/staff/sr0980/v1/sr0980v1.pdf#page=13.

centralized and there was not a similar piece of legislation governing nuclear exports. Moscow approached nuclear transfers on a case-by-case basis, and generally exported nuclear material, equipment, and know how to friendly states. The Soviet leadership, like their peers in the United States, assumed that the transfer of dual use atomic facilities would engender good will and help establish political support abroad.

Soviet attitudes began to change after the Sino-Soviet split (see Russia below for a more detailed explanation) and mutual concerns about the "nth" country problem. The "nth" country problem referred to a series of intelligence estimates released by the United States' Central Intelligence Agency warning that up to ten new countries could produce first generation nuclear explosives by the late 1960s.[9] The USSR – which had reached similar conclusions - was particularly worried about West Germany developing a nuclear weapon and the implications that such an act would have on the Cold War balance of power. These similar concerns eventually resulted in the two superpowers coming together and negotiating the NPT.

## *2.1. Proliferation Shocks: Suppliers Tightening Export Controls and the Residual Effects for Bilateral Nuclear Cooperation Agreements*

Articles 1 and 2 of the NPT are designed to prevent the spread of nuclear weapons. More specifically, the non-nuclear weapons states (NNWS) agreed not to develop or receive nuclear weapons, while the official nuclear weapons[10] (NWS) states agreed not to transfer nuclear weapons or know how to the NNWS. Article 3 of the NPT requires that the non-nuclear weapon states conclude a safeguards agreement with the IAEA. The task of verifying a state's nuclear declaration was initially contained in bi-lateral nuclear cooperation agreements. After the creation of the IAEA, the tasks for verification and inspection were slowly transferred to the new international agency. At the time, it was believed that a state could not develop enrichment or reprocessing technologies clandestinely. Thus, the safeguards system was based on a country's declarations and designed to prevent the diversion of nuclear material for non-peaceful uses.

While the Treaty's provisions are quite clear about the spread of nuclear weapons, specifics about how to enforce the Treaty are vague. According to NPT Article 3.2:

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9_ "Nuclear Weapons Production in Fourth Countries: Likelihood and Consequences," National Intelligence Estimate 100-6-57, Central Intelligence Agency, 18 June 1957.

10_ The NPT defines the official nuclear weapons states as those that tested a nuclear device before 1 January 1967. The five official nuclear weapons states are: 1) The United States, 2) Russia, 3) the United Kingdom, 4) France, and 5) China. India, Pakistan, and Israel are also known to possess nuclear weapons. The three countries are, however, not signatories to the NPT.

> Each State Party to the Treaty undertakes not to provide: (a) source or special fissionable material, or (b) equipment or material especially designed or prepared for the processing, use or production of special fissionable material, to any non-nuclear-weapon State for peaceful purposes, unless the source or special fissionable material shall be subject to the safeguards required by this article.

To help clarify ambiguities about how to implement safeguards, the nuclear suppliers came together in 1971 to discuss requirements and implications for a common export control list.[11] These discussions eventually led to the creation of the Zangger Committee – an informal group of states committed to adopting a common list of citems that should be controlled when exported. In September 1974, Australia, Denmark, Canada, Finland, Norway, USSR, the UK, and the United States established a "trigger list" (exports that would automatically trigger IAEA safeguards). The specifics were published in IAEA INFCIRC/209.[12] The annexes have since been updated and the list of Zangger Committee members has increased. While the Parties were negotiating a wide-ranging list, India detonated a nuclear device using plutonium derived from a Canadian supplied nuclear reactor that used American supplied heavy water as a moderator.

India's nuclear test prompted the major nuclear suppliers to come together again to discuss ways to tighten export control restrictions. Beginning in 1975, a new supplier group began to meet in London. The group was unofficially dubbed the "London Group" and later evolved into the official Nuclear Suppliers Group (NSG). The original seven members - United States, the Soviet Union, the United Kingdom, France, West Germany, Japan, and Canada – agreed on a first version of the "Guidelines on Nuclear Transfers" in 1976. The text was then discussed with eight new members - Belgium, Czechoslovakia, East Germany, Italy, the Netherlands, Poland, Sweden, and Switzerland – and accepted in 1977.[13] The document was then sent to the IAEA and published in INFCIRC/254.[14]

The NSG guidelines incorporated the Zangger trigger list, and include provisions requiring the importing state to make a peaceful use pledge, have IAEA safeguards (though not full scope safeguards), and a pledge not to re-transfer facilities

11_ Fritz Schmidt, "NPT Export Controls the Zangger Committee," *The Nonproliferation Review,* (Fall/Winter, 2000), http://cns.miis.edu/npr/pdfs/73schmi.pdf.

12_ International Atomic Energy Agency, *Communication Received from Members Regarding the Export of Nuclear Material and of Certain Categories of Equipment and Other Material*, Information Circular 209, 3 September 1974, http://www.iaea.org/Publications/Documents/Infcircs/Others/inf209.shtml.

13_ Tadeusz Strulak, "The Nuclear Suppliers Group," *The Nonproliferation Review,* (Fall/Winter, 1993), http://cns.miis.edu/npr/pdfs/strula11.pdf.

14_ International Atomic Energy Agency, *Communication Received from Certain Member States Regarding Guidelines for the Export of Nuclear Material, Equipment or Technology*, Information Circular 254, February 1978, http://www.fas.org/nuke/control/nsg/text/inf254.htm.

transferred.[15] Unlike the Zangger Committee, the NSG is not tied exclusively to the NPT. Rather it imposes more stringent restrictions on nuclear transfers to every non-nuclear weapons state. The members agreed to change domestic legislation to reflect the NSG supplier guidelines. After the submitting the guidelines to the IAEA, however, the NSG atrophied and the member states did not meet for another thirteen years.

Despite the guidelines and the Zangger trigger list, some supplier countries took a more relaxed approach to the transfer of dual use technologies to third parties. The calculus changed after the end of the Cold War, and the discovery that Iraq had diverted nuclear material and facilities that it acquired legally for a nuclear weapons program. Iraq was an NPT member state whose facilities were subject to IAEA inspections. Baghdad was able to elude detection and came close to acquiring the amount of HEU needed for a first generation nuclear weapon. The post-Gulf War revelations led the NSG to adopt more stringent guidelines for the transfer of sensitive dual-use equipment.[16] The updated guidelines require the recipient state to have am IAEA full scope safeguards agreement and ask that the supplier state consider whether or not the importing state is likely to use the transferred equipment for non-peaceful uses.[17]

## *2.2. Coming to a Consensus on Controlling the Spread of Enrichment and Reprocessing Facilities*

Since the start of the nuclear weapons age, policymakers have grappled with the dual use nature of nuclear technology. The same processes for enrichment and reprocessing (E&R) can be used for power reactors or nuclear weapons. With the proliferation of the gas centrifuge in the late 1970s, the problem has grown more acute. In the 1970s, the United States began to lead efforts to significantly limit the spread of enrichment and reprocessing in states that did not already have facilities. After the end of the Cold War, a new consensus amongst the supplier states about significantly limiting the spread of enrichment and reprocessing technologies began to emerge. There continues to be, however, disagreements between the

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15_ According to the NSG Guidelines: The transfer guidelines "should also apply to facilities for reprocessing, enrichment, or heavy-water production, utilizing technology directly transferred by the supplier or derived from transferred facilities, or major critical component thereof. (b) The transfer of such facilities, or major critical components thereof, or related technology, should require an undertaking (1) that IAEA safeguards apply to any facilities of the same type (i.e. if the design, construction or operating processes are based on the same or similar physical or chemical processes, as defined in the trigger list) constructed during an agreed period in the recipient country and (2) that there should at all times be in effect a safeguards agreement permitting the IAEA to apply Agency safeguards with respect to such facilities identified by the recipient, or by the supplier in consultation with the recipient, as using transferred technology.

16_ International Atomic Energy Agency, *Communication Received from Certain Member States Regarding Guidelines for the Export of Nuclear Material, Equipment and Technology,* Information Circular 254, July 1992, http://www.iaea.org/Publications/Documents/Infcircs/Others/inf254r1p1.shtml.

17_ Ibid

major nuclear suppliers and some in the developing world/non-aligned movement (NAM) about the placement of onerous conditions on the spread of nuclear facilities.

NSG guidelines have tried to strike a balance between the right of all NPT signatories to pursue peaceful nuclear research and practical policies designed to limit the spread of sensitive dual use facilities. Key differences remain between the NWS and NNWS about how to balance nonproliferation efforts and NPT Article IV. During the 2000s, Turkey, and a number of other NSG members, challenged the American backed proposal to ban the transfer of enrichment and reprocessing technologies to states that are not currently operating plants. To help break the political stalemate, France put forward a criteria based approach that conditioned the supply of enrichment and reprocessing facilities on specific criteria like NPT compliance, adherence to the Additional Protocol, compliance with safeguards obligations, implementation of United Nations Security Council Resolution 1540[18], agreements with the supplier state that facilities will not be used for nuclear explosive devices, adherence to international safety commitments, and physical protection in line with IAEA standards.[19] In addition, the suppliers would be asked to consider the following provisions before transferring facilities/material:

- If the transfer would have a negative impact on the stability of the importing state (A reference to proliferation chain, and the belief that states choose to proliferate reactively)
- If the importing state has a legitimate need for enrichment and reprocessing facilities as part of a civil nuclear program[20]

The United States, however, did not fully support the objective criteria and proposed a further set of "subjective" supplier guidelines. They were:

- Enrichment and reprocessing transfers have to be done under conditions that will not allow for the replication of the technology (so called "black box" criterion)
- If the transfer will spur other regional states to pursue similar technology
- Suppliers will not transfer sensitive facilities to states that have agreed to forego such activities in the past[21]

Argentina Brazil, Canada, South Korea, Spain, Switzerland, Turkey, and South Africa objected to the subjective proposals. Brazil and Argentina objected to the

18_ The binding United Nations Security Council Resolution requires all states to measures to prevent the spread of nuclear, chemical, biological, and missile components to non-state actors. United Nations Security Council, Resolution 1540, Adopted on 28 April 2004, http://daccess-dds-ny.un.org/doc/UNDOC/GEN/N04/328/43/PDF/N0432843.pdf?OpenElement.

19_ Fred McGoldrick, "Limiting Transfer of Enrichment and Reprocessing Technologies: Issues, Constraints, and Options," Project on Managing the Atom, Belfer Center for Science and International Affairs, May 2011, http://belfercenter.ksg.harvard.edu/files/MTA-NSG-report-color.pdf.

20_ Ibid

21_ Ibid

inclusion of the Additional Protocol, while Canada and the Netherlands argued against conditioning transfers on whether or not the importing state has a legitimate need for enrichment and reprocessing facilities as part of a civil nuclear program. South Korea disagreed with condition preventing the suppliers from transferring enrichment and reprocessing in the past (As part of the 1992 Joint Declaration of the South and North Korea on the denuclearization of the Korean Peninsula, South Korea agreed not to pursue enrichment and reprocessing).[22] Turkey argued against both the black box criterion and having suppliers take into account whether or not the supply of enrichment and the provisions asking the supplier state to consider if reprocessing technologies could spur neighboring states to pursue similar technologies. Ankara argued that its territorial proximity to Iran and Syria would forever preclude it from having access to nuclear facilities and technologies.

After months of negotiations, the NSG members agreed on a clean Text. Fred McGoldrick published the confidential draft in his report on the transfer of enrichment and reprocessing technologies. According to the published draft, the requirements for E&R transfers were:

– Compliance with NPT obligations
– Implementing IAEA safeguards and has the Additional Protocol in force, or an IAEA approved regional arrangement that mimics the AP's provisions (The mention of the regional arrangement was a concession to Argentina and Brazil)
– Has not been found to be in breach of IAEA safeguards
– Implementing export control in line with NSG and UNSC 1540 obligations
– Have concluded a bilateral agreement with assurances that the facilities will only be used for peaceful purposes, safeguards in perpetuity, and retransfer
– Adequate standards of physical protection
– Accepted international safety conventions

Eventually, the NSG members agreed to the new guidelines in 2011. The new guidelines are based largely on the 2008 clean text. References to the American proposed "subjective" criteria are alluded to vaguely in the conditions for exports, but they are not nearly as explicit as the U.S. originally intended. The guidelines condition the transfer of E&R technology on full scope safeguards, or a comparable regional arrangement approved by the IAEA. If a recipient meets the specific conditions contained in Article 6 (see Annex 1 for a full copy of the latest NSG guidelines), the suppliers should receive legal assurances from the recipients that the facilities will not be modified to allow for the enrichment of uranium above 20 percent. In a reference to the earlier "black box" proposals, the new guidelines state that suppliers should "seek from recipients an appropriate agreement to accept sensitive enrichment equipment, and enabling technologies, or an operable enrichment facility under conditions that do not permit or enable replication of the facilities."

22_ Joint Declaration of the South and North Korea on the Denuclearization of the Korean Peninsula, Joint Declaration Text, Entry into force 19 February 1992, http://cns.miis.edu/inventory/pdfs/aptkoreanuc.pdf.

This evolution of the nonproliferation regime is critical for understanding Turkey's efforts to acquire nuclear technology. In all cases, Turkey's nuclear cooperation agreements are a direct reflection of language used in the NSG guidelines. Thus, the evolution of specific export control guidelines has played an important role in shaping Ankara's nearly four decades long effort to acquire reactors. In order to understand how Turkey has been affected, it is necessary to dissect further how the suppliers have approached nonproliferation historically and followed through on their NSG commitments.

# 3- Balancing Nuclear Exports and Export Controls: Supplier States Interpretation of NSG Guidelines

NSG members agreed that the guidelines would be enacted domestically with national legislation. While the NSG member states, especially after the end of the Cold War, have taken steps to universalize restrictions on the transfer of enrichment and reprocessing, during the 1970s and 1980s there were fundamental differences about how to interpret the guidelines. Generally, the United States has taken a more hardline approach to export controls, while some European countries were a bit more relaxed in their implementation of NSG guidelines. These differences are reflected in Turkey's nuclear cooperation agreements (the details will be elaborated on further later in the report). Before analyzing Turkey's nuclear cooperation agreements, it is necessary to dissect how some of the supplier states interpreted the NSG guidelines.

## *3.1. The United States*

The United States, as mentioned earlier, first thought that the spread of nuclear technology was a critical way to further influence in "friendly" and "potentially friendly" states during the 1950s and early 1960s. The Atoms for Peace initiative was an American policy and was pursued with vigor by successive Administrations. The United States showed little concern for the spread of weapons grade enriched uranium globally, believing that safeguards and state pledges for non-diversion were enough to prevent proliferation. The real concern amongst American nonproliferation advocates was spent fuel reprocessing. At the time, the gas centrifuge was still being developed and officials believed that gaseous diffusion was far more economical for enrichment.[23] Gaseous diffusion plants are large, conspicuous, and easily identifiable by technical means.

To counter the threat of plutonium separation, the United States "reserved the right to regain such fissionable material after usage in the reactor."[24] In addition, it was assumed that the fissionable material created in reactor was "insignificant" and that the amount of HEU provided was "not of weapons quality."[25] If the recipient state had wanted to divert fissionable material for non-peaceful uses, the high rate of contamination requires the fuel rod "to be reprocessed in special facilities . . . that only the United States, the United Kingdom, and the Soviet Union" were thought to possess at the time.[26] The United States believed that the spread of such facilities would not take place for at least 25 years, thus minimizing the proliferation risk.

However, the thinking began to change as more and more states began to approach the technical threshold for nuclear weapons development. One of the many catalysts for a change in policy was American President John F. Kennedy's preoccupation with preventing proliferation. Kennedy worried that uncontrolled spread of nuclear weapons was destabilizing and had the potential to spark a nuclear exchange. Consequently, the United States and the Soviet Union –which shared many of the same concerns – began a process to strengthen nonproliferation norms and to coordinate and tighten export controls. The centerpiece was the negotiation and passage of the NPT. However, as mentioned earlier, the real work of negotiating a minimum standard for universal export controls had yet to be completed.

Domestically, the United States began to work on legislation to govern U.S. origin fissile material in third countries in the late 1970s. By the mid-1970s, the United States had provided more than 90 percent of the West's research reactors and was the primary supplier of enriched uranium for reactors.[27] Intent on overcoming reliance on U.S. enriched fuel; Britain, the Netherland, and Germany decide to build the URENCO enrichment facility. (See Germany and France below)

Early drafts of the Nuclear Nonproliferation Act (NNPA) contained provisions barring the reprocessing or further enrichment of U.S. origin fissile material in third countries and conditioned nuclear exports on the recipient states foregoing

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23_ Scott Kemp, "Gas Centrifuge Theory and Development: A Review of U.S. Programs," *Science and Global Security*, vol. 17, no. 1 (2009), http://www.princeton.edu/sgs/publications/sgs/archive/17-1%20Kemp-Gas-Centrifuge.pdf.

24_ National Security Council, "Cooperation with other nations in the peaceful uses of atomic energy," 13 August 1954.

25_ Ibid

26_ Ibid

27_ Sharon Squassoni, "Looking Back: The 1978 Nuclear Nonproliferation Act," *The Arms Control Association*, December 2008, http://www.armscontrol.org/act/2008_12/lookingback_NPT.

E&R. Eventually, the legislation was passed with provisions mandating NPT compliance and the conclusion of an IAEA safeguards agreement as conditions for the receipt of U.S. nuclear exports (The NSG amended its supplier guideline with the full scope safeguards provision in 1991).[28] The United States was trying to dissuade states from reprocessing in favor of a once through fuel cycle supplied with American origin reactor fuel. This necessitated states foregoing research into breeder/burner reactors, the building of geological repositories, and the establishment of a reliable and guaranteed of reactor fuel. (Notably, the legislation did not include a take back provision for spent fuel)

In the 1980s, the United States introduced a catch all provision, which allows the supplying country to regulate nuclear exports that could contribute to proliferation even if they are not included on control lists. These efforts have become a staple of the American nonproliferation policy. As noted earlier, proposals to ban enrichment and reprocessing in recipient countries was part of the American proposals during negotiations for new NSG guidelines. Moreover, the idea of an international fuel bank has been around since the Acheson-Lilienthal report. Notably, however, many of the early provisions called for in the NNPA are still being debated today. Since 1991, there has been a general consensus amongst the major suppliers that the supply of enrichment and reprocessing facilities should be limited. However, there continues to be frictions over the supply of nuclear reactors to countries like Iran, and worries that states can still take advantage of exports to clandestinely acquire nuclear weapons capability.

A 2005 decision, however, to begin discussions to grant India an NSG trade exemption did not conform to United States' decades old approach to nonproliferation. In 2008, the United States granted non-NPT member India a waiver that allows for the transfer of E&R facilities.[29] The U.S. decision has had widespread implications for the behavior other NSG states (see Russian Federation and China below.) The India waiver demonstrates that the supplier states continue to be tempted to break nonproliferation norms for commercial and political benefits.

In 2008, the Bush administration signed a memorandum of understanding with the United Arab Emirates pertaining to nuclear energy. The UAE was one a number of states that announced new or long dormant plans for the construction of nuclear reactors in 2006. After the signing of the MOU, the United States and the UAE began to negotiate terms for a nuclear cooperation agreement. At the time, the Bush administration was pursuing a no-transfer policy of E&R facilities at the NSG. The UAE's announcement raised concerns that Abu Dhabi was hedging against the threat of a nuclear-armed Iran by taking its first steps towards achieving nuclear

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28_ Nuclear Regulatory Legislation, Office of the General Counsel, Nuclear Regulatory Commission, 111th Congress, 2nd Session, vol. 1, no. 9, January 2011, pp. 1029-1063, http://www.nrc.gov/reading-rm/doc-collections/nuregs/staff/sr0980/v1/sr0980v1.pdf#page=13.

29_ Javier Serrat, "NSG's India Waiver Highlights Flawed U.S. Approach," *World Politics Review*, 7 July 2011, http://www.worldpoliticsreview.com/articles/9399/nsgs-india-waiver-highlights-flawed-u-s-approach.

latency. However, the UAE tried to assuage international concerns from the outset. The Kingdom released a comprehensive white paper stating that the UAE would sign the additional protocol and forgo enrichment and reprocessing. In 2009, the Bush Administration signed the nuclear cooperation agreement, but it wasn't submitted to Congress for ratification.

According to the original document, the UAE was to rely on a guaranteed fuel supply and spent fuel was to be sent for reprocessing in France or the United Kingdom. In return, the UAE was to pledge not to seek to acquire and to establish domestically E&R facilities.The agreement also included a provision allowing for the United States to terminate the deal if the UAE violated its E&R pledge. After Obama was elected, the U.S. strengthened the nuclear cooperation agreement's nonproliferation provisions by adding a clause that explicitly forbids the UAE's possession of enrichment and reprocessing facilities on its territory.[30] The Obama Administration submitted the cooperation agreement to Congress on 21 May 2009 and it came into force 5 months later. After the UAE agreed to the United States' E&R conditions, the United States sought to use it as a model for all of its future nuclear cooperation agreement.

These efforts, however, have been resisted by other states currently negotiating the terms of cooperation agreements with the United States. Specifically, the United States has failed to convince Jordan and Vietnam to accept similar provisions and has abandoned earlier efforts to condition the conclusion of nuclear cooperation agreements on a non-enrichment or reprocessing pledge.[31]

## 3.2. Russia

Unlike the United States, the Soviet Union did not have one single piece of legislation governing nuclear exports. In the centralized Soviet system, the Minsredmash - the ministry responsible for the nuclear program – made export decisions on a case-by-case basis. Beginning in the 1950s, the Soviet Union agreed to provide ample assistance to China's early nuclear program. The depth of cooperation grew, and eventually the USSR transferred nuclear weapons designs and sensitive nuclear enrichment information to China. However, after the Sino-Soviet split, and the eventual designation of Communist China as a nuclear threat, the USSR cancelled its nuclear cooperation.

The Soviet Union joined the Zangger committed in 1970 and was one of the original 15 NSG member states. After the collapse of the Soviet Union, however, the gap between Russian declaratory policy and the enforcement of export

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30_ Aaron Stein, "U.S. – UAE Nuclear Cooperation," Nuclear Threat Initiative, 13 August 2009, http://www.nti.org/analysis/articles/us-uae-nuclear-cooperation/.

31_ Jay Solomon, "U.S. Shifts Policy on Nuclear Pacts," *The Wall Street Journal*, 25 January 2012, http://online.wsj.com/article/SB10001424052970203806504577181213674309478.html.

controls widened.[32] The financial conditions after the collapse placed enormous pressures on Russian export controls. Almost overnight, funding for the former Soviet Union's massive nuclear, chemical, and missile programs evaporated. Some scientists sold sensitive information to well paying customers abroad and site security deteriorated. The threat of Russian brain drain prompted the United States to implement the Nunn-Lugar Cooperative Threat Reduction Program.

In 1999, the Russian Duma passed a new export control law that brought Russian export controls in line with similar Western legislation.[33] Notably, the new law contains a catch all provision. Nevertheless, there continues to be allegations that private Russian companies – and individuals[34] - have circumvented export controls and shipped controlled dual use items abroad.

Russia has also been criticized for its transfer of nuclear material to India. After the Bush Administration announced its intention to grant India an NSG waiver, Russia announced that it would supply fuel for the Tarapur reactors. The NSG had not yet considered the exemption, so the Russian announcement violated NSG guidelines. It also confirms that Russia, like the United States, is susceptible to placing economic and political consideration above their nonproliferation commitments.

## 3.3. Canada

Canada's civil nuclear program stems from its participation in the Manhattan project. Eager to avoid the costly development and construction of national enrichment centers, Canada opted to pursue the development of large natural uranium reactors. After the initial development of the CANDU heavy water reactor, policymakers decided to market reactor technology abroad. During the 1950s, there were few restrictions governing the sale of reactors abroad. Consequently, Canada concluded sales agreements for CANDU heavy water reactors with India, Pakistan, Argentina, and South Korea with minimal safeguards.[35]

Canada's attitude towards safeguards and export controls dramatically changed after India's 1974 nuclear test. It was later discovered that plutonium used for the nuclear test came from a Canadian supplied reactor. Afterwards, Canada cancelled nuclear cooperation with India and Pakistan and renegotiated it supplier contracts with Argentina and South Korea. Since the establishment of the NSG, Canada's nuclear exports have largely mirrored the supplier guidelines. This

32_ Vladimir Orlov, "Export Controls in Russia: Policies and Practices," *The Nonproliferation Review*, (Fall, 1999), http://cns.miis.edu/npr/pdfs/orlov64.pdf.

33_ Ibid

34_ Mark Gorwitz, "Vyacheslav Danilenko – Background, Research, and Proliferation Concerns," Institute for Science and International Security, 29 November 2011, http://www.isisnucleariran.org/assets/pdf/Yscheslav_Dainlenko_ISIS_article.pdf.

35_ Duane Bratt, "CANDU or CANDON'T: Competing Values Behind Canada's Nuclear Sales," *The Nonproliferation Review*, (Spring/Summer 1998), http://cns.miis.edu/npr/pdfs/bratt53.pdf.

included a continued willingness to continue supplying E&R facilities in line with international obligations.

During the most recent negotiations to update NSG guidelines, Canada opposed the American backed "black box" criterion because it wanted to keep open the option of buying centrifuge technology.[36] According to Fred McGoldrick, the United States and Canada agreed on the following language for "black box" provisions:

> Avoid, as far as practicable, the transfer of specialized design, development, and manufacturing technology associated with such items; and seek from recipients an agreement to accept enrichment equipment, facilities, and technology under conditions that, at a minimum, do not permit or enable replication of the facilities.[37]

The language that was eventually adopted reflects the U.S. – Canadian compromise. According to the 2011 NSG guidelines:

> Suppliers should avoid, as far as practicable, the transfer of enabling design and manufacturing technology associated with such items; and seek from recipients an appropriate agreement to accept sensitive enrichment equipment, and enabling technologies, or an operable enrichment facility under conditions that do not permit or enable replication of the facilities.

Notably, Canada overturned its decades old policy of nuclear cooperation with India. The two countries signed a nuclear cooperation agreement that allowed for the transfer of Canadian nuclear facilities and materials to safeguarded Indian nuclear facilities.[38] Like the other suppliers, Canada's actions indicate that it is willing to reverse decades old proliferation policy if given the chance, and the prospects are lucrative.

## 3.4. Germany

Germany and France, in particular, were early advocates for lesser controls on the spread of enrichment and reprocessing technologies. Germany was rumored to have had nuclear weapons ambitions, and, at the very least, considered developing dual use capabilities to become nuclear latent. During the NPT negotiations, Germany, like many other advanced nuclear countries at the time, worried that stringent inspections would put it at a commercial disadvantage.

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36_ Fred McGoldrick, "Limiting Transfer of Enrichment and Reprocessing Technologies: Issues, Constraints, and Options," Project on Managing the Atom, Belfer Center for Science and International Affairs, May 2011, http://belfercenter.ksg.harvard.edu/files/MTA-NSG-report-color.pdf.

37_ Ibid

38_ "India, Canada sign nuclear cooperation agreement," *World Nuclear News*, 28 June 2010, http://www.world-nuclear-news.org/RS-India-Canada_sign_nuclear_cooperation_agreement-2806107.html.

West German officials believed that the lack of inspection in the NWS would grant them an unfair economic advantage.[39] Germany joined the NSG after the Indian nuclear test, but refused to accept language banning the sale of full fuel cycle technologies.[40] Bonn was only willing to support the NSG's provision calling for the suppliers to show "restraint" when transferring sensitive nuclear facilities.

Bonn, however, had a liberal interpretation of "restrain" and began negotiations with a number of sates for the sale of reactors and fuel cycle facilities. In 1975, West Germany concluded an agreement with Brazil for the supply of the full nuclear fuel cycle[41] and negotiated similar contracts with Iran and Argentina. The deals were eventually cancelled after technical challenges slowed the enrichment project and the United States put pressure on Bonn to scale back its cooperation. During the 1980s, however, public opposition to nuclear weapons grew and Germany's view on export controls began to change. After a series of embarrassing incidents involving the legal transfer of dual use nuclear and chemical technologies to Pakistan, Libya, and Iraq domestic pressure for reforms began to grow.

By the time that the UNSCOM inspectors revealed after the first Gulf War that German companies had supplied a host of equipment for Iraq's clandestine nuclear weapons program, Germany had already taken steps to tighten export control restrictions. In 1990, Germany passed domestic legislation conditioning the supply of nuclear facilities on the receiving state having in place full scope safeguards and later updated the legislation with a catch all provision. Shortly thereafter, Germany pressed the European Union to adopt a universal export control guidelines (The EU's dual use export controls mirror those contained in INFCIRC/254 and were passed in 2000).[42] Germany supported the 2008 clean text at the NSG meetings and did not raise any major concerns after the NSG's export control guidelines were updated in 2011.

## 3.5. France

France, like Germany, resisted early efforts to ban the transfer of enrichment and reprocessing equipment.  Like many of the other suppliers, French nuclear equipment has been used for the development of nuclear weapons. Specifically, France supplied Israel with the technology and expertise for the Dimona nuclear reactor. At the time, few doubted Israel's intention to use the reactor to create plutonium for their nascent nuclear weapons program. France, however, remained willfully ignorant, claiming that it had received a peaceful use pledge from

39_ Harald Muller, "Germany and WMD Proliferation," *Nonproliferation Review* (Summer, 2003), http://cns.miis.edu/npr/pdfs/102mull.pdf.

40_ Ibid

41_ "Brazil and France Plan Nuclear Pact," New York Times Wire Services, 6 July 1975, http://news.google.com/newspapers?id=37wqAAAAIBAJ&sjid=A2cEAAAAIBAJ&pg=1358,2269777&dq=germany+brazil+nuclear+cooperation&hl=en.

42_ Muller, "Germany and WMD Proliferation," http://cns.miis.edu/npr/pdfs/102mull.pdf.

the Israeli's. While French – Israeli nuclear cooperation pre-dates the NPT and established nonproliferation norms, Paris' perceived indifference to the spread of dual use nuclear weapons technology is indicative of early French attitudes to nonproliferation.[43]

After the passage of NSG guidelines, France continued to market and sell fuel cycle facilities abroad. France signed reprocessing contracts with South Korea and Pakistan, but heavy U.S. pressure eventually forced Paris to cancel the contracts. French attitudes to nonproliferation began to change after UNSCOM inspectors uncovered the depth of Iraq's clandestine nuclear weapons program. In 1995, France changed its domestic legislation and conditioned exports on a full scope safeguards requirement. France was also the state that stepped in and proposed the NSG's clean text. Paris also included a catch all provision in in their update export control legislation in 2009. At the same time, however, France and India signed a nuclear cooperation agreement in 2008.[44]

## 3.6. China

China's nuclear program was significantly aided by a massive Soviet effort to help its former communist ally establish a robust nuclear energy program. After relations with Moscow soured, Beijing continued its dual use nuclear work and eventually tested a nuclear weapon on 16 October 1964. During the 1950s and 1960s China believed that the Russian and American efforts to negotiate the NPT were part of a larger plot to maintain nuclear superiority. Chinese attitudes on export controls began to change in the 1970s after the country began to liberalize its economy. According to Jin-Dong Yuan, Phillip Saunders, and Stephanie Lieggi, in an article for the *Nonproliferation Review,* "Over the next two decades, China gradually joined major international, political, economic, and security organizations and institutions and began to take a more critical attitude toward proliferation of weapons of mass destruction."[45]

In the early 1980s, China began to cooperate in nuclear areas with Algeria, Pakistan, and Iran. China's original intent was to raise money to buy Western technology for its own nuclear reactor project, but it soon emerged as a provider of nuclear technology and services.[46] During this time period, China is accused of providing Pakistan with a design for a first generation nuclear weapons design and assisting with Pakistan's early nuclear weapons program.[47]

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43_ See Avner Cohen, *Israel and the Bomb* (New York: Columbia University Press, 1998)

44_ "France-India nuclear cooperation deal," *World Nuclear News*, 30 September 2008, http://www.world-nuclear-news.org/IT_NP_No_nuclear_deal_from_Singhs_Paris_trip_3009081.html.

45_ Jin-Dong Yuan, Phillip Saunders, and Stephanie Lieggi, "Recent Developments in China's Export Controls: New Regulations and New Challenges," *The Nonproliferation Review*, (Fall/Winter, 2002), http://cns.miis.edu/npr/pdfs/93yuan.pdf.

46_ Ibid

47_ U.S. State Department, "The Pakistani Nuclear Program," 22 June 1983, Secret, excised copy, State Department FOIA release, http://www.gwu.edu/~nsarchiv/NSAEBB/NSAEBB114/chipak-11.pdf.

Starting in the mid-1980s, China's export control policy began to change. Beijing concluded a safeguards agreement with the IAEA in 1984 and acceded to the NPT in 1992. China's declaratory export control policy during that timeframe maintained that all Chinese nuclear exports should be used for peaceful purposes, exports should be conditioned on IAEA safeguards (notably not full scope safeguards, but the weaker facility safeguards system), and no re-transfer of nuclear technologies without Chinese approval.

Following revelations in 1995 that Chinese companies sold centrifuge components to Pakistan, China tightened its export controls even further. Beijing introduced legislation governing the export of dual use items and announced that it would not provide assistance for unsafeguarded nuclear facilities.[48] The dual use guidelines borrowed heavily from the NSG's control list. Following the announcement, China joined the Zangger Committee in 1997, but continued with its policy of only requiring limited safeguards for technology transfers.

In 2004, China formally joined the nuclear suppliers group. However, issues still remain. China quietly lobbied against India's NSG waiver, but has since taken advantage of the precedent. China has announced that it intends to sell Pakistan two nuclear reactors, after rebuffing the Pakistani requests since it joined the NSG. The sale violates NSG guidelines, but China argues that the sale is legal because its nuclear cooperation agreement with Pakistan pre-dates its NSG membership.[49]

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48_ Jin-Dong Yuan, Phillip Saunders, and Stephanie Lieggi, "Recent Developments in China's Export Controls: New Regulations and New Challenges," *The Nonproliferation Review*, (Fall/Winter, 2002), http://cns.miis.edu/npr/pdfs/93yuan.pdf.

49_ Mark Hibbs, "The Breach," *Foreign Policy.com*, 4 June 2010, http://www.foreignpolicy.com/articles/2010/06/04/the_breach.

# 4- Turkey and Nuclear Negotiations

## *4.1. NSG Guidelines*

Despite the differing interpretations of the meaning of "restraint", the fact remains that the suppliers have not transferred E&R facilities to states that don't already possess the technology since the 1970s. Moreover, very few states have expressed interest in pursuing E&R facilities. Therefore, the disagreements in the NSG are largely due to differing opinions about the NPT's peaceful use clause, and the extent to which the nuclear weapons states are obligated to assist in the development of peaceful nuclear technology globally. The major suppliers, and the officials weapons states, have taken the approach that the spread of E&R could be interpreted as a not being in the spirit of NPT Article's I and II. Others have argued that limits encroach on Article IV and are contradictory to the spirit of the NPT.

While it appears as if the overt spread of enrichment and reprocessing technologies is unlikely, the major nuclear suppliers remain intent on marketing and selling reactors abroad. Turkey has indicated that it hopes to have 3 nuclear plants built by 2023.[50] Given the evolution of nonproliferation norms, it is likely that future power plants in Turkey will rely on nuclear fuel supplied from abroad. Spent fuel is likely to be returned to the supplier state or transferred to a country currently operating reprocessing facilities for reprocessing and storage. The language in Turkey's current nuclear cooperation agreements reflect NSG supplier guidelines, which allows for a reasoned analysis of the limits and opportunities Turkey will have in the nuclear field moving forward.

## *4.2. Turkey Gets into the Nuclear Business*

Ankara first began to seriously consider developing an indigenous nuclear power program shortly after the Atoms for Peace program was announced. In 1956, Turkey established the Atomic Energy Commission under the auspices of the Prime Ministry to coordinate nuclear research and issue licenses for nuclear power plants.[51] Construction began on Turkey's first nuclear research reactor in 1959 at the Cekmece Nuclear Research and Education Center (Cekmece Nukleer Arastirma

50_ "Turkey to have 23 nuclear units, minister says," *Hurriyet Daily News*, 6 June 2012, http://www.hurriyetdailynews.com/turkey-to-have-23-nuclear-units-minister-says.aspx?pageID=238&nID=22486&NewsCatID=348.

51_ Mustafa Kibaroglu, "Turkey's Quest for Peaceful Nuclear Power," *The Nonproliferation Review*, (Spring/Summer 1997), http://cns.miis.edu/npr/pdfs/kibaro43.pdf.

ve Egitim Merkezi, or CNAEM). The firm American Machine and Foundry (AMF) was chosen to construct a 1-megawatt thermal (MWt) light water pool type research reactor on a turnkey basis. The reactor first went critical in 1962 and operated until 1977. It was replaced in 1982 with a 5 MWt TR-2 research reactor.[52]

Turkey also operates a General Electric built 250 KWt TRIGA Mark II light water reactor at the Ayazaga campus of Istanbul Technical University. The reactor went critical in March 1979 and is fueled with American supplied 20 percent enriched fuel rods. The reactor is used for research, educational purposes, neutron radiography experiments, non-destructive testing using gammagraphy and neutron-activation analysis.

The Atomic Energy Commission opened a second nuclear research facility near Ankara in 1966. The Ankara Nükleer Araştırma ve Eğitim Merkezi (Ankara Nuclear Research and Training Center - ANRTC) oversaw the first studies for the construction of a 300 – 400 MWe heavy water natural uranium power plants and the initial studies into the mining of uranium. The ANTRC was replaced with Sarayköy Nükleer Araştırma ve Eğitim Merkezi (Sarayköy Nuclear Research and Training Center - SANAEM) in 2005.

## *4.3. Nuclear Legislation and Chronology of Nuclear Negotiations*

Between 1972 and 1974, the Turkish Electric Authority carried out and concluded the site selection and studies for 600 MWe nuclear power plant at Akkuyu Bay on Turkey's southern Mediterranean coast.[53] Shortly after the commission issued the site license in 1976, Turkey began negotiating with an international consortium for the supply of nuclear power reactor. Talks broke down after the 1980 military coup.

The Atomic Energy Commission was replaced in 1982 with the Turkish Atomic Energy Authority (Turkiye Atom Enejisi Kurumu - TAEK). The TAEK is authorized to draft and oversee regulations related to nuclear safety and site licensing. In 2002, the Turkish government re-organized the TAEK and expanded its mandate. The TAEK is now affiliated with the Ministry of Energy and Natural Resources. The TAEK's president is appointed by the Prime Minister and oversees the implementation of Turkey's nuclear energy program. Three vice presidents are chosen to assist the president. Together, they oversee the Atomic Energy Commission, an advisory council, and an advisory committee on nuclear safety.[54]

The Atomic Energy Commission is made up of representatives from the Ministries

52_ "Regulatory and Institutional Framework for Nuclear Activities: Turkey," Nuclear Legislation in OECD Countries, Nuclear Energy Agency, 2008, http://www.oecd-nea.org/law/legislation/turkey.pdf.

53_ Mustafa Kibaroglu, "Turkey's Quest for Peaceful Nuclear Power," *The Nonproliferation Review*, (Spring/Summer 1997), http://cns.miis.edu/npr/pdfs/kibaro43.pdf.

54_ "TAEK Organizational Chart," Turkish Atomic Energy Authority, 10 February 2012, http://www.taek.gov.tr/eng/about-us/taek-organization-chart.html.

of National Defense, Foreign Affairs, Energy and Natural Resources, and four faculty members from Turkish universities. The representatives are selected by the Prime Minister to serve four-year terms.[55] The AEC is responsible for drafting budgets, laws, and an annual report for the Prime Minister. Members of the advisory council are appointed by the AEC, and then submitted to the Prime Minster for approval. The advisory council conducts studies assigned to it by the AEC and reports its findings to the AEC during regularly held meetings.

The TAEK oversees research at CNAEM, ANRTC, and SANAEM. Research at CNAEM is heavily focused on the research and development of nuclear reactor and fuel technology.[56] ANRTC's research focuses on nuclear safety and SANAEM's research is focused on medical and industrial uses of nuclear technology.[57]

### 4.3.1. Turkey and Canada's Nuclear Cooperation Agreement

In 1983, Turkey invited seven companies to submit bids for the construction of nuclear power plants. Eventually, Turkey sent three letters of intent to Atomic Energy of Canada, Ltd. (AECL), Kraftwerk Union (KWU) of West Germany, and General Electric (GE) of the United States.[58] Shorty thereafter, talks with KWU and GE broke down due to differences about the financing arrangements. Negotiations with Canada continued, and the two sides eventually agreed to terms on a nuclear cooperation agreement in 1985.[59]

The Parties agreed to cooperate in the following areas:

– The supply of information that includes, but is not limited to,
    - Research and development
    - Health, nuclear safety, emergency planning, and environmental protection
    - Equipment (including the supply of designs, drawings and specifications)
- Uses of equipment, material, and nuclear material (including manufacturing and processes and specifications)
- The supply of material, nuclear material, nuclear fuel, and equipment
- The implementation of projects for research and development as well as for design and application of nuclear energy for use in such fields as agriculture, industry, medicine, and power generation

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55_ "Atomic Energy Commission," Turkish Atomic Energy Authority, 10 February 2012, http://www.taek.gov.tr/eng/about-us/aek.html.

56_ "Cekmece Nukleer Arastirma ve Egitim Merkezi," Turkish Atomic Energy Authority, 10 February 2012, http://www.taek.gov.tr/eng/cnaem.html.

57_ "Sarykoy Nuclear Research and Training Center," Turkish Atomic Energy Authority, 10 February 2012, http://www.taek.gov.tr/eng/sanaem.html.

58_ Mustafa Kibaroglu, "Turkey's Quest for Peaceful Nuclear Power," *The Nonproliferation Review*, (Spring/Summer 1997), http://cns.miis.edu/npr/pdfs/kibaro43.pdf.

59_ The Turkish Parliament ratified the agreement on 29 June 1986. "Agreements," Turkish Atomic Energy Authority, 27 February 2012, http://www.taek.gov.tr/eng/international/agreements.html.

- Licensing arrangements and the transfer of patent rights
- Access to and use of equipment
- The rendering of technical assistance and services, including exchange of experts and specialists
· Visits by scientists
· Technical training
· The exploration for and development of uranium and thorium resources
· Cooperation specific to the various aspects of the advanced nuclear fuel cycle

The Parties agreed to place limits on the transfer of enrichment and reprocessing technologies. While not specifically prohibited, the agreement specifies that Turkey would be required to notify Canadian authorities for up to twenty years if Turkish companies developed or designed indigenous enrichment and reprocessing capabilities from Canadian supplied technology. The agreement also mandates that Turkey not enrich uranium above 20 percent or reprocess spent fuel rods.

The agreement's nonproliferation provisions are built around the technological traits of the CANDU heavy water moderated reactor. The CANDU reactor produces larger quantities and higher concentrations of PU-239 than light water reactors (LWR). While spent fuel from LWRs can also be used for plutonium production, the quantity and concentration of Pu-239 is much less.[60] In a specific reference to the proliferation dangers of the CANDU reactor, the agreement states that the sale of a reactor capable of producing significantly more than 100 grams of plutonium every year is legal. One other feature of some heavy water reactors is that they can be refueled while operating. This feature allows a potential proliferator to "burn" the fuel rod for less time. The shorter "burn" time maximizes the concentration of weapons grade PU-239 in the fuel rod.[61] In order to help prevent this, the agreement states that the supply of equipment to re-fuel the reactor online is not normally made available.

These efforts to prevent proliferation were matched with a series of articles enumerating Turkey's right to pursue peaceful nuclear technology and research. Specifically, the agreement calls for the exchange of data and the training of scientists. It also specifies that transferred facilities and technologies cannot be re-transferred to third parties, and that site security needs to be in accordance with specific provisions outlined in Annex E of the agreement. The parties agreed that the IAEA would be responsible for inspecting Turkish nuclear facilities. In the event that the IAEA could not conduct inspections, the parties agreed to conclude a separate protocol that mimics the inspections and techniques called for in Turkey's 1981 full scope safeguards agreement.

60_ Victor Gilinsky, Marvin Miller, and Harmon Hubbard, "A Fresh Examination of the Proliferation Dangers of Light Water Reactors," Nonproliferation Education Center, 22 October 2004, http://www.npolicy.org/files/20041022-GilinskyEtAl-LWR.pdf.

61_ "Plutonium Production," Federation of American Scientists, Special Weapons Primer, updated 20 June 2000, http://www.fas.org/nuke/intro/nuke/plutonium.htm.

## 4.3.2. Canada and Turkey's Nuclear Negotiations

While the two sides were negotiating the specific terms of their nuclear cooperation agreement, Atomic Energy of Canada Limited (AECL) and the Turkish government were amid negotiations for the sale of a 600 MW pressurized heavy water reactor. Progress slowed, however, when Turkey raised the financing requirement for the three foreign firms competing to build the country's first power plant. In the original offer, Canada's AECL had guaranteed 85 percent of the financing for construction.[62] Turkey then changed the tender terms and asked that AECL provide 100 percent financing and accept a build, operate, and transfer model (BOT).

The BOT model has never been used for nuclear reactor construction. It calls for the foreign firm to pay for the cost of construction, operate the reactor for a specific period of time, recoup expenses from guaranteed electricity sales, and then transfer the reactor to the importing state in exchange for a share of total electricity sales. At the time, AECL asked that "risk coverage" be written into the contract, as well as a guarantee that Turkey's electricity purchase would be in dollars and sufficient enough to cover the debt of service.[63] In order to meet Turkey's financing requirements, AECL turned to Canada's Export Development Corp. to help raise money for construction.[64] Nevertheless, the two sides could not agree and the tender was eventually cancelled.

In 1996, Turkey once again invited foreign suppliers to submit bids for the construction of a turnkey nuclear reactor at the Akkuyu site.[65] However, the postmodern coup complicated Turkey's tender process.[66] After seven missed deadlines, the Turkish government cancelled the tender in 2000. At the time, Turkey was amid a severe financial crisis and the terms of their International Monetary Fund economic program precluded the government from making the necessary financial guarantees.[67]

In 2008, the current government once again solicited proposals for a nuclear tender. Despite showing some initial interest, AECL opted to not submit a proposal.

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62_ Ann Taboroff, "The Turkish Electrical Authority has Raised the Financing Requirement," *Nucleonics Week,* 3 May 1984.

63_ Ann Taboroff and Ann MacLachlan, "AECL ready to consider Turkish government's terms for Akkuyu Project," *Nucleonics Week*, 22 November 1984.

64_ "Financing key to reactor sale to Turkey," *The Financial Post,* 17 August 1985.

65_ "Turkey's renewed plans for nuclear plant," *FT Energy Newsletters,* 4 October 1996.

66_ Mark Hibbs, "Turkey pulls back on reactor, Europe's vendors skeptical," *Nucleonics Week*, 23 May 1996.

67_ "Turkey postpones nuclear plant project due to financial hardship," Agence France Presse, 21 April 2000.

### 4.3.3. Turkey and Argentina's Nuclear Cooperation Agreement

In May 1988, Turkey and Argentina signed a 15-year nuclear cooperation agreement. At the time of signing, Argentina was not a member of the NSG, which explains the Agreement's language. The Parties agreed to cooperate in the following areas:

- Research, development and technology for nuclear research and power reactors
- Installation, operation and maintenance of nuclear power plants and fuel cycle facilities, including production of fuel elements.
- Industrial production of nuclear material and equipment including services related to maintenance
- Exploration and exploitation of natural resources (i.e. uranium and thorium)
- Management of radioactive waste
- Production of radioisotopes
- Environmental protection and nuclear licensing
- Radioactive waste management
- Fundamental and applied research in the nuclear energy field, and other research, development and development of peaceful nuclear applications.

The Parties agreed to facilitate scientific cooperation through an exchange of experts, assistance and education, stipends and scholarship for research and study, the setting up of joint working groups, the delivery of equipment, and the exchange of information relating to the areas of cooperation. The agreement explicitly states that all material and information transferred is for peaceful uses only. However, it does not place any limits on enrichment or reprocessing equipment. There is also no reference to enrichment above twenty percent or the reprocessing of spent fuel.

The absence of specific limits on enrichment and reprocessing is reflective of Argentina's approach to the global efforts to control the spread of nuclear technology. Beginning in the 1960s, Argentina rebelled against the global effort to curb proliferation. At the time, Buenos Aires refused to sign the 1963 Partial Test Ban Treaty, the 1967 Outer Space Treaty, the 1967 Tlatelolco Treaty for the Prohibition of Nuclear Weapons in Latin American, the 1968 NPT, and the 1971 Seabed Treaty.[68] Buenos Aires placed a strong preference on self-sufficiency, and thus sought to purchase natural uranium – i.e. heavy water – reactors from AECL and Siemens. Officials argued that the pursuit of heavy water reactor technology would allow Argentina to use it own domestic uranium reserves, rather than import enriched nuclear fuel from abroad. Given Argentina's nuclear history, the agreement's provisions are not particularly surprising. In the past, Ankara has also explored the idea of contracting with foreign suppliers for heavy water reactors that would eventually use Turkey's own reserves of natural uranium.

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68_ Jacques Hymans, *The Psychology of Nuclear Cooperation: Identity, Emotions, and Foreign Policy* (Cambridge: Cambridge University Press, 2006), pp. 141 – 171.

The Parties agreed to consult each other about the implementation of safeguards. At the time, Argentina had not yet concluded a safeguards agreement with the IAEA and had been steadfast in its opposition to strict limits for technology transfers. The agreement says, "both Parties shall, when it considered necessary, conclude with the International Atomic Energy Agency agreements on safeguards." At the time Turkey had already concluded a safeguards agreement, so it can be assumed that Ankara would have invited the IAEA to inspect facilities if any had been transferred.

## 4.3.4. Turkey and Argentina's Nuclear Reactor Negotiations

Turkey and Argentina's Empresa Nuclear Argentina de Centrales Electricas (CNEA) began negotiations for the sale of a 380 MWe Argos pressurized heavy water reactor in 1988.[69] Turkey also expressed interest in a 25 MWe CAREM-25 light water reactor developed by Argentina's state owned Investigaciones Aplicadas (Invap).[70] In October 1990, Turkey and Argentina agreed to form a joint engineering company to oversee construction of the CAREM-25. According to *Nucleonics Week*, Argentina agreed to provide Turkey with the nuclear steam and supply system (NSSS) and basic and detailed engineering for the balance of plant, construction management, and regulatory expert.[71] In exchange, Turkey agreed to finance the construction of one prototype in Argentina and a second in Turkey.[72]

Argentina claimed that the reactor could be built for less than one hundred million U.S. dollars, and sought to market it as a cost effective alternative for developing nations intent on exploiting nuclear power. At the time the CAREM-25 had never been built and industry experts criticized the cost assessments and optimistic construction timetable.

Through out the negotiations, Argentina's controversial nuclear history added to speculation that Turkey was seeking to acquire the full nuclear cycle in order to have the capability to produce nuclear weapons. Professor Yalcin Sanalan, the former director of the TAEK, alluded to these proliferation concerns when he said, "the CAREM-25 was too small for electricity generation and too big for research or training, however, very suitable for plutonium production."[73] Sanalan worried that Western concerns about proliferation could stunt Turkey's nuclear plans. Ankara eventually concluded that it was in its best interest to cancel deal. To date, no progress has been made on implementing the deal and Argentina has not been involved in any of Turkey's subsequent nuclear tenders.

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69_ Eric Kessler, "Argentina says Nuclear Accord with Turkey sets stage for exports," *Platts Nucleonics Week*, 12 May 1988.

70_ Richard Kessler, "Argentina said to be near deal with Turkey for 25-MW LWR," *Platts Nucleonics Week*, 8 May 1988

71_ Richard Kessler, "Argentina and Turkey to form nuclear A/E to build small PWRs," *Nucleonic Week*, 25 October 1990.

72_ Ibid

73_ According to Mustafa Kibaroglu, "Turkey's Quest for Peaceful Nuclear Power," *The Nonproliferation Review*, (Spring/Summer 1997), http://cns.miis.edu/npr/pdfs/kibaro43.pdf.

### 4.3.5. Turkey and South Korea's Nuclear Cooperation Agreement

In 1999, the national utility Korea Electric Power Corp (KEPCO), in conjunction with Korea Heavy Industries and Construction, Daewoo Corp and Atomic Energy of Canada Ltd, submitted a tender for the construction of a 1,400 MWe reactor at the Akkuyu site in Turkey.[74] Shortly thereafter, Turkey and South Korea concluded a nuclear cooperation agreement. The areas of cooperation are:

- Basic and applied research and development with respect to the peaceful use of nuclear energy
- Research, design, construction, operation and maintenance of nuclear power plants and research reactors
- Utilization of research reactors and particle accelerators
- Exploration and ore processing of nuclear material and handling, transportation, manufacture and supply of nuclear fuel elements to be used in nuclear power plants and research reactors
- Production and application of radioactive isotopes in industry, agriculture, medicine, and biotechnology
- Nuclear safety, radiation protection, environment protection, radioactive waste management
- Nuclear safeguards and physical protection

The Parties agreed to facilitate cooperation through the exchange of scientific personnel, data, and technical information. South Korea also agreed to provide consultancy services, and set up joint working groups to carry out studies and projects in fields of mutual interest.

The agreement states that all transferred materials shall not be used for an explosive device or other military uses. The Parties agreed that Turkey shall not enrich above twenty percent or reprocess spent fuel rods, unless the two sides agree beforehand. Turkey is required to implement specific physical protection measures in accordance with IAEA INFCIRC/225. The Parties agreed that the IAEA is responsible for inspecting transferred technology and material and that none of the material can be retransferred.

### 4.3.6. Turkey and South Korea's Nuclear Reactor Negotiations

In 2008, KEPCO signed a Memorandum of Understanding (MOU) with ENKA – Turkey's largest construction firm – to help facilitate the sale of nuclear reactors.[75] However, KEPCO quickly announced that it would not submit a bid

74_ "South Korea; Nuclear; KEPCO bids for Turkey Nuclear Project," *Modern Power Systems*, 31 January 1999.

75_ "KEPCO Eyes 1st Atomic Power Plant in Turkey," *Korea Times*, 27 January 2008.

for construction because Turkey continued to insist on the BOT financing model and would not grant loan guarantees. In 2009, KEPCO and Turkey discussed the sale of two APR 1400 light-water reactors at the Sinop site on Turkey's Black Sea coast.[76] The negotiations eventually resulted in the signing of a MOU on nuclear cooperation in June 2010.[77] Once again, however, disputes relating to Turkey's BOT financing terms derailed the deal. This time around, the two sides failed to agree on the price of guaranteed electricity sales. South Korea is reported to have favored a higher price per kilowatt-hour, while Turkey sought to keep prices low.[78]

The information suggests that KEPCO had agreed to a build, own, and operate (BOO) arrangement, but had sought certain guarantees from the Turkish government to minimize financial risk. The BOO scheme stipulates that KEPCO would provide 100 percent financing for construction, recoup its investment through guaranteed electricity sales, and maintain a majority ownership stake in the reactor. KEPCO reportedly asked the Turkish government to become the largest shareholder in the project, in order to reduce the risk and financial burden on KEPCO.[79]

In May 2011, the talks appeared to get a boost when South Korea decided to drop its demands for Turkey to provide treasury loans for construction.[80] Nevertheless, reports to date do not suggest that the two sides have agreed on the guaranteed price per kilowatt hour of electricity, nor have any details about site licensing at Sinop been released.

## 4.3.7. Turkey and France's Nuclear Cooperation Agreement

France and Turkey signed their nuclear cooperation agreement on 21 September 1999 and its was ratified on 25 February 2011. The Parties agreed to cooperate in the following areas:

- Basic and applied research
- Agriculture, medicine, and industry uses of nuclear energy
- The use of nuclear energy for electricity generation
- Nuclear safety, radiation protection, and environmental protection
- Nuclear fuel and waste management
- Exploration and exploitation of uranium and thorium reserves

In the event that the parties come to terms for the transfer of material or technology, France and Turkey have agreed to personnel exchanges and training,

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76_ "S.Korea, Turkey in talks on nuclear power deal," *Trend Daily Economic News,* 27 December 2009.

77_ "S. Korea, Turkey sign nuclear power accord," Agence France Presse, 15 June 2010.

78_ Sarah Tzinieris, "Turkish Nuclear Plant Project Falters over Pricing Disagreement with South Korea," *IHS Global Insight,* 17 November 2010.

79_ Ibid.

80_ Umit Enginsoy, "South Korea revisits Turkish nuclear power plant bid," *Hurriyet Daily News,* 26 May 2012, http://www.hurriyetdailynews.com/south-korea-revisits-turkish-nuclear-power-plant-bid.aspx?pageID=238&nID=21620&NewsCatID=348.

joint research and development activity, and the co-organization of conferences and symposia on nuclear technology. The agreement specifies that the details of the scientific exchanges will be agreed upon separately. To facilitate implementation, the Parties agreed to establish a Joint Liaison Group, as well as, a Joint Expert Group to discuss specific issues, and how they can best be delegated.

The agreement has a provision mandating that Turkey not enrich above twenty percent or reprocess spent fuel rods. The agreement states that the IAEA would be counted on to carry out inspections to ensure peaceful use. The transfer of nuclear technology or material to third parties is prohibited, unless the two sides agree beforehand. The Parties agreed that transferred material be stored in accordance with the provisions of IAEA INFCIRC/225.

## 4.3.8. Turkey and France's Nuclear Negotiations

Despite the agreement, the two sides have never been able to agree on terms for the sale of French nuclear technology. In 1983, Framatome submitted a proposal for the construction of a 900 MW reactor at the Akkuyu site.[81] However, Turkey quickly turned to GE, KWU, and AECL and negotiations were abandoned. In 1996, Turkey invited Framatome, and seven other suppliers, to submit a tender for a reactor at the Akkuyu site.[82] Eventually, Framatome and Siemens formed a joint venture and submitted a nulcea tender.[83] Former Turkish Prime Minister Necmetting Erbakan is reported to have been more in favor of the Canadian proposal because of his desire to use Turkey's domestic uranium reserves to fuel the reactor. Erbakan's interest in developing a self-sufficient nuclear program, combined with the terms of the 1996 tender, effectively eliminated the Framatome-Siemens venture from contention.[84] As mentioned earlier, the tender was eventually cancelled because of financing problems in 2000.

In 2007, French nuclear company AREVA cautiously considered submitting a bid for Ankara's latest nuclear tender. AREVA and the other major suppliers were hesitant to get involved in drawn out negotiations unless Turkey reformed its nuclear laws and put forward a more realistic timetable for construction.[85] Despite having some interest in selling Turkey a 1,600 MWe European Pressurized Reactor (EPR),[86] AREVA eventually decided not to submit a tender.

81_ "Framatome and Alshtom-Atlantique have submitted a technical proposal to Turkey," *Nucleonics Week,* 15 September 1983.

82_ "Ankara invites bids for first reactor at Akkuyu by end-June 1997," *FT Energy Newsletters – European Energy Report,* 30 December 1996.

83_ "Turkey extends tender for nuclear power station," *FT Energy Newsletters – European Energy Report,* 27 January 1997.

84_ Mark Hibbs, "NPI sees little hope, AECL edge Turkish nuclear project," *Nucelonics Week*, 1 May 1997.

85_ Mark Hibbs, "Areva and AECL react cautiously to Turkey's bid for reactors," *Platts Nucleonics Week*, 8 February 2007.

86_ Ann MacLachlan, "Areva wants to sell EPRs to Turkey, but awaiting invitation to bid," *Platts Nucleonics Week,* 21 February 2008.

In January 2011, a team of representatives from AREVA and GDF Suez Energy held preliminary discussion for the construction of a nuclear reactor at the Sinop site. At the time, however, Turkey's December 2010 agreement with Japan's Toshiba prevented more detailed discussions for a period of three months.[87] After the agreed upon moratorium expired, no details about negotiations have been reported.

The nuclear cooperation between Turkey and France has visibly been hindered by the Turkey sceptic policies of the Sarkozy administration. It was politically impossible for a French company to partipate in the large nuclear tenders of Turkey. The change in administration in France is set to change these conditions. Going forward, AREVA may take part in the future of Turkey's nuclear program.

### 4.3.9. Turkey and the United States' Nuclear Cooperation Agreement

Despite close relations and long history of nuclear cooperation, Turkey and the United States struggled to agree on the terms and conditions of a nuclear cooperation agreement. Negotiations began in 2000, but slowed after the United States began advocating for its nuclear partners to forgo enrichment and reprocessing. Turkey - which has not ruled enrichment or reprocessing - refused to agree to provisions that limited access to nuclear technology.

The negotiations took place against the backdrop of a strong effort by the George W. Bush Administration to prod members of the Nuclear Suppliers Group to ban the transfer of enrichment and reprocessing equipment to states that do not already have plants in operation.[88] Turkey resisted these efforts, saying that there should be no provision against the transfer of E&R technology as long as the receiving state is in good standing with the IAEA.[89]

After six years of negotiations, the Turkish parliament ratified the nuclear cooperation agreement in 2006. The final document does place some limits on the enrichment and reprocessing of U.S. origin fissile material, but noticeably does not contain provisions that ban the practice outright. Instead, the two sides opted to mimic the provisions in all but one of Turkey's other nuclear cooperation agreements. The Parties agreed to cooperate in the following areas:

- Development, design, commissioning, operation, maintenance, and use of reactors, reactor fuel fabrication, reactor experiments, and decommissioning
- The use of material in physical and biological research, medicine, agriculture, and industry

87_ "Turkey discussing cooperation with French nuclear companies," *Platts Nucleonics Week*, 13 January 2011.

88_ Fred McGoldrick, "Limiting Transfers of Enrichment and Reprocessing Technology: Issues, Constraints, Options," Report for Belfer Center for Science and International Affairs, Harvard Kennedy School, May 2011, http://belfercenter.ksg.harvard.edu/publication/21010/limiting_transfers_of_enrichment_and_reprocessing_technology.html?breadcrumb=%2Fexperts%2F368%2Fmatthew_bunn%3Fpage%3D3.

89_ Ibid

· Fuel cycle studies of ways to meet future world wide civil nuclear needs, including multilateral approaches to guaranteeing nuclear fuel supply and appropriate techniques for management of nuclear waste

· Safeguards and physical protection of materials, equipment, and components

· Health, safety, and environmental consideration related to nuclear energy

· Assessing the role nuclear power may play in national energy plans

To address the E&R issue, the parties agreed to discuss ways to universalize the nuclear fuel cycle, so as to guarantee aspiring nuclear states nuclear fuel for future reactors. The agreement obligates Turkey not to further enrich U.S. origin fissile material or alter in form or content, except in the case of reactor irradiation, spent nuclear fuel, unless the parties agree beforehand.

The Parties agreed that all U.S. origin fissile material transferred to Turkey would be low enriched uranium, except if the parties amend the agreement or if the HEU is intended to produce medical radioisotopes. If HEU or weapons usable plutonium is transferred, the amount shall not exceed the needs for research or the continuous operation of a reactor. However, the transfer of HEU targets or other special nuclear materials for radiation detectors are not bound by these restrictions.

The agreement, like all of the others, specifically mentions that the material transferred will not be used for nuclear weapons production. The U.S. agreement also mentions that none of the transferred material will be used for weapons research. To ensure compliance, the agreement specifies that the IAEA is responsible for inspections, in accordance with Turkey's safeguards agreement. The parties are also obligated to establish a method of accounting in accordance with IAEA INFCIRC/153 (corrected), to ensure control and proper accounting and storage of all material transferred. Moreover, both Parties agreed to apply physical protection measures in line with IAEA INFCRIC/22.

## 4.3.10. Turkey and the United States' Nuclear Reactor Negotiations

Turkey and U.S. nuclear companies have never been able to reach terms for the sale of nuclear power reactors. Like other major suppliers, U.S. nuclear companies General Electric and Westinghouse have been involved in most, if not all, of Turkey's nuclear tenders. In 1983, General Electric, AECL and West Germany's Kraftwerk Union (KWU) signed a letter of intent for the construction of three nuclear power reactors at two different sites in Turkey. However, in December 1983, *Nucleonics Week* reported that the Turkish government had altered the terms of the original tender. The Turkish government requested that the three suppliers now compete for the construction of just one power plant at the Akkuyu site. At the time, General Electric was negotiating for the sale of a reactor at the Sinop site. The Turkish request voided the original letters of intent and called for another round of bidding by the three potential suppliers.[90]

90_ "The Contest for the Sale of a Nuclear Reactor to Turkey is Wide Open," *Nucelonics Week*, 15 December 1983.

In October 1984, Westinghouse joined with Mitsubishi Heavy Industries, Ltd, and approached Turkey about bidding on the Akkuyu project.[91] After months of negotiations, the Turkish government asked the Westinghouse consortium, AECL and KWU to pay $1 billion up front in construction costs and another $1 billion in interest for a reactor at the Akkuyu site. The Turkish government would then pay back the investment with guaranteed electricity sales for fifteen years. Ankara also indicated that it would not nationalize the plant for the duration of the contract.

At the time, Turkey was reportedly using Westinghouse for leverage, even though the Westinghouse – Mitsubishi consortium's bid was reportedly $200 million less than both AECL and KWUs.[92] Nevertheless, Turkey never sent Westinghouse a formal letter of intent notifying them of the financing changes. Soon thereafter, the talks with Westinghouse ended.[93]

In 1997, Turkey once again invited international suppliers to bid on a nuclear tender. At the outset, Ankara indicated that it would abandon its insistence on the BOT financing model in favor of a turnkey reactor project.[94] Turkish officials specified that the reactor be either a pressurized light or heavy water reactor because they had a long history of use, a proven track record, and had been licensed in their country of origin.[95] The tender insisted that the supplying country construct one or more reactors with a maximum power output of 1,400 MW. Turkey also wanted the bidding company to include an option for the construction of more power stations. Turkey insisted on 100% vendor financing, and once again pursued bids from AECL, Siemens (which had acquired Kraftwerk Union after German re-unification), and Westinghouse.

It was reported that the Refahyol government of the former Prime Minister Necmettin Erbakan had favored Canada's CANDU reactor, but after the change in government Westinghouse moved to the top of Turkey's preferred vendor list. The new Anasol-D government led by Mesut Yilmaz had for instance extended the bidding process twice to accommodate Westinghouse over the objections of AECL and Siemens,.[96]

Turkey pushed back a final decision on the tender in March 1998 because of delays with the tender's technical analysis. A final decision on the project was again delayed in February 1998. The government eventually cancelled the tender in July 2000.[97] All together, seven self-imposed deadlines had passed. At the time, Turkey

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91_ "Westinghouse, Mitsubishi launch joint contract bid," Nuclear News, October 1984.

92_ Ann Taboroff, "Turkish Government Trying to Negotiate Akkuyu Financing by December," *Nucleonics Week,* 18 October 1984.

93_ Ray Silver, "Akkuyu financing guarantees being sought from three nations," *Platts Nucleonics Week*, 19 December 1985.

94_ Mark Hibbs, "World Finance, Regional Gas Market keys to Turkey's Akkuyu Project," 28 August 1997.

95_ Ibid

96_ Mark Hibbs, "Turkey's pro-U.S. regime extends bidding, which may boost Westinghouse bid," *Nucleonics Week*, 4 September 1997.

97_ Mark Hibbs, Ann MacLachlan, and Ray Silver, "Turkey drops Akkuyu project, citing IMF Economic Program," *Platts Nucleonics Week*, 27 July 2000.

was amidst a severe economic downturn, natural gas was a more attractive option, and the government decided to pass on financing an expensive turnkey nuclear project.

## 4.3.11. Turkey and Russia's Nuclear Cooperation Agreement

In August 2009, Turkey and Russia concluded negotiations on a nuclear cooperation agreement. Specifically, the Parties agreed to cooperate in the following areas:

- Research and development in the field of peaceful use of nuclear energy
- Controlled thermonuclear fusion
- Engineering, construction, commissioning, operation, modernization, testing, maintenance and decommissioning of commercial and research nuclear reactors
- Supply of nuclear materials, particularly, fuel assemblies and equipment for commercial and research nuclear reactors as well as nuclear fuel cycle services
- Prospecting and mining of uranium deposits; development and production of components and materials for commercial and research nuclear reactors
- Regulatory activity in the field of nuclear and radiation safety; development of improved and innovative reactor and nuclear fuel cycle technologies
- Nuclear and radiological safety, environment protection, emergency response, treatment of radioactive waste
- Recording and control of nuclear and radioactive materials and physical protection of nuclear and radioactive materials, facilities and sources of radiation
- Production and use of radioisotopes.

The cooperation is to be implemented by the pursuit of mutually agreed upon projects, the establishment of joint working groups, the exchange of data and personnel, the organization of conferences, the training of personnel, and consultation on specific problems. Currently, forty-nine Turkish students are studying nuclear related disciplines at Mephi University in Moscow. The students will eventually be part of the first wave of Turkish citizens tasked with assisting in the operation of the Akkuyu power plant.[98] To control and coordinate the impressive number of activities stipulated to in the agreement, the parties have agreed to hold consultation on matters of mutual interests, and establish a Joint Coordination Committee. The procedures for exchange are to decided by the Committee in accordance with national legislation in Russia and Turkey.

The Parties agreed that Turkey shall not enrich Russian origin fuel above twenty percent or reprocess spent fuel rods. Transferred dual use technology, including reproductions, is not to be used by either party for the manufacture of nuclear explosives. In addition, the agreement states that no material or equipment for

98_ "Turkish students learning nuke know-how in Russia," Hurriyet Daily News, 26 March 2012, http://www.hurriyetdailynews.com/turkish-students-learning-nuke-know-how-in-russia.aspx?pageID=238&nID=16804&NewsCatID=348.

reprocessing or enrichment will be transferred to third parties, unless the Parties agree beforehand. Russia is obligated to provide Turkey with fuel rods for its future reactor and take back the spent fuel once it has cooled sufficiently in on-site nuclear fuel ponds. Both sides agreed that the facilities for the chemical reprocessing, uranium enrichment, heavy water production, as well as, uranium enriched above twenty percent will not be transferred.

The agreement obligates Turkey provide site security in line with IAEA INFCIRC/225 and to ensure that any material transferred from Russia is not sent to third parties. The facilities transferred will be monitored by Turkey's IAEA safeguards agreement to ensure compliance. Responsibility for nuclear damage shall be defined in implementing arrangements by authorized authorities from both parties.

## 4.3.12. Turkey and Russia's Nuclear Negotiations

In May 2010, Turkey and Russia agreed on the terms for the construction of four nuclear power reactors at the Akkuyu site. The $20 billion dollar agreement is the first to use the build, operate, and own format. Under the terms of the agreement, Rosatom will provide 100 percent equity through a Turkish subsidiary set up to own and operate the plant.[99] 70 percent of the power produced from two of the units will be sold to the Turkish market at 12.35 us-cents per kilowatt-hour for 15 years after commissioning.[100] 30 percent of the power produced from the third and fourth reactors will be sold to the Turkish market, while the remaining power will be sold on the international market for competitive prices.

At the end of the 15 year period, Rosatom will give twenty percent of the profits to the Turkish government. The reactor will majority Russian owned, but a 49 % local ownership is possible. Rosatom estimates that construction will start by 2014. The first reactor is scheduled to go critical in 2019. Reactors two, three, and four are scheduled to go critical in year intervals thereafter.[101]

99_ "Nuclear Power in Turkey," World Nuclear Association, April 2012, http://www.world-nuclear.org/info/inf128-nuclear_power_in_turkey.html.

100_ David O'Byrne, "Akkuyu plant construction to begin in 2011, says Turkish energy ministry," *Platts Nucleonic Week*, 27 May 2010.

101_ Rosatom: Projects, http://www.rosatom.ru/wps/wcm/connect/rosatom/rosatomsite.eng/investmentstrategy/projects/.

# 5- Export Control Guidelines and Turkey's Nuclear Future: Recommendations for the Future

Turkey's numerous nuclear cooperation agreement all share similar provisions about the scale and scope of peaceful nuclear cooperation. All outline a desire to cooperate on nuclear power and research reactor maintenance, operation, decommission and safety, the mining of uranium and thorium, and provide the legal authority to transfer nuclear reactor technology. All agreements specify using scientific exchanges and material transfers to help bolster Turkey's radioisotope production and research. In all cases, the parties agreed to exchange data and scientific personnel, hold regular symposiums and meetings, and collaborate on joint projects. These provisions are emblematic of NPT Article IV and help shed some light on how the suppliers envision their NPT obligations.

The agreements are also written to make extremely difficult the misuse or diversion of foreign origin fissile material for nuclear weapons production. All specifically mention that none of the material or technology will be used for non-peaceful uses. In all but one of the agreements, there are specific provisions against the enrichment of uranium above 20 percent and the reprocessing of spent fuel. These provisions are emblematic of NSG guidelines. Notably, in all but one of the agreements, the suppliers do not specify the extent to which they are willing to transfer E&R technologies. Instead, vague language referring to elements of the fuel cycle is used.

The one exception is the Turkish – Argentinian nuclear cooperation agreement. The agreement was signed before Argentina joined the NSG and reversed many of its decades old nuclear policies. While little progress was made in implementing the deal, the agreement specified cooperation on the front end of the fuel cycle, and the production of small reactors that had questionable value for large-scale electricity production. Nevertheless, the agreement still had specific provisions relating to the non-diversion of fissile material, and an explicit clause barring the manufacture of nuclear weapons. However, the terms of the agreement were not in line with the NSG and established nonproliferation norms.

In all cases, the IAEA is counted on to ensure that material is not being used for non-peaceful uses. The agreements specifically reference Turkey's 1981 full scope safeguards agreement as the main enforcement mechanism, and have separate provisions that call for the conclusion of a bilateral safeguards agreement if it is found that the IAEA cannot perform its duties. In addition, Turkey's decision to sign the additional protocol, which allows the IAEA far greater authority and powers to inspect nuclear and nuclear related facilities, makes even more remote the idea that Ankara could or would divert material for weapons production.

Turkey should expect to continue to receive lots of interest from foreign companies eager to sell Ankara power reactors. However, it is unlikely that supplier states will agree to sell Turkey E&R facilities. Therefore, Ankara should seek to find a middle ground between its position that all countries in good standing with the IAEA should retain their right to pursue E&R, and the prospect that the supplier states aren't likely to break with the established norms of discouraging the sale of sensitive fuel cycle facilities. If one uses Turkey's nuclear negotiations with Russia as a baseline, it appears that Ankara has unofficially been pursuing a policy of relying on fuel guarantees and take back provisions. While not willing to acquiesce to UAE style provisions, Turkey could help alleviate some lingering concerns about its nuclear intentions by clarifying its future fuel cycle intentions. Ankara should release a comprehensive strategy paper[102] detailing Turkey's nuclear ambitions, how it plans to fuel those reactors, the current plans for dealing with waste and spent fuel, and the conditions in which Turkey would consider pursuing E&R.

Ankara should match these efforts with a more proactive effort to negotiate bilateral agreements for the exchange of experts and the training of students in nuclear sciences. Ankara should also strive to ensure that future reactor sales are not "black boxed" so as to ensure that technology transfer will "spill over" and have residual effects on Turkey's current nuclear industry. However, these efforts appear to be complicated by the decision to accept the BOO arrangement for reactor sales. According to the Turkish-Russian agreement, the reactor that will be built in Turkey will be owned and operated by Russian personnel. Even if a Turkish company were to acquire a percentage of the company operating the reactor, it is unclear whether or not they will receive access to the design information for reactor technology. Moreover, it is unclear what role the Turkish students currently being trained in Moscow will have at the reactor site. While there are certainly some safety reasons for the Turkish decision, a clearer sense about a gradual transition to Turkish operation would help clarify some of the benefits that Turkey will receive from the technology transfer. In particular the uncertainties related to whether in the middle or long run, a Turkish company will end up taking part in the operation of the Akkuyu power plant clouds the technology benefits that Turkey could derive from this large investment.

The issues with the BOO are indicative of a larger problem that has plagued Turkey's quest for nuclear power. Ankara's difficulties are largely a result of its continued insistence on the BOT and BOO financing model. Suppliers have been wary of the insistence that the supplier recoup expenses through artificially low guaranteed electricity sales. While Turkey's nearly six decade long quest for nuclear power reactors has recently had some success, the overall pattern suggests that government will have a difficult time meeting its self imposed goal of building additional nuclear power plants by 2023 with the same investment model.[103] In order for Turkey to expand its nuclear energy industry, history suggests that Ankara should alter its approach to the nuclear tender process and consider following the more traditional turnkey approach.

In addition, the government should begin a concerted effort to explain how and why nuclear energy benefits Turkey as a whole. These efforts should not only be limited to the benefits of power rectors, but how the technology transferred and the skills gained from dual operation can help Turkey further develop its nuclear medicine and agricultural sectors. These initiatives should be coupled with a state led effort to bring a clearer sense of how Turkey intends to utilize the skills learned to benefit society.

102_ The paper of Hasan Saygın in this compilation deals more extensively with these issues.

103_ "Turkey to have 23 nuclear units, minister says," *Hurriyet Daily News,* 6 June 2012, http://www.hurriyetdailynews.com/turkey-to-have-23-nuclear-units-minister-says.aspx?pageID=238&nID=22486&NewsCatID=348.

# Section IV
# Turkey's Nuclear Fuel Cycle Strategy

# IV

Hasan Saygın

# Executive Summary

The nuclear fuel cycle comprises a series of industrial processes which involve the production of electricity from uranium fuel in nuclear reactors. It comprises several stages, extending from uranium mining to the final storage of used fuels and waste. These stages may vary, depending on design and type of reactor and whether spent fuels are reprocessed. The most commonly used nuclear fuel cycle is the "Open Fuel Cycle", also named the once-through cycle, since it uses each uranium-based fuel element only once. Spent fuel assembly is then taken out from the reactor after a certain working period and stored. However, the "Closed Cycle", in which spent fuel is reprocessed and recycled, is becoming increasingly used in some European countries and Japan. This paper examines the potential long term strategies regarding the front end and back end of the nuclear fuel cycle in Turkey in the light of the international conjuncture. A discussion about the advantages and disadvantages of reprocessing versus storage is undertaken in order to contribute to raising awareness among the Turkish public opinion about the different options for the long term management of waste.

### *The Nuclear Fuel Cycle*

The nuclear fuel cycle starts with uranium exploration and ends with disposal of the materials used and generated during the cycle. The series of industrial processes related to the nuclear fuel cycle can be subdivided into three, as the front-end, irradiation or nuclear power reactor operation and the back-end. The front-end of the fuel cycle comprises the stages before irradiation of the fuels whereas the back-end begins with the discharge of spent fuels from the reactor.

### *Options for Turkey and a General Decision Analysis*

While switching to nuclear power, a country is faced with a number of important questions such as the types of reactors and fuels to be used, and the methods to be selected for long term waste storage. The most critical decisions are about:

- The choices of the type of fuel cycle (open, closed or partially closed) and spent fuel management strategy (the choice of the type of nuclear fuel cycle is vitally important since it will have major and very long term impact).

- The establishment of its own fuel cycle plants, especially the enrichment and reprocessing facilities.

### *Choice of the Fuel Cycle*

While switching to nuclear power, making the best suitable technology and fuel cycle choices is vitally important for a country. Other major decisions are related to the front end (enrichment) and back end (spent fuel management). For the near and medium term, Open Cycle operating Advanced Light Water Reactors is recommended, since they are the most economic, safe and appropriate option. Whereas closed or partially closed fuel cycles including reprocessing and recycling are not recommended, as they are not expected to become economically viable for the foreseeable future.

### *Spent fuel*

Moreover, it is seen from past and current operating practices that there is no clear advantage of the reprocessing option either in terms of waste volume or repository area. For spent fuel management, the "wait and see" strategy based on long term temporary (interim) storage is recommended. However, temporary storage should be considered as an integral part of the reactor installation and relevant physical and legal infrastructure should be established.

### *Enrichment*

At this stage, establishment of its own enrichment facility does not seem economically feasible and reasonable for Turkey. Economic justification of a decision for the establishment of enrichment facilities depends on future development and realization time period of its nuclear program. But, these aspects may be strategically important from a security and energy security perspective. However, due to the association made by the international community, between the nuclear fuel cycle and the potential proliferation of nuclear weapons, the question of whether "Turkey should establish its own enrichment facility", will remain on the agenda in the foreseeable future as a thorny question where the international political context will play a more decisive role than a purely economic assessment.

Finally, due to the risks related to environment, proliferation and public health associated with it, nuclear energy is a subject of interest to a broad spectrum of people ranging from the local community to people in neighboring countries as well as the international community. As with all topics related with nuclear energy, a maximum degree of transparency and, ultimately, an effective public participation in the decision making process should be sought with regard to fuel cycle and especially about the disposal mode of spent fuels. First of all, the Ministry of Energy and the Turkish Atomic Energy Authority should establish long term strategies and a "White Paper" should be published and shared with the public opinion . It is vitally important to establish a base for polyphonic debate and ensure the participation of all the stakeholders and citizens to the decision-making process, especially related to major nuclear matters. The policies to be implemented will become ethically justifiable and maintain their sustainability in the long term if a consensus is achieved between the public opinion and the decision makers.

# 1- Introduction

The nuclear fuel cycle comprises a series of industrial processes which involve the production of electricity from uranium fuel in nuclear reactors. It comprises several stages, extending from uranium mining to the final storage of used fuels and waste. These stages may vary, depending on design and type of reactor and whether spent fuels are reprocessed. The most commonly used nuclear fuel cycle is the "Open Fuel Cycle", also named the once-through cycle, since it uses each uranium-based fuel element only once. Spent fuel assembly is then taken out from the reactor after a certain working period and stored. However, the "Closed Cycle", in which spent fuel is reprocessed and recycled, is becoming increasingly used in some European countries and Japan.

There are multiple viable fuel cycles. Yet, it is not possible to fully avoid subjective criteria when making a selection among these. There are still significant technical, economic, political, legal and financial uncertainties. Furthermore, different fuel cycles will cater to different objectives differently. Therefore, making an optimal choice among current fuel cycle options is not an easy task. For countries newly switching to nuclear power, the decision about the front end (uranium enrichment) and the back end (spent fuel management) are still the most critical decisions.

Furthermore, a developing country which intends to establish its own uranium enrichment or reprocessing facilities to enhance its energy security, may face heavy international pressure for constraining its nuclear program, even if there is no objective evidence that it is seeking nuclear weapons. National security and international stability are now threatened not only by the risk of proliferation among different states, but also by the potential of organized terrorist groups obtaining access to weapons-usable materials.

One notable example is the case of Iran's recent situation. Particularly due to the recent concerns relating to Iran and North Korea, International Atomic Energy Agency (IAEA) Director, Mohamed El Baradei suggested that enrichment and reprocessing are limited to facilities under international control and that the disposal and management of spent nuclear fuels is strictly controlled under multinational arrangements. In line with these developments, it would not be realistic to expect Turkey or any developing country to be encouraged for establishing its own critical fuel cycle facilities.

This paper will address the potential long term strategies regarding the front end and back end of the nuclear fuel cycle in Turkey in the light of the international conjuncture. A discussion about the advantages and disadvantages of reprocessing versus storage will also be undertaken in order to contribute to raising awareness among the Turkish public opinion about the different options for the long term management of waste. At this point, it should be underlined that, due to the risk of proliferation, uranium enrichment and reprocessing constitute a technical as well as a political problem.

The following section briefly describes the major nuclear fuel cycle options and overviews the global situation. The third section offers an analysis on Turkey's situation in order to provide a country perspective for decision makers, while brief evaluations are presented regarding the conclusion in the final section.

# 2- Major Nuclear Fuel Cycle Options

## *2.1. Nuclear Fuel Cycle*

Nuclear fuel cycle involves a series of industrial processes and operations for the production of electricity from uranium fuels in nuclear reactors, starting with the mining of Uranium metal, continuing with the storage or reprocessing and recycling of the fuel spent and ending with the final storage of radioactive waste. It comprises the intermediary processes related with the use and interim storage of uranium fuels in the reactors.

### 2.1.1. Stages of the Nuclear Fuel Cycle

The nuclear fuel cycle starts with uranium exploration and ends with disposal of the materials used and generated during the cycle. The series of industrial processes related to the nuclear fuel cycle can be subdivided into three, as the front-end, irradiation or nuclear power reactor operation and the back-end. The front-end of the fuel cycle comprises the stages before irradiation of the fuels whereas the back-end begins with the discharge of spent fuels from the reactor.

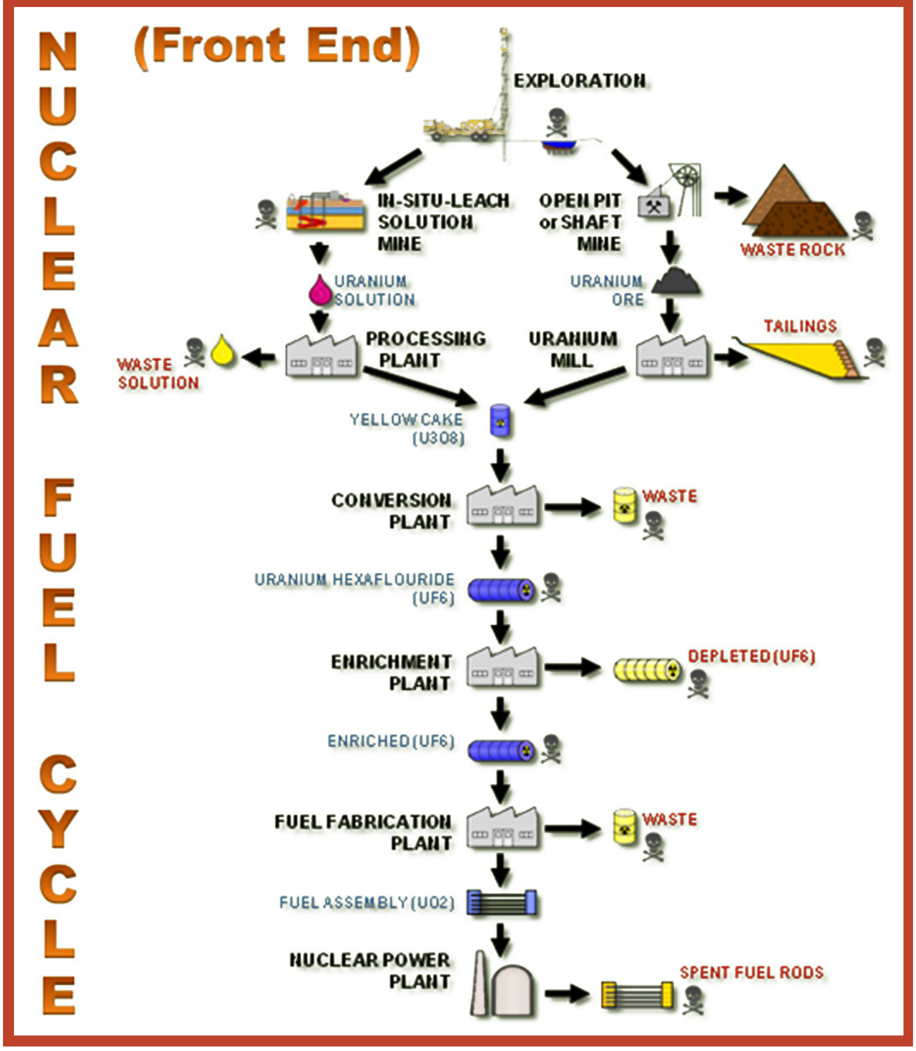
### *Front-end:*

As shown in Figure 1, the front-end of the fuel cycle comprises the following steps :

- **Uranium Exploration**
- **Uranium Mining:** It involves the processes related to the underground extraction of uranium ore.
- **Ore Processing Phase:** It comprises the chemical processes related to the milling and refining and purification (including in-situ leaching) of the Uranium ore extracted so as to obtain Ammonium Uranate, named as Yellow Cake, containing 80-90% $U_3O_8$.
- **Conversion Process:** It involves the activities related to refining and conversion to the most suitable form for the consequent processes. Yellow cake is converted into UF6 (Uranium Hexafluoride) gas through a multi-step chemical process.

- **Enrichment:** It involves the processes related to the enhancement of the isotopic enrichment of the UF6 gas in terms of Uranium, in order to obtain an appropriately enriched Uranium concentration.
- **Fuel Fabrication:** It involves processes related to the production of nuclear fuel to be inserted into the nuclear reactor.

**Figure 1. The front end of the fuel cycle**




### Irradiation/Nuclear Reactor Operation

The fuel elements are placed down in the reactor and energy generation is achieved by the fission reactions caused upon their exposure to neutron radiation. Irradiated / spent fuels are then taken out from the reactor after a working period of 3 to 5 years in Light Water Reactors (LWRs) and of up to 1 year in Gas Cooled Reactor (GCRs) and Pressurized Heavy Water Reactors (PHWRs).

### *Back-end*

Basically, there are two main options for the management of spent fuels:

- Decomposition and recycling of Uranium and Plutonium in the spent fuels and storage of the remaining waste (Closed Cycle)
- Direct storage of spent fuels (Open Cycle).

It should be noted that, in both cases, the material resulting from the process is highly radioactive waste. Even if long lasting low level wastes and medium level radioactive wastes are mostly obtained in case of reprocessing, both types of waste require geological storage.

All nuclear countries have a certain practice with regard to high level waste. The two following methods are used for interim storage of spent fuels:

- Wet storage where they are generally stored in the pools at the Reactor site;
- Dry storage: Spent fuels are typically stored in steel casks cooled by a ventilation system or natural air circulation at the reactor site or in specifically allocated sites.

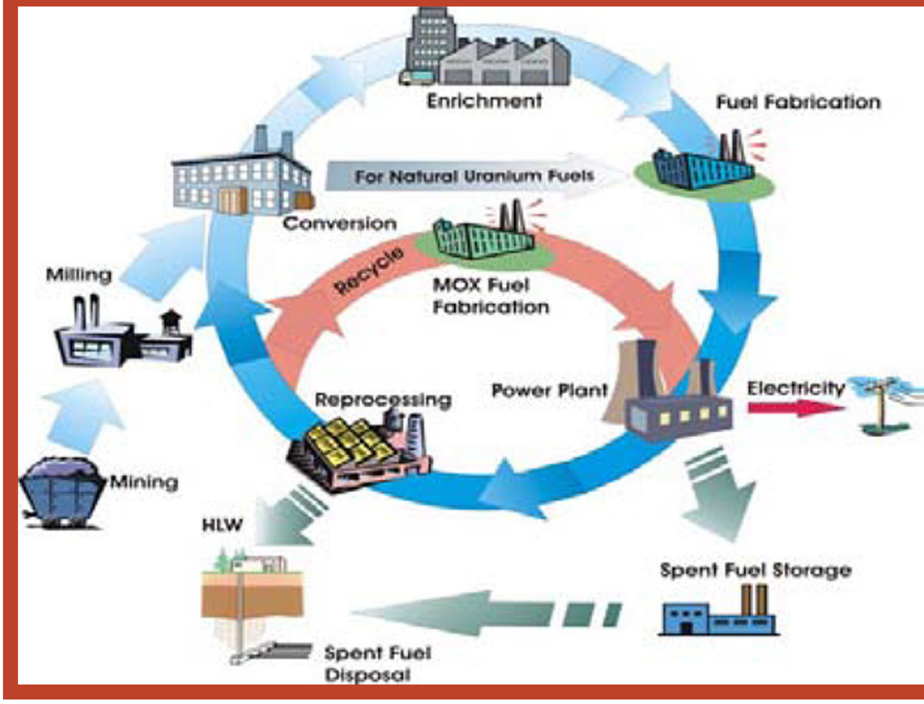
The back-end stage of the Nuclear Fuel Cycle involves some of the following steps, depending on the fuel cycle:

- Processes enabling the temporary storage of spent fuel at-reactor (AR) in (wet type) spent fuel storage facilities.
- Storage of spent fuel away-from-reactor (AFR), in (wet or dry) fuel storage facilities outside, upon being moved away from the reactor,
- Processes related to the extraction of useful materials contained within the spent fuel to enable to be recycled and be re-used in the reactor.
- Disposal of spent fuels: Placement of spent fuel in an appropriate facility without the intention of retrieval.

## 2.1.2. Current Nuclear Fuel Cycle Types

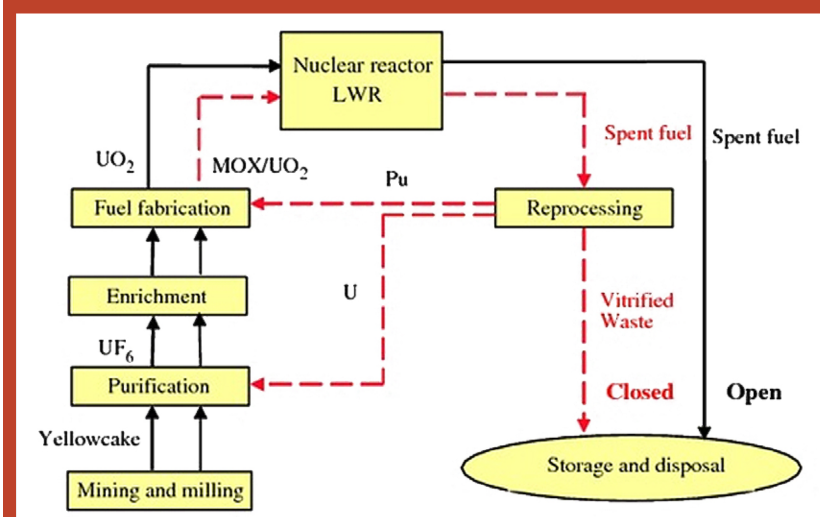
There are a few different nuclear fuel cycles categorized according to the technology of the reactor used and the type of fuel and whether or not the spent fuel will be processed and recycled. In today's technology they are divided into two, as "Open Cycle" and "Closed Cycle", as indicated schematically in general terms in Figure 2.

**Figure 2. Nuclear fuel cycle options**




Open and Closed cycles are shown in a flow chart in Figure 3. Spent fuels reaching the end of their useful life are removed from the reactor core and replaced with fresh fuels. If spent fuels are not reprocessed, the fuel cycle is called an "Open Cycle or "Once-Through Cycle". After being used in the reactor, the fuels are kept in at-reactor pools until they are sent to the away- from-reactor storage. The fuels are planned to be placed in the final repository upon reaching conditions suitable for being transported. Although most nuclear states have adopted this fuel cycle strategy, no final repositories for spent fuels have yet been established. This strategy is commonly used for Pressurized Heavy Water Reactors (PHWR) and Graphite Moderated Light Water Cooled Reactors (RBMK).

**Figure 3. Open and Closed Cycle**



If spent fuels are reprocessed to extract the remaining Uranium and Plutonium from the other actinides and fission products after a sufficient cooling period, the fuel cycle is called a "Closed" or "Twice-Through" Fuel Cycle. The Uranium and Plutonium obtained upon reprocessing are used for manufacturing new fuel elements. This reprocessing and recycling strategy has been adopted by some countries mainly in light water reactors (LWR) in the form of Mixed Oxide (MOX) fuel. The recycling of nuclear materials in fast reactors is another recycling strategy, in which reprocessed Uranium and Plutonium are used for production of Fast Reactor (FR) fuel. Fast Reactors which feed on Transuranics (TRUs) extracted from fuel spent in Light Water Reactors (LWRs) can significantly reduce the total radiotoxicity of nuclear waste, dramatically decrease the amount of waste and are seriously considered as a future technology. However, currently they do not constitute an economically viable option and their commercial development is uncertain.

Closed cycle involving chemical reprocessing which separates nuclear weapons usable Plutonium from spent fuels is of special concern, since it increases the proliferation risk. Furthermore, not only is it expensive, but it is also a sensitive topic in terms of environmental protection due to its chemical properties and radiotoxicity. Therefore, fuel cycles involving reprocessing are not the preferred option for most of the countries using nuclear energy.

### 2.1.3. Advanced Nuclear Fuel Cycle Concepts

After a few decades, there will probably be a transition from the traditional fuel cycles to advanced nuclear fuel cycles by using Generation IV Reactors, with one-half comprising innovative thermal reactor designs and the other half comprising advanced fast reactors. There are currently several concepts of advanced nuclear fuel cycles predicted to be implemented within the next 25- 30 years. In the advanced fuel cycles where innovative Light Water Reactors (LWRs) will be combined with Fast Reactors (FRs), Uranium Oxide (UOX) and (Uranium-Plutonium) Mixed Oxide (MOX) fuel obtained by reprocessing spent UOX fuels will be used for generating energy.

It should be emphasized at this point that, in theory, a "Closed Cycle" refers to all of the fissile material left over from or produced during the operation of the reactor, which is returned to the reactor for further conversion of energy. Only the waste with no more potential for energy conversion, in other words the fission products and any other material that is not fissile, shall be disposed of. Whereas, in the traditional fuel cycle named "Open" or "Once-through" Cycle, the fuels are disposed of upon being used only once, regardless of the amount of fissile (or fertile) material remaining within them. When considered within this context, the current Closed (Twice-Through) Cycle is in fact just a partially closed cycle. Therefore, currently there is need for different perspectives that may reflect these facts relating to nuclear fuel cycles.

Nuclear fuel cycles are categorized as follows on the basis of a new understanding arising with the activities on nuclear fuel cycle conducted within the scope of the researches relating to Generation IV Reactors[2]:

(1) **Once-Through Nuclear Fuel Cycle:** It is used for the production of energy in the fuel reactor manufactured from Uranium (or potentially from Thorium). Spent fuels are removed from the reactor after a certain period of use and stored in the pools at the rector until the decay heat is sufficiently reduced. Consequently, they are directly disposed of as High Level Waste (HLW).

(2) **Partially Closed Nuclear Fuel Cycle:** Fissile materials remaining in the spent fuel are recovered via reprocessing in order to produce additional energy and are recycled once or several times (generally not exceeding three). The resulting spent fuel is disposed of as waste. One example is the classical system of the French nuclear industry: Low enriched Uranium based spent fuels are reprocessed and recycled as mixed oxide (MOX) fuel. The spent fuel is used as waste. Another example will be the proposed DUPIC (Direct Use of Pressurized Reactor Spent Fuel in CANDU) fuel cycle, currently in design stage, which converts spent LWR fuels into new CANDU fuels.

(3) **Nuclear Fuel Cycle with Full Fissile Material Recycling:** All spent fuels are processed for the recovery and recycling of all fissile materials (U-235, Pu-233, U-233). The spent fuels are repeatedly processed in order to fully consume all the fissile material contained within through multiple usages in a reactor. Secondary actinides and fission products are separated during the reprocessing and transferred to the waste stream. One example is the traditional Liquid Metal Fast Breeder Reactor (LMFBR) Fuel Cycle. However, this cycle has not yet been implemented at an industrial scale.

(4) **Nuclear Fuel Cycle Recycling Actinides and Long Lived Fission Products:** In this fuel cycle all actinides recycled via multiple recovery processes until all fissionable materials are fully consumed. One (or more) fission product(s) (e.g. Tc-99 and I-129) may also be recycled. An example of such a fuel cycle is a combination of Light Water Reactors (LWRs) with Liquid Metal Fast Reactors (LMRs) and Molten Salt Reactors. In such a system the Light Water reactors generate power; the Liquid Metal Fast Reactors generate power and manufacture excess fissile material from Fertile U-238 (or Th-232) to fuel the LWRs, while Molten Salt Reactors destroy higher actinides that would otherwise be sent to the final repository. Currently, some countries are conducting laboratory-scale studies for the development of such kind of a Nuclear Fuel Cycle.

Many concepts of more advanced reactors, regarded as Generation IV, where one half consists of fast reactors while the other half consists of innovative thermal reactors, are promising. The primary design objective of most of these is to reduce the inventory of Transuranic (TRU) elements.

## *2.2. Situation in the World Regarding Critical Nuclear Fuel Cycle Technologies: Reprocessing and Uranium Enrichment*

The nuclear fuel cycle strategies have changed considerably due to varying conditions during nuclear power developmental period across the world. Commercial Reprocessing Programs originated in the 1960s and 1970s when power reactor operators worldwide expected that plutonium would be needed to make start up for fast breeder reactors. In those years the use of nuclear power was expected to increase so rapidly that the world's high-grade uranium ores would quickly be depleted, since uranium was considered a scarce resource, reprocessing and fast breeder technologies appeared as an important means of utilization of uranium supplies in a more efficient way by capturing remaining fissile elements in the spent fuels after it had been discharged from a reactor. However, world nuclear capacity reached a plateau at one-tenth the level that had been projected for the year 2000; huge deposits of high-grade uranium ore were discovered in Australia and Canada and both breeder reactors and reprocessing were found to be much more costly than expected. The economics of this advanced nuclear technology became questionable with the decline of fossil fuel prices and increase of uranium supplies as of the 1980s. Moreover, growing environmental and proliferation concerns raised strong opposition to the programs or reprocessing and development of Fast Breeder Reactors. Most national programs were paused.

However, energy security is also a growing concern and depending on strategic and geopolitical dimensions of energy security, choosing an "Open" or "Closed" fuel cycle is a also political decision and thus a matter of national policy. Since there are currently multiple viable nuclear fuel cycles, countries using nuclear power should make a choice between fuel cycle options by considering their own conditions and priorities. Good decisions among different proposed systems require clear, consistent and well-thought-out criteria, based on justifiable system objectives. A decision analysis for determining an optimal fuel cycle should be made by considering multiple criteria weighted by their importance or priority, such as number of planned nuclear power plants, time scale for nuclear energy planning, required investment for enrichment and/or reprocessing, presence of neighboring states enrichment or reprocessing facilities, resources availability and public support. Sufficiently objective quantitative measures for choosing fuel cycle are not yet available. Moreover, different fuel cycles will meet the different objectives differently. There are still great uncertainties in terms of economic, political, social, legal and technologic, while determining the fuel cycle choice. Thus, making an optimal choice among current fuel cycle options is not an easy task. It should also be emphasized that, for countries switching to nuclear power, the decisions about the front end (uranium enrichment) and the back end (reprocessing) still continue to be the most critical decisions.

## 2.2.1. Reprocessing Strategies

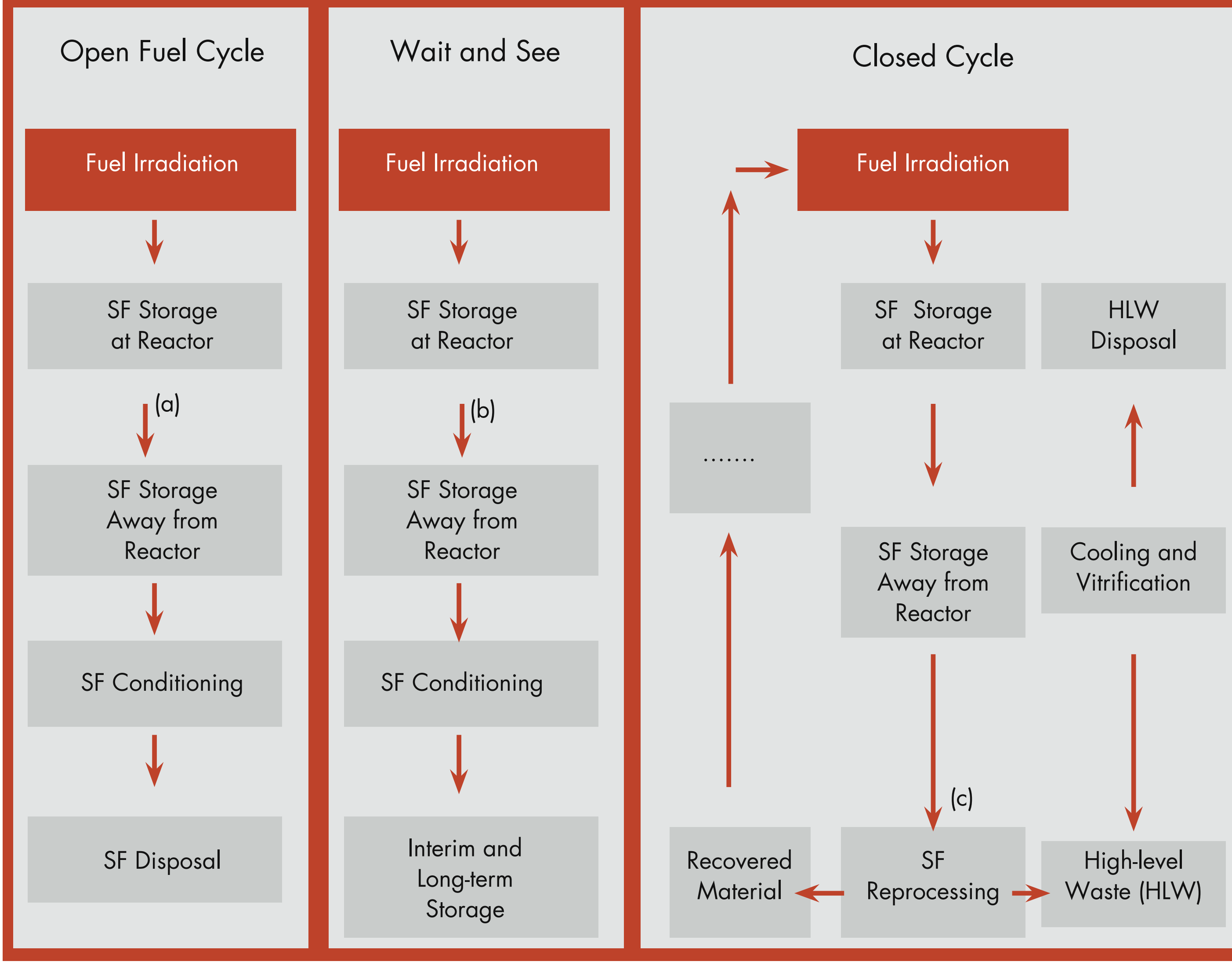
When considered from a global context, it is seen that Nuclear Fuel Cycle strategies differ significantly from country to country. Moreover, national fuel cycle strategies have changed considerably during the developmental period of nuclear energy depending on the changes in the country's own economic, political, technological and strategic conditions and priorities. The most commonly used nuclear fuel cycle is the Open Cycle, which uses Uranium-based fuel. However, it is also observed that the Closed (twice-through) fuel cycle is becoming increasingly used in some European Countries and Japan.

France, Germany, Belgium, Switzerland, the Netherlands, Japan, the Russian Federation, China and India have used (mostly partially) a closed nuclear fuel cycle. After having experienced the "Reprocessing and Recycling" strategy up until the 1990s, some of them decided to store directly their spent fuels. Belgium, Germany and the Netherlands have stopped the "Reprocessing/Recycling" practices in 2001 and moved towards an Open Cycle. Almost all of the EU states, except for the United Kingdom and France, have abandoned reprocessing and the United Kingdom plans to end it within the next decade. Whereas some countries like Canada, Finland and Sweden used the open cycle right from the beginning and preferred to dispose of their spent fuels directly [4].

The United States, being the world's largest producer of nuclear power, is also the country which has changed its fuel cycle policy most frequently. The most widely used and developed reprocessing method, called PUREX (Plutonium and Uranium Recovery by Extraction), was originally developed in the USA in 1940s for the first time. After having developed a closed fuel cycle in the early years of its nuclear power program, the US switched to the Open Cycle strategy at the beginning of 1978 mainly due to proliferation concerns. It stopped its commercial reprocessing and recycling of spent fuels and corresponding commercial Fast Breeder Reactor Development Program based on a government decision. The US Government banned the recycling of separated uranium in commercial reactors. This constraint significantly affected the development of strategies relating reprocessing. After spending many years working on it, the US Department of Energy - DOE submitted a license application for a geological repository for spent fuels and high-level waste at the Yucca Mountain. The license has yet to be awarded. The US Government is reconsidering its policy for reprocessing and recycling spent fuels [1,4,5].

Figure 4 illustrates different options for spent fuel management strategies.

**Figure 4. Various spent fuel management strategies**




Current preferences of nuclear power states and their installed capacities relating to various stages of the fuel cycle are demonstrated in Table 1. As seen, a significant number of states mostly availing of a small nuclear power program adopted "a wait and see" policy with regard to the disposal of the spent fuels.

Table 1. National practices relating to the fuel cycle[1,4]

| Country | Nuclear Fuel Cycle | Mining and Milling (t U/a) | Conversion to $UF_6$ (t U/a) | Enrichment ($10^3$ SWU/a) | Fuel Fabrication (t HM/a) | Reprocessing (tHM/a) |
|---|---|---|---|---|---|---|
| Argentina | No decision | 120 | 62 | 20 | 150 | - |
| Armenia | Not applicable | - | - | - | - | - |
| Australia | No decision | 9438 | - | - | - | - |
| Belgium | No decision | - | - | - | 435 | - |
| Brazil | No decision | 340 | 40 | - | 280 | - |
| Bulgaria | No decision | - | - | - | - | - |
| Canada | Open | 14800 | 12500 | - | 2700 | - |
| China | Closed | 840 | 1500 | 1000 | 400 | - |
| Czech Rep. | Open | 650 | - | - | - | - |
| Finland | Open | - | - | - | - | - |
| France | Closed | - | 14350 | 10800 | 1585 | 1700 |
| Gabon | Not Applicable | - | - | - | - | - |
| Germany | Open &Closed | - | - | - | - | - |
| Hungary | No decision | - | - | - | - | - |
| India | Closed | 175 | - | - | 594 | |
| Japan | Closed | - | - | 1050 | 1689 | 120 |
| Kazakhstan | Not Applicable | 5950 | - | - | - | - |
| Korea | Open | - | - | - | 800 | - |
| Lithuania | No decision | - | - | - | - | - |
| Mexico | No decision | - | - | - | - | - |
| Mongolia | | - | - | - | - | - |
| Namibia | | 4000 | - | - | - | - |
| Netherlands | Closed | - | - | 2500 | - | - |
| Niger | Not Applicable | 3800 | - | - | - | - |
| Pakistan | No decision | 30 | - | 5 | 20 | - |
| Portugal | Not Applicable | - | - | - | - | - |
| Romania | Open | 300 | - | - | 110 | - |
| Russia | Closed | 4200 | 30000 | 15000 | 2600 | 400 |
| Slovakia | No decision | - | - | - | - | - |
| Slovenia | No decision | - | - | - | - | - |
| South Africa | No decision | 1272 | - | - | - | - |
| Spain | No decision | - | - | - | 400 | - |
| Sweden | Open | - | - | - | 600 | - |
| Switzerland | Open &Closed | - | - | - | - | - |
| Ukraine | No decision | 1000 | - | - | - | - |
| UK | Open& Closed | - | 6000 | 2300 | | |
| USA | Open | 1150 | 14000 | 11300 | 3450 | |
| Uzbekistan | Not Applicable | 2300 | - | - | - | - |

Table 2 shows the reactors which are currently in operation across the world and their fuel types and basic characteristics. The dominant nuclear power reactor type today is the Light-Water Reactor (LWR) using uranium fuel with Open Cycle. The most important reason is that they are relatively proliferation-resistant as they use an open fuel cycle. Their fuels include low-enriched Uranium which cannot be used to make nuclear weapons without further enrichment. Their spent fuels contain one percent Plutonium which can directly be used for making nuclear weapons. However, as it is mixed with other highly radioactive fission products which makes it inaccessible without being reprocessed[7]. These features make this type of reactors resistant to proliferation.

**Table 2.** Reactors and fuel types[1]

| Reactor Type | PWR/WWER | BWR | PHWR | RBMK | AGR | MAGNOX | FR |
|---|---|---|---|---|---|---|---|
| Neutron spectrum | Thermal | Thermal | Thermal | Thermal | Thermal | Thermal | Fast |
| Moderator | H2O | H2O | D2O | Graphite | Graphite | Graphite | _ |
| Coolant: type | Press. H2O | Boiling H2O | Pr. D2O | Boil. H2O | $CO_2$ | $CO_2$ | Na |
| Pressure, bar | 155 | 70 | 110 | 70 | 40 | 19 | 5 |
| temperature, outlet, 0C | 320 | 286 | 310 | 284 | 630 | 400 | 550 |
| Fuel: type | UO2 /MOX | UO2/ MOX | UO2 | UO2 | UO2 | U metal | UO2* |
| Enrichment | up to 5% 235U | Up to 5% 235U eff. | Nat. U | Up to 3% 235U | 2.5-3.8% 235U | Nat. U | 17-26% 235U* |
| Cladding | Zr alloy | Zr alloy | Zr alloy | Zr alloy | SS** | MgO-Al | SS** |
| Burnup, GWD/t HM | Up to 60 | Up to 55 | 7 | Up to 25 | Up to 30 | 4 | Up to 100* |
| Number of operating reactors | 229 | 93 | 39 | 16 | 14 | 8 | 1 |
| Total power, GWe | 240.6 | 82.6 | 20 | 11.4 | 8.4 | 2.3 | 0.6* |

Additionally, Plutonium reprocessing and recycling processes are not expected to become economically viable in the foreseeable future. It is estimated that worldwide Uranium resources will be sufficient for at least a few more decades. Uranium supply has become highly diversified, with more uranium mining across the world. Although Uranium conversion, enrichment, and fuel fabrication are concentrated in a handful of countries, major efforts are undertaken for the establishment of an international fuel bank to reduce the uncertainty in nuclear fuel supplies. Moreover, it is seen that reprocessing and recycling Plutonium in LWR spent fuels, as practiced today in France, does not reduce the problem of radioactive waste. Thus, there seems to be no good economic or waste-management reason for the implementation of the reprocessing and recycling process.[7]

Reprocessing policy preferences of the countries using nuclear power are summarized in Table 3. Today, five nuclear weapon states (China, France, India, Russia and the United Kingdom) plus Japan reprocess some of their own spent fuels. The Netherlands has signed a contract with France to have the spent fuels from its single reactor reprocessed. Out of the countries with reprocessing facilities, France, India and Japan currently reprocess most of the spent fuels or plan to do so. However, the United Kingdom is expected to end reprocessing upon the termination of its existing contracts with other countries. Russia reprocesses only the spent fuels from its first-generation VVER-440 LWRs and its BN-600 demonstration Fast-Breeder Reactor. China has built but not yet operated a pilot reprocessing facility[7].

**Table 3.** Distribution of reprocessing facilities[9]

| Countries that reprocess (GWe)) | | Customer Countries that have quit or are planning to quit (GWe) | | Countries that have not reprocessed | (GWe) |
|---|---|---|---|---|---|
| China (pilot plant) | 8.6 | Armenia (in Russia) | 0.4 | Argentina | 0.9 |
| France (80%) | 63.3 | Belgium (in France) | 5.8 | Brazil | 1.8 |
| India (≈50%) | 3.8 | Bulgaria (in Russia) | 1.9 | Canada | 12.6 |
| Japan (90% planned) | 47.6 | Czech Republic (in Russia) | 3.6 | Lithuania | 1.3 |
| Netherlands (in France) | 0.5 | Finland (in Russia) | 3.0 | Mexico | 1.4 |
| Russia (15%) | 21.7 | Germany (in France/U.K.) | 20.5 | Pakistan | 0.4 |
| U.K. (ending) | 10.2 | Hungary (in Russia) | 1.8 | Romania | 1.3 |
| | | Slovak Republic (in Russia) | 2.0 | Slovenia | 0.7 |
| | | Spain (in France/U.K.) | 7.5 | South Africa | 1.8 |
| | | Sweden (in France/U.K.) | 9.0 | South Korea | 17.5 |
| | | Switzerland (in France/ U.K.) | 3.2 | Taiwan, China | 4.9 |
| | | Ukraine (in Russia) | 13.1 | U.S. (since 1972) | 100.6 |
| Total | 155.7 | Total | 71.8 | Total | 145.2 |

Out of the remaining 24 countries with nuclear energy programs, 12 have not reprocessed their spent fuels. Although the other 12 countries shipped their spent fuels to France, the United Kingdom or Russia to be reprocessed in the past, those whose contracts have expired did not renew them. All of these 24 countries have currently decided to apply interim storage[7].

## 2.2.2. Uranium Enrichment Strategies

Uranium enrichment is another critical component of nuclear fuel technologies for generating civil nuclear power and producing military nuclear weapons. There are large commercial enrichment plants in operation in France, Germany, the Netherlands, the UK, the USA and Russia, with smaller plants elsewhere. Historically, France and the United States dominated the enrichment market with Gaseous Diffusion. But, firms using the Centrifuge technology, such as the Russian Rosatom and the British-Dutch-German Urenco, have captured an increasing share of the market. The U.S. Enrichment Corporation's (USEC's) share declined from 39% in 1998 to 17% in 2005, as the diffusion plants of 1940s and 1950s (at Oak Ridge and Portsmith) were retired. Meanwhile, Urenco is building a new centrifuge plant in New Mexico and AREVA has announced plans to build another centrifuge plant in the United States.

Moreover, the enriched Uranium derived from materials excess to defense programs in the Russian Federation and United States has in effect resulted in the introduction of an important new energy supply (app. 5.5 Million SWU/a) in recent years, as seen in Table 4.

**Table 4** Enriched uranium excess from defense programs

| | Quantity (tonnes) | Natural U equivalent (tonnes) |
|---|---|---|
| Plutonium from reprocessed fuel | 320 | 60,000 |
| Uranium from reprocessed fuel | 45,000 | 50,000 |
| Ex-military plutonium | 70 | 15,000 |
| Ex-military high-enriched uranium | 230 | 70,000 |

*Source: WNA http://www.world-nuclear.org/info/inf29.html*

Nearly 68,000 tons of Uranium are required annually for the nuclear power plants worldwide that have a combined capacity of 375 GWe. The factors increasing fuel demand are offset by a trend for higher burn-up of fuel and other efficiencies, thus making demand stable. Between 1980-2008, the electricity generated by nuclear power plants increased 3.6-fold, while Uranium demand increased only 2.5 times. The distribution of operational and planned enrichment capacity across the world, according to countries is provided in Table 5.

'Other' includes Resende in Brazil, Kahutab in Pakistan, Rattehallib in India and Natanz in Iran.

According to The World Nuclear Association projections, this demand will grow by 33% in the next decade in accordance with a projected increase of 27% in nuclear reactor capacity. The global nuclear reactor Uranium requirement is projected to increase to 74 kilo tons-81 kilo tons by the year 2020 and to 82 kilo tons-101 kilo tons by the year 2025.Demand in North America and Western Europe is expected

**Table 5.** Enrichment capacity(thousand SWU/yr)[10]

| COUNTRY | COMPANY AND PLANT | 2010 | 2015 | 2020 |
|---|---|---|---|---|
| France | Areva, Georges Besse I & II | 8500* | 7000 | 7500 |
| Germany-Netherlands-UK | Urenco: Gronau, Germany; Almelo, Netherlands; Capenhurst, UK. | 12,800 | 12,800 | 12,300 |
| Japan | JNFL, Rokkaasho | 150 | 750 | 1500 |
| USA | USEC, Paducah & Piketon | 11,300* | 3800 | 3800 |
| USA | Urenco, New Mexico | 200 | 5800 | 5900 |
| USA | Areva, Idaho Falls | 0 | 0 | 3300 |
| USA | Global Laser Enrichment | 0 | 2000 | 3500 |
| Russia | Tenex: Angarsk, Novouralsk, Zelenogorsk, Seversk | 23,000 | 33,000 | 30-35,000 |
| China | CNNC, Hanzhun & Lanzhou | 1300 | 3000 | 6000-8000 |
| Pakistan, Brazil, Iran | Various | 100 | 300 | 300 |
| | Total SWU approx | 57,350 | 68,000 | 74-81,000 |
| | Requirements (WNA Reference Scenario) | 48,890 | 56,000 | 66,535 |

either to remain fairly constant or decline slightly, whereas in the rest of the world it is set to increase. These estimations suggest that there is enough Uranium to fuel Open/Once-Through cycles for at least another 50 years. If a Closed/Twice-Through Cycle is used, with a more efficient reactor technology such as the Fast Reactors, the supplies will be sufficient for nuclear energy generation for many more years. However, although spent fuels can be reprocessed so as to be used again, it is currently less economical than producing new fuels since Uranium resources will not be scarce for a long period of time. Thus, it seems that LWRs (Light Water Reactors) using the Once-Through Fuel Cycle are the preferred option for most countries for the next upcoming years, and even in the remaining part of this century. This fact puts forward the challenges related to the direct disposal of spent fuels. Unless cycles are completely closed, spent fuel and waste management, used especially for the Open / Once-Through Fuel Cycle as well as the Closed / Twice-Through Fuel Cycle, remains to be one of the major issues for countries using nuclear power.

## 2.2.3. Spent Fuel Management Strategies

The management of spent fuels from reactors is a major issue that burdens all countries that have a nuclear power program. The management of the fuels and waste used both with Open (Once-Through) and Closed (Twice-Through) cycles without closing the nuclear fuel cycle completely remains one of the most significant concerns for all nuclear countries. Spent fuel management is currently considered as an integral part of the nuclear fuel cycle. Fuel management strategy involves a series of technical operations beginning with the discharge of spent fuels from the core of a power reactor and ending with its transfer to the final storage.

As indicated in the sections above, upon being discharged from the reactor core and temporarily stored at the reactor, the spent fuels are either sent to reprocessing facilities or directly to the final storage facilities. It is necessary to store the spent fuels in the pool regardless of whether the cycle is open or closed. A decision should be taken from the following options once the initial intense radioactivity decays:

- They can be sent to a reprocessing facility in order to be reprocessed.
- In principle, they can also be sent to a geological repository for direct final storage. However, since no such repositories have yet been opened for spent fuels, Reactor operators do not yet avail of this option in reality.

Currently, long term temporary storage solutions are replaced with final repository solutions all around the world, depending on the delay in the construction of final repository plants.

Today, there are two technologies in use for temporary (intermediate) storage:

- Wet Storage: Spent fuels are stored in storage pools where they are cooled via circulating water.
- Dry storage: Spent fuels are preserved in casks, typically composed of steel cylinders. The fuel rods inside the casks are surrounded by inert gases and cooled by ventilation or natural convection. Each cylinder cask is surrounded by additional steel, concrete and other materials to provide radiation shielding for workers and members of the public. Figure 5 shows a spent fuel storage pool and a dry storage area.

**Figure 5.** Spent fuel storage pool and dry storage area

The temporary storage of spent fuels for a longer period of time offers s a safe, flexible and cost-effective short and medium-term approach towards spent fuel management. It provides the possibility of implementing a “wait and see” strategy which is currently adopted by a significant majority of countries, i.e. deferring the decision between the two options mentioned in the sections above. In some countries, temporary storage plants have been initially licensed to operate for a period of up to 50 years. Periods of up to 100 years or longer are also under consideration.

Historically, the options relating to spent fuels were assessed upon being categorized into two groups, namely storage at the site of the Nuclear Power Plant (at reactor storage-AR) and storage in special facilities away from the Power Plant (away from reactor storage-AFR). At-reactor storage is a more suitable system for the interim storage of spent fuels. Away-from-reactor storage is generally developed as a result of the requirements arising from the absence or insufficiency of such facilities within the reactor. In some countries, like in Germany, it became official policy of the political administration to force the reactor company to build long term temporary storage capacity on-site. Wet storage will remain the preferred approach for interim storage during the first decade after discharge. Short term wet storage has become a traditional technology that does not need any elaborate discussion. Long term wet storage is not further discussed here due to its low future perspectives. According to current trends, the intermediate (interim) storage of spent fuels for a period of up to 100 years without being transferred to the final storage areas should be planned as an integral part of fuel cycle designs. Regardless of the decision on which option - once-through or twice-through- is preferred for the back-end of the cycle, the problem related with the final storage of spent fuels and/or radioactive wastes still continues to exist. A general overview on the storage concepts developed by IAEA member states for high level wastes, including the direct storage of spent fuels, is provided in Table 6.

**Table 6.** Spent Fuel Storage Practices[2]

| Member States | Belgium | Canada | Czech Republic | Finland | France |
|---|---|---|---|---|---|
| Waste form | HLW, VHLW | SNF | SNF | SNF | VHWL |
| Over pack<br>- Dimension(m)<br>- Capacity<br>- Material<br>-Life time(as) | 0.50 _x2.68<br>- 2 canisters<br>- Carbon steel<br>>2000 | - 1.24x3.9 (one of several designs)<br>- 324 used CANDU fuel bundles<br>- Cu corrosion barrier with steel Insert<br>- 100,000 | - EDU (440) 3.237 _x 0.368; ETE(1000) 4.720 _x 0.423<br>- 7FA (EDU) or 3FA (ETE)<br>- Carbon steel<br>- 5000 | 1.05_x4.8(BWR)<br>- 12 BWR FA or 4 PWR (EPR) or 12 PWR ( WWER-440)<br>- Copper<br>- 100000 | 1.607 _x 0.590<br>- 1 primary waste package<br>- Carbon steel<br>- 1 000–4 000 |
| Repository<br>- Capacity<br>- Host rock<br>- Depth<br>- Emplacement | - 1150m³ HLW 625m³<br>- Boom clay<br>- 230 m<br>- Horizontal | 3.6 million CANDU bundles (design)<br>- Crystalline rock or sedimentary rock<br>- 500m (design will depend onsite conditions)<br>- Vertical in-floor or horizontal tunnel | 3600t<br>- Granite<br>- 500m<br>- Horizontal/ vertical | Olkiluoto-3, 1980 t·U<br>Loviisa1-2 , 1020 t·U<br>- Crystalline rock<br>- 420 m<br>- Vertical | - 6300m3<br>- Clay (argillite)<br>- 500m<br>- Microtunnels |
| Current status | R&D | R&D | SS | SC | Design and preparation of application to be provided in 2014 |
| Operation | 2040/2060 for B-waste 2090/2100 for C-waste | 2035 (earliest estimated inservice date for financial planning purposes) | 2065 | 2020 | 2025 |

| States | Japan | Republic of Korea | Russian Federation | Sweden | Switzerland | USA |
|---|---|---|---|---|---|---|
| Waste form | HLw | SNF (PWR, CANDU) | HLW | SNF | SNF (UO2 and MOX)/HLW | SNF, HLW |
| Over pack<br>- Dimension(m)<br>- Capacity<br><br>- Material<br><br>-Life time(as) | 0.82_x1.73 (ref. option)<br>- HLWcorrespond. to 8.6 x 10-2 $m^3$/FA(PWR)<br><br>- Carbon steel (reference option)<br>- 1000 (ref. option) | - 1.02_x4.83<br>- 4 PWR FA./ 297 CANDU bundles<br><br>- Cast iron insert + Cu outer shell<br>- 1000 | | - 5 x 1.75<br>- 1-2 BWR or 4 PWR FA<br><br>- Copper<br>- 100000 | Cylinder, diameter/length: 0.94/3.25 Volume: 2.26 m3 for two 180-l-HLW canisters Diameter/length: 1.05 /4.92, Volume: 4.26 $m^3$ for max. 4 PWR or 9 BWR FA's<br>- Capacity see above<br>- Carbon steel<br>-10000 years | 1.644_ x5.16<br>- 21PWR FA<br><br>- Alloy 22<br><br>- 10000 |
| Repository<br>- Capacity<br><br>- Host rock<br><br>- Depth<br>- Emplacement | - More than 40 000 Canisters<br><br>- SR/HR<br><br>- More than 300m<br>- Vertical./ Horizontal | 36 000 t (PWR 20000 t + CANDU 16000 t)<br>- Cristalline rock<br><br>- 500m<br>- Vertical | - HR<br><br>- 100 to 1000m | 9000 t<br><br>- crystalline rock (granite)<br><br>- 500 m<br>- Vertical/ | - SNF from 2435 t·U , HLW from 1140 t·U, volume of packaged waste (SNF and HLW):7325 $m^3$.<br>- Clay rich sedimentary rock (OPA)<br>- 500-900m<br>- Horizontal | -<br>-63 000 t<br><br>- Tuff<br><br>- 300 m<br>- Drift |
| Current status | Siting | R&D | R&D | SC | Sitting | LA |
| Operation | 50 year from around 2035 | | 2030 | 2020 | | 2020 |

*HLW - High level waste from reprocessing; CS – Carbon steel; SNF – Spent nuclear fuel; SR – Soft rock; HR – Hard rock; SR – Sedimentary rock; HR – Hard rock; T or C – Tunnel or cavern disposal;GS – Geological study; SS – Site screening; SC – Site characterization; VHLW – Vitrified high level waste; LA – Licensing application for construction permit; can. – Canisters; FA – Fuel assemblies.*

# 3- Options for Turkey and a General Decision Analysis

While switching to nuclear power, a country is faced with a number of important questions such as the types of reactors and fuels to be used, and the methods to be selected for long term waste storage. The most critical decisions are about:

- The choices of the type of fuel cycle (open, closed or partially closed) and spent fuel management strategy (the choice of the type of nuclear fuel cycle is vitally important since it will have major and very long term impact).
- The establishment of its own fuel cycle plants, especially the enrichment and reprocessing facilities.

A general decision analysis has been presented here for the purpose of establishing a country perspective for Turkey.

## *3.1. Choice of the Fuel Cycle*

The dominant Reactor Technology today is the Light Water Reactor Technology (LWR), comprising 89% of global operating nuclear-power capacity[7]. The major reactor vendors have developed advanced or "Generation III+" LWRs. They are currently licensing and selling these reactors. Although there is an increased interest in exploring alternatives to the LWR due to apparently renewed interest in nuclear power, there is no reason to expect the dominance of LWRs to end within the system in a foreseeable future. Today's nuclear fuels are derived from natural uranium. LWRs are fueled with low-enriched uranium and uranium resources are not expected to face any constraint for a long time. According to an MIT report, the worldwide supply of uranium ore will be sufficient to fuel the deployment of more than 1,000 reactors over the next 50 years[3]. Currently, LWRs are:

- The most economic option providing the lowest cost for nuclear electric production;
- The safest nuclear power plants and are safe in each phase of the fuel cycle.
- They provide a technology that may maintain its commercial existence and is mature.
- The market entry of other reactor types will be slow especially due time-consuming processes such as the testing and licensing of new technologies[2];
- When used in open cycle, they provide the best option in terms of non-proliferation compared to other power reactors - particularly GCR and HWR types – as they are proliferation resistant when operated on an open cycle. They produce the lowest rate of Plutonium compared to GCRs and HWRs at the same power[9];

· They are also suitable for use of MOX fuel.

Closing (partially) the nuclear fuel cycle by means of reprocessing and recycling in fast reactors can be regarded as a standard strategy for spent fuel management. Reprocessing is an accessible and proven technology. Spent fuel reprocessing has evolved significantly since the start of nuclear energy applications. There is a large body of industrial experience in fuel cycle technologies complemented by research and development programs in several countries. The selection of a strategy for spent fuel management is a complex decision with many factors to be taken into account such as those related with politics, economy, environment and security as well as public support. Both approaches (open and closed/twice through) have their respective advantages and disadvantages. Over long-term, "closed" fuel cycles may provide a more sustainable option over open fuel cycles[3]; that is to say, they;

1. Enable the use of all fissile and fertile resources,
2. Minimize fissile fuel flows, including those at reprocessing facilities,
3. They avail of multiple reactor options rather than a single Fast Reactor option,

and,

4. There is a wider choice of nuclear reactor core design, with desirable features such as removable blankets for extra plutonium production. Some of these design options may have better economic, nonproliferation, environmental, safety and security and waste management characteristics.

However, reprocessing is more expensive than producing new fuel under current conditions. Currently, closed cycle is less economic but also less secure in terms of the risk of proliferation compared to the open fuel cycle. The reality is that reprocessing and recycling strategy have been reinforced by energy security concerns arising in consequence to the oil crisis in the 1970s. This strategy was based on the assumptions of a rapid growth in nuclear energy and uranium demand and hence on an expected scarcity of uranium. However, the growth in nuclear energy since 1970s did not unravel as assumed initially and forward plans were progressively downsized[5]. It is seen from past and current operating experiences that no clear advantage is offered by the reprocessing options either in terms of waste volume and repository area. Reprocessing of spent fuels does not completely close the cycle, as is often claimed, since it involves at each stage the production of significant waste streams. Moreover, the underground storage volume required for spent MOX fuel and waste can be smaller or larger than that for direct storage of spent LWR fuel, depending upon assumptions. There are some radiologic impacts due primarily to annual releases of the low-level but long-lived radioactive elements such as Krypton-85 (half-life of 11 years), Carbon-14 (half-life of 5,700 years) and Iodine-129 (half-life of 16 million years) to the atmosphere[6]. One of the main reasons for the move towards a direct disposal policy was also the concern over proliferation. Subsequently, various socio-economic concerns influenced the divergence from the reprocessing and recycling strategies [4].Consequently, there is an increasing number of countries that have abandoned the closed fuel cycle, either by turning to the open cycle and adopting direct disposal of spent fuels or by deferring a final decision on the fate of spent fuels to a future time and adopting a "wait and see" position. While interim/temporary disposal cannot be considered as a final solution for spent fuel management, it provides time for enabling the development of new technical options [3].

The recent research and activity activities have focused on the transition to a safer new generation technology and the reduction of nuclear fuel cycle costs. Therefore, no investments are expected to be made to radically innovative technologies in a foreseeable future. It is estimated that focus will be placed on the back end of nuclear fuel cycle, especially on the solutions relating to the development of waste management composed of long-term transuranic elements in spent fuels, in the medium term. It appears that priority will be given in the next decades to the deployment of open fuel cycle involving cutting edge thermal or fast reactor technologies, rather than the closed cycle. Thus, Open/ Once-Through Nuclear Fuel Cycle using Light Water Reactors will likely be the dominant feature of the nuclear energy system across the world within the next several decades and even for the rest of this century. It would be unrealistic for a country newly transitioning to nuclear power to make a marginal individual choice independent from these realities. Therefore, Open Cycle with Light Water Reactors should be the preferred option for Turkey in near and medium term investments. Under these uncertain conditions, those countries with a low waste production due to a small nuclear program do not yet avail of long term policies for the disposal of spent fuels. Just like these countries, a wait and see policy based on longer term interim storage will be a more reasonable approach also for Turkey at this stage.

Choosing an advanced technology that can use both $UO_2$ and MOX fuel, offers the possibility to convert into Closed (twice-through) cycle when required. In this context, the technology choice made for Turkey's first reactor, Russian-based VVER -1200 491 M, is a suitable option bearing these features at least on paper. It seems that all the responsibilities related to the management of spent fuels and waste as well as fuel supply are left to Russia. The nuclear plant will be built, owned and operated by a Russian subsidiary of Rosatom, a state-owned Russian company. The project company (to be owned mostly by the Russian side) shall be responsible for spent fuel and waste management and the decommissioning of the power plant. The agreement signed between the governments of Turkey and the Russian Federation also provides the possibility to cooperate in other areas of the fuel cycle, including the treatment of spent fuel and radioactive waste, decommissioning and the possible construction of a fuel fabrication plant.

According to Article 12 of the Agreement, the fuels for Akkuyu Nuclear Power Plant will be sourced from Russia on the basis of long term agreements and spent fuels may be reprocessed in the Russian Federation. Russia will also be responsible for the transportation of the spent fuels. According to the Deputy Director of the Project Company Akkuyu NGS Corporation, Mr. Kasumov, the fuels of the Power Plant will be brought from Russia and the waste will be sent back to Russia upon being spent. Mr. Kasumov also stated that spent fuels are valuable as they may be used again upon being reprocessed and said that the fuels could stay in Turkey if Turkey decided to purchase them. Furthermore, it is stated that the Akkuyu Nuclear Power Plant will have a fuel storage capacity of 20 years. However, there is no clear plan on how the spent fuel and waste generated in the power plant will be disposed of. In the light of all these, it seems that Turkey has postponed its decision on spent fuel and waste management.

Although this strategy provides short term solutions for the Akkuyu Nuclear Power Plant, it still contains significant uncertainties. For other power plants to be built in the longer term and in future, Turkey should remove these uncertainties and establish well-rounded and comprehensive strategies and policies for its spent fuel and waste management.

## *3.2. Decision Analysis on the Establishment of the Country's Own Enrichment/Facilities*

Another challenging question for a country deciding to switch to nuclear energy, is whether it should establish its own enrichment/reprocessing facility as part of its nuclear program. The construction of an enrichment facility is a process that requires a very high initial capital investment. The construction of an enrichment facility may cost as much as a few billions of dollars[1]. A standard uranium enrichment facility may generate enriched uranium enough to supply the annual reload requirements of 8-9 large power reactors. In order for the power facility to amortize its capital cost most rapidly within a reasonable period of time, it should be operated at full capacity. Therefore, the presence of indigenous uranium enrichment plants becomes justified for a country only when it possesses at least 10 GW of installed capacity (app. 8-10 Reactors).

Still, independent from economic considerations, a country may want to establish its own enrichment facility due to energy security concerns against fuel supply interruptions to be used as a political tool [10]. Various decision factors considered by countries availing of a nuclear energy program have been outlined by Ferguson [8]:

- **Number of Nuclear Power Plants:** The establishment of an uranium enrichment facility is not economically viable until there are eight or more power reactors.
- **Time Scale for Nuclear Energy Plans:** Have they focused on the next few years or on the next decades? Investments delivering fast results are required for the former and this may prevent the establishment of fuel fabrication plants. With regard to the latter, a country may be willing to wait several decades for an investment to pay off. In that case, reprocessing, for example, may be regarded as a strategic investment to hedge against potential future uranium shortages.
- **Investment in Enrichment and/or Reprocessing:** If the real or perceived energy security of a country fits its vision, investment in such type of plants may be considered. Countries with substantial Uranium resources but with no nuclear power programs may decide to build enrichment plants in order to enhance the economic value of their indigenous Uranium sources.
- **Adherence to the Nonproliferation Treaty, Safeguards Agreements and Convention on the Physical Protection of Nuclear Materials:** How well is the nonproliferation system and relevant safeguards established and implemented

1_ Estimated cost of a new Standard gaseous diffusion facility is $ 5 billion, whereas that of a gaseous centrifuge enrichment facility is around $ 6 billion. The annual operation cost of a gaseous diffusion plant is $ 500 million, while that of a gaseous centrifuge facility is around $ 100-200 million.

by a country? Has that country become part of the Additional Protocol relating to comprehensive safeguards?

- **Security Alliances:** Is the country part of a security alliance receiving protection from at least one or more nuclear-armed allies?
- **Nuclear energy cooperation agreements:** Do these agreements prohibit or forego enrichment and reprocessing or do they allow the conduct of such activities?
- **Political statements regarding the pursuit of enrichment or reprocessing:** Does the country have a leader making statements against these activities?
- **Presence of enrichment or reprocessing facilities in neighboring countries:** Do neighboring countries have such plants; if so, which ones and why are they pursuing such a policy?
- **Availability of resources:** Does the country have access to other relatively abundant indigenous energy resources or reliable supplier states for electricity generation? Are these resources inexpensive compared to nuclear power?
- **Public support for nuclear power:** How supportive is the public about nuclear-generated electricity?
- **Public support for waste management:** Even if the public is generally supportive of nuclear power, they may largely oppose waste storage. This opposition may drive decision makers to consider reprocessing or other options that would alter the perceptions surrounding permanent repositories.
- **Degree of government ownership of utilities:** What is the share of the public sector in electricity generation? Can the government push through decisions to build nuclear power plants or reprocessing facilities?
- **Level of enthusiasm among nuclear technology scientists and engineers for fuel cycle plants:** Are technical people against these plants or do they have any influence and political power on those shaping the political will?

The establishment of its indigenous Uranium enrichment facility enables a country to ensure sufficient fuel supply for its nuclear power plants. Such an infrastructure will enhance the energy independence of a country and contribute to its national energy security. However, as mentioned above, a country may not economically justify the construction of its own fuel cycle plants, especially enrichment plants, before establishing eight or more large reactors. Although the Turkish government has announced its long term plans for establishing eight nuclear power plants, it seems that there are still great uncertainties related with this program. The economic cost of establishing an enrichment facility is sizeable for a country with only one or two reactors. Furthermore, as seen on Figure 8, there are a number of countries with uranium enrichment plants around the world and also a significant overcapacity.

On the other hand, nuclear fuel cycle investments generate concerns of proliferation. Uranium enrichment or reprocessing facilities may use the raw materials – enriched uranium or plutonium – that constitute the basis of nuclear weapon production. The same technologies that are needed to enrich uranium to make reactor fuel and to separate plutonium from spent fuel to be used in fresh reactor fuel can be used to produce the fissile material needed for nuclear weapons.

The training of personnel to design, operate and regulate such plants would also provide the skilled labor necessary to move to the construction of nuclear weapons [11].

Therefore, the potential expansion of nuclear power plants and fuel cycle plants in developing countries exploring nuclear energy as a potential option cause a growing concern in major developing countries about proliferation of nuclear materials and the capability to manufacture nuclear weapons. Thus, international rules are imposed on the transfer of sensitive nuclear technologies starting with enrichment and reprocessing technologies. Detailed information regarding the referred rules formulated by the Nuclear Suppliers Group (NSG) has been assessed extensively in the analysis within this report by Sinan Ülgen and Aaron Stein on the transfer of nuclear technology.

Due to the association between the proliferation of nuclear weapons and such technologies, efforts for internationalization of fuel cycle services have recently been intensified and a number of proposal have been made with regard to this topic for the purpose of enabling countries to forego the establishment of indigenous enrichment capabilities. The aim of internationalization of fuel cycle efforts to enable countries using nuclear power feel more secure upon assuring reliable fuel supply for their reactors and thus deter them from building their own enrichment facility [11].

Turkish decision makers should encourage independent research to analyze in detail the interplay of these factors. They should then make a decision by evaluating the different options and associated risks. The following can be stated as a result of an initial evaluation:

Turkey has announced a new national energy strategy including the initiation of nuclear energy production. The process for the establishment and licensing of the first power plant in Akkuyu has been initiated. In addition, statements have been made, confirming that the nuclear program will continue also after Akkuyu. In fact, negotiations have begun with Japan, South Korea, China and Canada for the construction of the country's second nuclear power point near Sinop on the Black Sea coast. The planned and proposed power reactors of Turkey have been presented in Table 7. Although there have been no clear plans announced regarding fuel cycle capabilities, it is clear that Turkish leaders have not ruled out this option. While speaking about NPT states' right for Uranium enrichment in the context of Iran, Prime Minister Erdogan stated that if needed for its civilian nuclear program, Turkey would also go ahead with domestic uranium enrichment [12].

**Table 7.** Planned nuclear reactors

| | Reactor type | Mwe gross | Start construction | Start operation |
|---|---|---|---|---|
| Akkuyu 1 | VVER-1200 | 1200 | 2013 | 2018 |
| Akkuyu 2 | VVER-1200 | 1200 | | 2019 |
| Akkuyu 3 | VVER-1200 | 1200 | | 2020 |
| Akkuyu 4 | VVER-1200 | 1200 | | 2021 |
| Sinop 1 | APWR? | 1550 | | 2019 |
| Sinop 2 | APWR? | 1550 | | 2020 |
| Sinop 3 | APWR? | 1550 | | ? |
| Sinop 4 | APWR? | 1550 | | |

# 4- Concluding Remarks

While switching to nuclear power, making the best suitable technology and fuel cycle choices is vitally important for a country. Other major decisions are related to the front end (enrichment) and back end (spent fuel management). For the near and medium term, Open Cycle operating Advanced Light Water Reactors is recommended, since they are the most economic, safe and appropriate option. Whereas closed or partially closed fuel cycles including reprocessing and recycling are not recommended, as they are not expected to become economically viable for the foreseeable future. Moreover, it is seen from past and current operating practices that there is no clear advantage of the reprocessing option either in terms of waste volume or repository area. For spent fuel management, the "wait and see" strategy based on long term temporary (interim) storage is recommended. However, temporary storage should be considered as an integral part of the reactor installation and relevant physical and legal infrastructure should be established. At this stage, establishment of its own enrichment facility does not seem economically feasible and reasonable for Turkey. Economic justification of a decision for the establishment of enrichment facilities depends on future development and realization time period of its nuclear program. But, these aspects may be strategically important from a security and energy security perspective. However, due to the association made by the international community, between the nuclear fuel cycle and the potential proliferation of nuclear weapons, the question of whether "Turkey should establish its own enrichment facility", will remain on the agenda in the foreseeable future as a thorny question where the international political context will play a more decisive role than a purely economic assessment.

Finally, due to the risks related to environment, proliferation and public health associated with it, nuclear energy is a subject of interest to a broad spectrum of people ranging from the local community to people in neighboring countries as well as the international community. As with all topics related with nuclear energy, a maximum degree of transparency and, ultimately, an effective public participation in the decision making process should be sought with regard to fuel cycle and especially about the disposal mode of spent fuels. First of all, the Ministry of Energy and the Turkish Atomic Energy Authority should establish long term strategies and a "White Paper" should be published and shared with the public opinion[2]. It is vitally important to establish a base for polyphonic debate and ensure the participation of all the stakeholders and citizens to the decision-making process, especially related to major nuclear matters. The policies to be implemented will become ethically justifiable and maintain their sustainability in the long term if a consensus is achieved between the public opinion and the decision makers.

2_ The White Paper published in 2008 by the United Arab Emirates on their nuclear strategy and long term goals can be accessed at http://www.uaeembassy.org/sites/default/files/UAE_Policy_Peaceful_Nuclear_Energy_English.pdf

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# Section V

# A Regulatory Authority for Nuclear Energy: Country Experiences and Proposals for Turkey


İzak Atiyas & Deniz Sanin

# Executive Summary

The regulatory framework in the field of nuclear energy is actually composed of two key components. The first consists of the norms, standards, rules and recommendations established by international agreements and international organizations. The second consists of the elements of the regulatory framework prepared individually for each country. As it may be observed below, the most important of these elements is the establishment of a regulatory authority. The degree of independence of this authority, its powers, the extent of transparency in the activities to be conducted; in short the organizational and managerial characteristics of the regulatory authority are among the most important factors determining the quality of the regulatory framework.

Among these characteristics, emphasis should be placed on the independence of the authority. Nuclear energy generation comprises many financial and safety risks. These financial and safety risks are not independent from each other. Regulations aiming to maintain the safety risks at a reasonable and acceptable level generally increase, at the same time, the costs of activities such as construction, operation and management of spent fuel and waste. Moreover, the implementation of these regulations may sometimes give rise to interruptions in electricity generation at times of risk. Therefore, the priorities of the power plant operator and even of the Ministry responsible for electricity supply may not always be in line with the principles and regulations relating to safety and may even be in conflict with each other in many cases. In that case, it is highly critical, in ensuring nuclear safety, to adopt the regulatory decisions regarding safety independently from the power plant operator or the relevant ministry, sometimes even in opposition to their interests. So, administrative independence is regarded as one of the key prerequisites for ensuring an independent decision making process.

Yet, although the compatibility of regulations with internationals standards is often necessary for the high quality of regulations, this is not sufficient. The quality of regulations will also depend on the nature of enforcement . Here, again the independence of the regulatory authority will be one of the key determinants of the quality of enforcement. In literature a distinction is made between de-jure independence and de-facto independence. While many regulatory authorities in many countries appear to be independent in the legal sense, that is internationally accepted conditions for independence are fulfilled , there may not be any independence in the factual sense. This leads to the following outcome: the fulfillment of legal conditions for independence may not be sufficient for the fulfillment of factual independence.

Another factor impacting the quality of regulation is transparency and accountability. The scope of the transparency principle referred to here is considerably wide. The openness of the decisions to the public, for example their publication on the official gazette and most importantly on the website of relevant authorities is one the most basic conditions of transparency. However, transparency also requires that the justifications of these decisions are presented to

the public. Likewise, the public accessibility of the decision making processes is a characteristic enhancing transparency. In countries where the level of transparency is high, also the processes for preparing rules and regulations are accessible by the public, ensuring that public consultations are always carried out in a systematic manner.

Another factor impacting regulatory quality is technical capacity and, more generally, the quality of human capital. Many decisions of regulatory authorities require expertise in technical subjects. The presence or absence of this expertise depends on the education system in the country, on the characteristics of the personnel regime of the regulatory authority as well as on the degree of prevalence and strength of the merit system. Certainly, in a field like nuclear energy, the presence of technical capacity will depend on the presence of nuclear engineering and similar university programs in the country. In case the efforts aimed at developing nuclear energy comprise plans and programs focused on remedying the limitations, technical capacity will become a less important limitation in time. In a way, it would be more appropriate to consider that technical capacity "is a limitation that may be remedied", that is to think that it is also a result of quality as much as being a factor impacting the regulatory capacity. A regulatory authority that would like to produce high quality work may create adequate technical capacity.

Abovementioned principles (compliance of regulations with international standards, independence of the regulatory authority, transparency and technical capacity) will certainly have a critical importance also in the field of nuclear energy. Safety is one of the most important goals in nuclear energy regulations. Weakness in regulatory and supervisory framework in the field of safety will increase the possibility of accidents and the public cost of an accident is significantly high. On the other hand, deficiencies in the regulatory and supervisory framework have played a major role in nuclear accidents. The lessons drawn from the Fukushima nuclear accident are highly striking in this area.

### *The situation in Turkey*

Currently, the regulatory authority in the field of nuclear energy production is TAEK. There seems to be a consensus in Turkey on the view that TAEK does not bear the characteristics of an independent regulatory authority according to international norms. However, it appears like this consensus is formed because TAEK performs development activities and operates the reactor in addition to regulating and inspecting. So, according to this perception, the sole or the most important obstacle standing in front of the independence of TAEK is the development activities performed by TAEK. It would be beneficial to review the institutional characteristics of TAEK to show that this is not the case. In summary, TAEK is not independent not only because it performs development activities in the field of nuclear energy or because it operates the reactor; it also does not avail of other key legal and institutional characteristics of independence. The new authority to be established should avail of these characteristics of independence.

On the other hand, the presence of these legal characteristics in a regulatory authority does not guarantee actual or de-facto independence. These characteristics are required but are not sufficient. To give a very simple example: there is a considerable weight of the political authority in the process of appointing managers of any authority. In case the closeness to the political authority precludes the principle of merit in the management of the authority during the appointments, independence would de-facto receive a severe harm. According to the institutional characteristics of the country, various methods may be used by the political authority or the establishment under inspection for influencing the decisions of the regulatory authority.

Another measure aimed at ensuring the accountability of the regulatory authority, and thus the high regulatory quality, is transparency. Transparency may also play a role in ensuring de-facto independence. There are no provisions on transparency in the TAEK Law. The topic of transparency should be extensively tackled in the establishment law of the regulatory authority and measures should be adopted for ensuring that the agency conducts its regulatory activities in a transparent manner.

In addition to the institutional elements discussed above, it is known that there are major deficiencies in terms of legislations and regulations in the legal and regulatory framework with regard to nuclear energy in Turkey. For instance, there are major deficiencies in the legal and regulatory framework in Turkey about spent fuel and decommissioning of power plants.

Finally, another important factor impacting the quality of the regulatory framework relating to nuclear energy is the presence of adequate human capital. Therefore, relevant planning should certainly be made, a pool with an adequate number of experts should be created and a human resources plan should be made for the relevant training of experts for this important element of the regulatory framework. In Turkey there are universities providing graduate and undergraduate education in the field of nuclear engineering. In case the right planning is made via this infrastructure, no major limitation should be expected with regard to human resources.

Actually, these deficiencies reflect the presence of a larger and more fundamental problem. Turkey does not yet have an integrated policy with regard to nuclear energy. First of all, the political authority has not yet presented a serious study comprising a critical analysis on whether the country need a nuclear power plant and discussing the benefits and costs of nuclear energy compared to its alternatives. The process of creating such a study should be in the form of a process where the views of the public are received and responses to these views are provided. After this stage, there is the need for a policy document indicating how the nuclear policy will be developed, how the relevant legal and regulatory infrastructure is to be formed, how the safety culture will be created and what type of steps are to be taken in topics such as spent fuel and decommissioning. These documents should be prepared in a participatory manner, the public should be informed, their views should be received and sufficient responses should be provided to these views.

# 1- Introduction and Some Key Principles

The objective of this study is to discuss the characteristics of the regulatory framework in the field of nuclear energy in Turkey in light of international trends and country experiences and examine the qualifications required in an independent regulatory authority.

The regulatory framework in the field of nuclear energy is actually composed of two key components. The first consists of the norms, standards, rules and recommendations established by international agreements and international organizations. The second consists of the elements of the regulatory framework prepared individually for each country. As it may be observed below, the most important of these elements is the establishment of a regulatory authority. The degree of independence of this authority, its powers, the extent of transparency in the activities to be conducted; in short the organizational and managerial characteristics of the regulatory authority are among the most important factors determining the quality of the regulatory framework.

Among these characteristics, emphasis should be placed on the independence of the authority. Nuclear energy generation comprises many financial and safety risks. These financial and safety risks are not independent from each other. Regulations aiming to maintain the safety risks at a reasonable and acceptable level generally increase, at the same time, the costs of activities such as construction, operation and management of spent fuel and waste. Moreover, the implementation of these regulations may sometimes give rise to interruptions in electricity generation at times of risk. Therefore, the priorities of the power plant operator and even of the Ministry responsible for electricity supply may not always be in line with the principles and regulations relating to safety and may even be in conflict with each other in many cases. In that case, it is highly critical, in ensuring nuclear safety, to adopt the regulatory decisions regarding safety independently from the power plant operator or the relevant ministry, sometimes even in opposition to their interests. So, administrative independence is regarded as one of the key prerequisites for ensuring an independent decision making process.

The subject of independent administrative authorities is not new for Turkey. The Capital Markets Board of Turkey was established in 1982, while the Competition Authority was founded in 1997. Independent administrative authorities were established in the fields of banking, electronic communication, energy and public procurement at the end of 1990s and during 2000s. International regulations and especially those formulated in the European Union played a guiding role in most of these fields have constituted the backbone of the regulations drafted at the national level in many fields. For instance, the regulations and notifications prepared in Turkey in the fields of energy and electronic communication were – mostly - prepared in line with the EU directives. In the field of competition law, the decisions of the European Commission and the European Court of Justice constitute an example for the decisions of the Competition Authority. Likewise, the main regulations of the Banking Regulatory and Supervisory Agency are in line with the recommendations of the Bank for International Settlements (BIS) and the EU directives.

Yet, although the compatibility of regulations with internationals standards is often necessary for the high quality of regulations, this is not sufficient. The quality of regulations will also depend on the nature of enforcement . Here, again the independence of the regulatory authority will be one of the key determinants of the quality of enforcement. In literature a distinction is made between de-jure independence and de-facto independence. While many regulatory authorities in many countries appear to be independent in the legal sense, that is internationally accepted conditions for independence are fulfilled , there may not be any independence in the factual sense. This leads to the following outcome: the fulfillment of legal conditions for independence may not be sufficient for the fulfillment of factual independence. To give an extreme example, if the decisions of a Chairman holding a managerial position in an authority or a Board fulfilling the legal independence conditions are exposed to the pressure of the establishment inspected or regulated by the relevant Minister or authority and if this impacts the decisions adopted, then it would be hard to talk about a real independence.

Another factor impacting the quality of regulation is transparency and accountability. The scope of the transparency principle referred to here is considerably wide. The openness of the decisions to the public, for example their publication on the official gazette and most importantly on the website of relevant authorities is one the most basic conditions of transparency. However, transparency also requires that the justifications of these decisions are presented to the public. Likewise, the public accessibility of the decision making processes is a characteristic enhancing transparency. In countries where the level of transparency is high, also the processes for preparing rules and regulations are accessible by the public, ensuring that public consultations are always carried out in a systematic manner. The publication of comments received during consultations on the website of the relevant authority is another element enhancing transparency. For instance, it has become a standard activity in Turkey to publish the regulations before they are finalized by independent authorities. However, comments provided on drafts are published very rarely.Why is transparency important and how does it impact regulatory quality? In environments where there is high transparency, newspapers, televisions, NGOs, trade unions, universities, academicians, specialist and advisory organizations in the private sector and lawyers may follow up regulatory decisions, criticize these decisions and propose alternatives; and, most importantly, may take legal action against decisions which they believe are unlawful. This type of monitoring, criticism and evaluation activities and the possibility of taking legal action may force the authority to take the decision making process seriously right from the beginning, which would enhance the quality of regulatory decisions. For instance, the fact that the Turkish Competition Authority was obliged to publish justifications for its decisions most probably had a major impact on the quality of the Board’s decisions.

Another factor impacting regulatory quality is technical capacity and, more generally, the quality of human capital. Many decisions of regulatory authorities require expertise in technical subjects. The presence or absence of this expertise depends on the education system in the country, on the characteristics of the personnel regime of the regulatory authority as well as on the degree of prevalence and strength of the merit system. Certainly, in a field like nuclear energy, the presence of technical capacity will depend on the presence of nuclear engineering and similar university programs in the country. In case the efforts aimed at developing nuclear energy comprise plans and programs focused on remedying the limitations, technical capacity will become a less important limitation in time. In a way, it would be more appropriate to consider that technical capacity "is a limitation that may be remedied", that is to think that it is also a result of quality as much as being a factor impacting the regulatory capacity. A regulatory authority that would like to produce high quality work may create adequate technical capacity.

Abovementioned principles (compliance of regulations with international standards, independence of the regulatory authority, transparency and technical capacity) will certainly have a critical importance also in the field of nuclear energy. Safety is one of the most important goals in nuclear energy regulations. Weakness in regulatory and supervisory framework in the field of safety will increase the possibility of accidents and the public cost of an accident is significantly high.[1] On the other hand, deficiencies in the regulatory and supervisory framework have played a major role in nuclear accidents. The lessons drawn from the Fukushima nuclear accident are highly striking in this area. The following was stipulated in the investigation report[2] prepared by the Japanese Parliament pursuant to the accident: "The TEPCO Fukushima Nuclear Power Plant accident was the result of collusion between the government, the regulators and TEPCO, and the lack of governance by said parties. They effectively betrayed the nation's right to be safe from nuclear accidents. Therefore, we conclude that the accident was clearly 'manmade.' We believe that the root causes were the organizational and regulatory systems that supported faulty rationales for decisions and actions, rather than issues relating to the competency of any specific individual."[3] Indeed the report demonstrates that the Nuclear and Industrial Safety Agency (NISA), which was the regulatory authority during that period, and TEPCO were aware of some safety gaps, but that NISA did not prepare the relevant regulations or did not force TEPCO to adopt relevant measures. NISA was reporting to the Ministry of Economy, Trade and Industry, responsible for developing nuclear technology. Pursuant to the Fukushima report, regulatory and supervisory role was assigned to the Nuclear Regulation Authority established under the Ministry of Environment. Hence, the

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1_ EDAM "Nükleer Enerjye Geçişte Türkiye Modeli" (Turkish Model for Transition to Nuclear Energy), 2011. See particularly Section 1 entitled "Türkiye'de Nükleer Enerjiye Geçişin Emniyet ve Güvenlik Yönlerine İlişkin Değerlendirme" (Study on the Security and Safety Aspects of Switching to Nuclear Power in Turkey) and Section 2 entitled "Büyük Nükleer Kazalar ve Nükleer Enerji Teknolojinin Evriminde Doğurdukları Sonuçlar" (Major Nuclear Accidents and Their Implications for the Evolution of Nuclear Power).

2_ The National Diet of Japan, The Official Report of the Fukushima Nuclear Accident Independent Investigation Commission, http://naiic.go.jp/en/

3_ "The TEPCO Fukushima Nuclear Power Plant accident was the result of collusion between the government, the regulators and TEPCO, and the lack of governance by said parties. They effectively betrayed the nation's right to be safe from nuclear accidents. Therefore, we conclude that the accident was clearly "manmade." We believe that the root causes were the organizational and regulatory systems that supported faulty rationales for decisions and actions, rather than issues relating to the competency of any specific individual."

goal of separating the function of developing nuclear energy and the regulatory and supervisory function, which is one of the first rules of independence in the field of nuclear energy in international literature, was achieved only in 2012 in Japan.

This study is organized as follows. In the next section some key international and EU norms will be reviewed with regard to the topic of nuclear safety and regulations. Some country experiences will be discussed in the third section. The regulatory framework will be assessed in light of these discussions and future-oriented proposals will be presented in the fourth and final section.

# 2- International Norms

## *2.1. Rules of the Convention on Nuclear Safety and the International Atomic Energy Agency (IAEA)*

Particularly after the Chernobyl accident which occurred in 1986, efforts aimed at harmonizing the standards relating to safety in nuclear energy at an international level and establishing them on joint common principles have accelerated. A series of international agreements resulted from these efforts. Maybe the most important of these joint efforts was the Convention on Nuclear Safety (CNS)[4], adopted in Vienna in 1994 and enforced in 1996. The purpose of CNS was to ensure that the signatory parties, that have established international standards, commit to establish a high level of safety. Generally, the liabilities of the parties are based on IAEA standards. Among the liabilities emphasized in the convention, there is the establishment of a regulatory authority for implementing the legal and regulatory framework in the field of nuclear safety, furnishing it with relevant powers, and the efficient separation of the agency with regulatory functions from the agencies developing and using nuclear energy (Article 8).

However, the Convention does not have any power of sanction. No supervisory mechanism is established over signatory countries. The Convention foresees that the parties submit reports showing to what extent they have fulfilled their liabilities and that these reports are exposed to a peer review in the meetings held regularly once every 3 years. The main sanction mechanism is composed of these peer reviews. The parties may express their views regarding each other's report in these meetings and are expected to consider these views (Stanic, 2010).

The most important agency establishing international standards in the field of nuclear safety is IAEA. One of the main duties of IAEA is to prepare international standards, rules and guidelines for the purpose of enhancing the nuclear safety regime. The revision of process of these standards began in mid 1990s. In 2006, IAEA adopted the "Fundamental Safety Principles".[5] There are 10 fundamental

4_ Another critical agreement on nuclear safety is the "Joint Convention on the Safety of Spent Fuel Management and on the Safety of radioactive Waste Management". OECD (2006) provides detailed information about international law in the field of nuclear energy. For a recent evaluation, see Kuş (2011).

principles identified regarding nuclear energy in this document. These 10 fundamental principles may be summarized as follows:

1. The prime responsibility for safety must rest with the person or organization responsible for facilities and activities that give rise to radiation risks.
2. An effective legal and governmental framework for safety, including an independent regulatory body, must be established and sustained.
3. Effective leadership and management for safety must be established and sustained in organizations concerned with, and facilities and activities that give rise to, radiation risks.
4. Facilities and activities that give rise to radiation risks must yield an overall benefit.
5. Protection must be optimized to provide the highest level of safety that can reasonably be achieved.
6. Measures for controlling radiation risks must ensure that no individual bears an unacceptable risk of harm.
7. People and the environment, present and future, must be protected against radiation risks.
8. All practical efforts must be made to prevent and mitigate nuclear or radiation accidents.
9. Arrangements must be made for emergency preparedness and response for nuclear or radiation incidents.
10. Protective actions to reduce existing or unregulated radiation risks must be justified and optimized.

These principles are not binding; in other words, IAEA does not have any power of sanction over member countries within the framework of these principles. These principles are regarded as recommendations for member countries.[6]

IAEA's rules and principles regarding safety are undergoing a restructuring process. In addition to these Fundamental Safety Principles that apply for all nuclear facilities and activities, also 7 "General Safety Requirements", which also apply for all facilities and activities, have been identified:

1. Legal and regulatory framework for safety
2. Leadership and management for safety
3. Radiation protection and safety of radiation sources
4. Safety assessment for facilities and activities

5_ Fundamental Safety Principles, Safety Standards Series No SF-1, www-pub.iaea.org/MTCD/publications/PDF/ Pub1273_web.pdf. For a summary, see Stanic (2010).

6_ The legal status of these principles may be compared with the safeguards also implemented by IAEA. The main goal of the safeguards system is to prevent the proliferation of nuclear weapons and abuse of nuclear technology. The nuclear safeguards system is composed of a series of detailed measurements used by IAEA for inspecting the accuracy of the reports of the countries with regard to nuclear activities and materials. Countries that have signed the safeguards agreement with IAEA thus also accept this inspection.

5. Predisposal management of radioactive waste
6. Decommissioning and termination of practices
7. Preparedness for emergency and intervention

IAEA has also published the General Safety Guides on these requirements.

IAEA developed a key approach on what needs to be done by countries that decide to develop nuclear energy. This fundamental approach is called "Milestones in the Development of a National Infrastructure for Nuclear Power" (IAEA 2007). This study aims to reveal in a systematic manner the steps that are required to be taken by the countries that plan to establish a nuclear power plant. The study is based on the acknowledgement that entering the field of nuclear energy is an extremely complicated process. The referred infrastructure encompasses a number of elements ranging from the choice of location, physical facilities and equipment to the relevant legal and regulatory framework. The study is focused especially on planning, tender preparation, construction and commissioning phases. However, also the operation, radioactive waste management and decommissioning phases have been considered as much as required in the initial plan. According to the study, also issues relating to phases such as operation, spent fuel and waste management and decommissioning should be considered at the phase of participation in the tender and the planning process should be initiated regarding these topics. As it will be discussed below, it is stated that the United Arabic Emirates is trying to structure its nuclear energy generation process in line with the recommendations of this study.

Finally, it would be beneficial to summarize what IAEA understands from the independence of the regulatory authority. One can look at the booklet entitled "Independence Regulatory Decision Making" of the International Nuclear Safety Advisory Group (INSAG), dated 2003, regarding this topic.[7] In this document the following are presented among the measures highlighted for ensuring independence in the regulatory decision making:

1) An effective separation of the regulatory functions and the nuclear energy development or utilization functions
2) Adoption of adequate legal measures for enabling regulatory decisions to be independent from external factors
3) Existence of a legal appeal option
4) Presence of a sufficient budget for the regulatory authority and its non-subjection to the approval of organizations developing and utilizing nuclear energy
5) Ensuring that regulatory decisions are open to public scrutiny
6) Assessment of regulatory performance

Moreover, some other measures, which aim to ensure independence in international literature with regard to regulatory authorities, are also highlighted. The first of

7_ www-pub.iaea.org/MTCD/publications/PDF/Pub1172_web.pdf these is the fact that the decisions of the independent authority are not subjected to any approval or inspection at a political level and are open only to legal appeal. The second is the fact that persons appointed to the management of the regulatory authority are appointed for a given period of time and that their employment may be terminated before the end of their term in case of misconduct or crime.

## *2.2. EU Nuclear Safety Directive*

The European Atomic Energy Community (EAEC or Euratom) was established in 1957 for coordinating the researches of member states focused on the peaceful use of nuclear energy. However, the topic of nuclear safety was not covered by a regulation at the EU level until recently. But, with the increase in nuclear power plant investments on one side and considering nuclear energy as an instrument for ensuring security of supply at the EU level prior to the Fukushima accident on the other side, as well as the concerns with regard to the safety of nuclear power plants in some of the new member states that joined the EU in 2004 led to efforts for the establishment of a legal framework on the safety of nuclear energy at the EU level. As a result of these efforts, the Council of the European Union adopted a directive forming the "community framework for the nuclear safety of nuclear installations" ("the EU Directive") in 2009. [8]

The basis of the referred directive contains certain standards of CNS and IAEA. As all EU member states and Euratom members of CNS anyhow, the directive refers to principles which are already engaged by member states. However, the important aspect of the directive is the fact that it comprises binding rule and measures. Member states that do not comply with the rules and measures may be confronted with sanctions.

With regard to the content of the Directive: the scope of the Directive has been kept wider than the scope of NCS. NCS only comprises nuclear power plants and the radioactive substance storage and processing facilities located in their place while the Directive encompasses also nuclear fuel generation, enrichment, reprocessing, waste storage and nuclear research reactors in addition to nuclear power plants. Stanic (2012) emphasizes that the Directive aims a minimum safety level regarding safety instead of presenting a specific legal and regulatory framework.

According to Article 4 of the Directive, each member state is obliged to establish a national legal, regulatory and organization framework with regard to nuclear safety. This framework should identify the responsibilities in the following fields:

- Identification of national nuclear safety requirements
- Licensing regime
- Inspection of nuclear safety

8_ Council Directive 2009/71/EURATOM of 25 June 2009 establishing a Community framework for the nuclear safety of nuclear installations. This was followed by the directive on spent and radioactive waste adopted in 2011 (Council Directive 2011/70/Euratom of 19 July 2011 establishing a Community framework for the responsible and safe management of spent fuel and radioactive waste).

· Sanctions including amendment of the license and its annulment

As in CNS, the operator holds first degree responsibility with regard to nuclear safety. Article 5 of the Directive is about the qualifications of the regulatory authority. Here, the need for the authority "to be effectively independent" was highlighted. In other words, the Directive emphasized that the authority should be not only de-jure independent, but also de-facto independent.

Member states are obliged to submit a report analyzing the degree of enforcement of the Directive until 2014. Consequently, they will be obliged to submit a report once every three years. Differently from CNS, in case of failure to submit the report, a sanction at the EU level may be applied. Furthermore, member states are obliged to conduct a self-assessment subjected to a peer review once every 10 years.

According to Stanic (2012), there are two main deficiencies in the Directive. Firstly, the Directive does not give green light to the inspection of nuclear power plants by the Commission directly or maybe by surprise inspections. Independent inspection will continue to be conducted not by the affiliate organizations of the Commission but by the regulatory authorities of countries. Secondly, it is not mandatory to make the reports public.

# 3- Country Examples

It may be stated that the corporate alternatives relating to the regulatory framework in the field of nuclear energy are shaped around two main models. In the first of these models there is no clear cut separation between the development/promotional function of nuclear energy and the dimensions of safety and inspection. For instance, both functions may be organized as different offices under the umbrella of a specific ministry. Although the functions are transferred to different bodies in time, it would not be possible to talk about a clear independence between the two functions. Probably, it is implicitly acknowledged at the basis of this model that there is a no clear conflict of interests between the functions of promotion and inspection. It may be stated that especially in countries where nuclear energy investments are performed by the public and particularly until recently this was the prevalent model. Until 2006, the nuclear energy programs appear to be shaped around this model although at different degrees in countries such as France, China, Korea and India. The other model is the independent administrative authority model. We may say that this model is applied since 1970s in the US where the private sector plays a major role in the investments right from the beginning. Individual country examples may certainly comprise the elements of both of these models. However, in recent years and especially pursuant to the Fukushima accident there seems to be a predisposition towards the model of an independent regulatory authority at the international level and a significant emphasis on transparency. In fact, the changes that have occurred recently in France, Korea and Japan appear to be examples of the predisposition towards the independent regulatory authority model.

## *3.1. United States of America*

In the US, the main law regarding nuclear energy is the Atomic Energy Law dated 1954. This law has removed the monopoly of the federal government over the activities relating to the generation and use of radioactive materials and paved the way for the participation of the private sector in these activities in addition to the field of defense. The Atomic Energy Commission (AEC) was established with the same law. AEC was abolished with a law issued in 1974, the duties of licensing and inspection were transferred to the Nuclear Regulatory Commission (NRC) established with the said law and currently continues to perform the duty of regulatory authority in the field of nuclear energy in the US. There are 5 members appointed by the President in the Commission. The members serve for a period of 5 years. The President may dismiss a commission member only in case of neglect of duty, lack of efficacy or abuse of position. Such a decision would also require the approval of the Senate.

The main duty of NRC is to ensure that the use of nuclear materials and facilities is in line with the goals of public health, defense of the US and protection of the environment. It avails of tools such as establishing standards, imposing rules, issuing licenses, technical reviews and inspection in order to fulfill this duty. NRC also avails of powers such as suspending the operation and imposing a penalty. Moreover, non-compliance to some regulations of the NRC may constitute a crime (OECD 2008).

There are offices working in affiliation with the Commission or the Chairman of the Commission. Among these, the Office of the Nuclear Reactor Regulation (NRR) is responsible for ensuring public health by licensing and supervision/inspection. This is the largest office within NRC. Another important office is the Office of New Reactors, NRO. The duty of this office, which was established in 2006, is to approve the safety of the reactors to be established for the first time in the US prior to the application for a license. The first stop of the approval process relating to new reactors is the "design certification approval". In order to receive this approval, the applicant company submits detailed information relating to the safety characteristics of the reactor. So, in a way, the approval of a new design is not only a political decision but also a technical decision. The interesting point is that this process advances in a transparent manner. For instance, currently, NRC continues to apply the approval process for the design certification approval of the application of the Evolutionary Power Reactor, EPR[9] of the French company Areva. The documents relating to the application as well as the assessments of NRC may be downloaded from the NRC website.[10]

The following may be mentioned among the implementations of NRC with regard to transparency. Most of the meetings are open to the public and the meeting dates are announced in advance. Meeting minutes are posted on the website within two days. NRC decisions, voties and dossiers may be found on the NRC website.

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9_ The same as the model known as the European Pressurized Reactor.

10_ See http://www.nrc.gov/reactors/new-reactors/design-cert/epr/overview.html . Gopalakrishnan (2011) draws attention to the contrast between the level of transparency and institutionalization of the NRC process and the degree arbitrariness of the decision of the Indian Prime Minister for purchasing 6 EPR reactors. Certainly, there is also a striking contrast between the NRC level and the process finalized with the Akkuyu agreement.

## *3.2. France*

Nuclear energy has been a long-term strategic goal for France. The first nuclear power plant was established in 1962 in this country where there are currently 58 power plants. These power plants constitute approximately 75 percent of the electricity production in France. The first regulatory authority in the field of nuclear energy in France was established as a department of the Ministry of Industry in 1973. The Directorate General on Nuclear Safety and Radiation Protection was established in 2002. This directorate general is responsible towards the Ministry of Industry and the Ministry of Environment. The current regulatory framework in France was prepared with the nuclear transparency and safety (TSN law) adopted in 2006. Also the Nuclear Safety Authority (ASN) which is an independent authority in the field of nuclear safety was established with this law.

The decision making body of ASN is composed of a committee of 5 members. Three members of this committee, including the chairman, are appointed by the President, while one member is appointed by the President of the Parliament and the other member is appointed by the President of the Senate. The term of duty of the committee members is 6 years. Committee members may retire only when they no longer can execute their duties, upon resignation or when they are dismissed by the President in case of misconduct.

Nearly half of the 450 employees of ASN are located in different regions and 235 of the employees are inspectors. [11] ASN receives support especially from the Institute for Radiation Protection and Nuclear Safety (Institut de Radioprotection et de Sûreté Nucléaire, IRSN) for the conduct of relevant technical assessments. IRSN is a public entity providing support not only to ASN, but also to some other public agencies and especially to the energy companies EDF and AREVA. A document of agreement was signed between ASN and IRSN in order to prevent potential conflicts of interest and, furthermore, the IRSN experts working for ASN were prevented from working in the projects of operations that had a license affiliation with ASN.

One of the most important characteristics of the regulatory framework is the importance placed on transparency. Section 3 of the TSN law regulates the right of access to information about nuclear safety and radiation protection.[12] In this section, it is stipulated that the government is responsible for informing the public about the procedures and results on nuclear safety. Furthermore, it is also stated that any person is entitled to obtain information from a licensed operator about the risk of radiation and the measures adopted for preventing this risk and that any disputes arising regarding this topic will be brought before the administrative court. The way in which the referred liability for providing information is to be fulfilled is explained extensively. For instance, Article 22 foresees the establishment of a local information committee at each power plant and the participation of representatives of municipal councils, local administrations, environmental, health related organizations and trade unions. This committee may receive consulting services, and commission for emission analyses and

11_ http://www.french-nuclear-safety.fr/index.php/English-version/About-ASN

12_ http://www.french-nuclear-safety.fr/index.php/content/download/22273/123572/file/loiTSN-uk.pdf measurements; the cost of these analyses are to be covered by the government or local administrations. Moreover, a High Committee for Transparency and Information on Nuclear Security is established. This committee is composed of parliamentarians, local information committees, scientific academies, scientists to be appointed by the Parliamentary Office for science and technology and persons of similar qualifications. It is indicated that the referred committee is a debate and information forum about the activities and their impact on the environment and personal health, and that, from that respect, the committee may express its opinion regarding these topics, that it is obliged to make its views public, and that it may commission the conduct of researches and collect relevant information.

## 3.3. Korea

In Korea, technology transfer and localization played a key role in the development of nuclear energy. The construction of the first nuclear power plant in Korea began in 1971. A turn-key system was used in the construction of this power plant; in other words, the power plant was constructed by foreigners and handed over. The first three power plants were constructed through turn-key projects. The first three power plants, where the turn-key method was utilized, the participation of local companies was limited to areas where security was not important. As of the fourth power plant, contract types where the main contractor was composed of foreign companies and local companies played a role as sub-contractors were used. Choi et. al. (2009) named this period as "on the job training" and "on the job participation" period. Public design, engineering and construction companies were established in time. It was mandatory for foreign companies to work with local companies. Whereas at the end of 1980s the electricity company KEPCO became the main contractor and foreign companies became sub-contractors. The decision for local production was taken in 1989. In 1995 order was placed for OPR1000 Korean Standard Nuclear Power Plant, which was the first local production. As of 2012, there are 20 nuclear power plants in Korea, and approximately 30 percent of electricity production is obtained from nuclear power plants.

One of the main characteristics of the Korean experience was the leadership displayed by the government for reducing financial risks. Choi et. al. (2009) highlights that after the Three Mile Island (TMI) and Chernobyl accidents, the construction of nuclear power plants was significantly reduced across the world while Korea continued to construct power plants and improve the measures for increasing safety. In Korea, nuclear energy is regarded as an essential component of the national development strategy as in sectors such as petro-chemistry and shipping and different governments maintained their commitment for the construction of nuclear power plants.

One of the most important issues confronted in the construction of power plants has to do with financial risks. With regard to Korea specifically, these financial risks were undertaken by the public electricity company and implicitly by the government at the beginning of the nuclear program. KEPCO was recognized as an effectively operating company and did not encounter major difficulties in terms of borrowing in international markets. In fact, the first nuclear power plant was financed by the Eximbank loan obtained by KEPCO.

Another important aspect of Korea's strategy was composed of the strategic measures adopted for the development of an adequate technical capacity and human capital. Korea sent 310 people abroad for education between 1955-1969 and only 204 of these came back. So, at the beginning of the program, Korea was faced with a brain drain problem (Choi et. al, 2009, p. 5501). Furthermore, foreign personnel were employed in order to compensate for the deficiency in specialized personnel, including in the operation of the first nuclear power plant.

According to the study of Choi et.al. (2009), another characteristic of the development of the nuclear program in Korea was that a significant benefit had been obtained from the practices of opinion seeking and reviewing with the participation of foreign experts right from the beginning of the program. The views from local experts, IAEA and an international consultancy company were consulted for the 20-year plan which began to be prepared in 1962. The preparation of the plan itself lasted almost 6 years. The number of international conferences either organized or participated in between 1957-1968 was 47. Furthermore, 81 foreign technical experts were invited and 16 international scientific projects were conducted with IAEA.

However, the development of the regulatory framework and the establishment of a regulatory authority took a long period of time. The first nuclear law of Korea (the Atomic Energy Act, AEA) was adopted in 1958. In the same year, the Atomic Energy Department (AED) was established under the Ministry of Education. The Korea Atomic Research Institute (KAERI) was established also in 1958 for the purpose of training nuclear engineers. The nuclear energy development plan was finalized in 1968, as a result of an 8-year work. The Nuclear Safety Center began operating under KAERI in 1981. This unit was separated from KAERI in 1990, becoming a unit with regulatory functions under the name of Korea Institute of Nuclear Safety, KINS) (Choi et. al. 2009). KINS, operated in affiliation with the Ministry of Education, Science and Technology.

Until 2011, the Ministry of Education, Science and Technology (MEST) assumed a nuclear energy developing role, via KINS, both as a regulator and also through its research and development activities. The Ministry of Knowledge Economy was responsible for the construction of nuclear power plants.[13] The fact that KINS assumed the role of a regulator as well as a developer gave rise to discussions and led to efforts for the establishment of an independent regulatory authority. The Fukushima accident accelerated these efforts. Finally, the Nuclear Safety & Security Commission, NSCC was established via a law adopted in 2011. The function of MEST was restricted to nuclear research and development upon the establishment of NSCC. KINS became affiliated to NSCC.

Some measures were adopted for the independence of NSSC:[14] NSCC's independence was stipulated by law. NSSC was exempted from the law in Korea empowering the Prime Minister to annul ministerial decisions that regarded as unlawful or unfair. Commission members are appointed for a term of 3 years and they may not be removed from office except for limited cases.

13_ Nuclear Engineering International, South Korea's Regulatory Changes, http://www.neimagazine.com/story.asp?storyCode=2062223; OECD (2009).

14_ Nuclear Engineering International, South Korea's Regulatory Changes, http://www.neimagazine.com/story.asp?storyCode=2062223

One of the major lessons to be drawn from the Korean experience relates to its radioactive waste policy. During the years when the nuclear program was initiated and the first power stations were constructed, priority was placed on the topics of cost, quality and completing the power plant in time. However, not enough importance was placed on creating a public opinion and waste management. According to Choi et. al., it has become even more difficult to find a place for the wastes with the increase in the income level of the country. The fact that Korea still does not avail of a clear waste management policy is regarded as one of the weakest aspects of the nuclear program in international assessments (IEA, 2006). The policy regarding radioactive wastes was finally established with a law adopted in 2009 (Şirin, 2010). However, the problem of nuclear wastes is not yet solved. The Korean government began seeking for a place to store low and medium level wastes in mid 1980s, but the first location was found only in 2005 as a result of the objections of local inhabitants. The construction of a waste plant built in the region named Gyeongju was accepted by the locals via a referendum and the municipality received US$ 300 million from the government in return for accepting the waste plant. [15] Whereas high level wastes are still stored at nuclear power plants and the storage capacity of these plants are almost saturated. [16]

Korea attained certain achievements with regard to the exportation of nuclear power plants. For instance, the nuclear power plant construction projection of the United Arabic Emirates was won by Korea. There seems to be a rather high level of consensus in the country regarding the development of nuclear energy. However, there is also news appearing on the press, indicating that this consensus is beginning to weaken especially pursuant to the Fukushima accident. The failures occurring in nuclear power plants in recent years give rise to the development of a suspicion against nuclear energy. [17]

## *3.4. China*

In 2010, nuclear energy based electricity production constituted approximately 2 percent (70 TWh) of the overall electricity production in China.[18] China's nuclear capacity amounts to nearly 12.5 GW. Although this constitutes a very small part of the overall electricity production capacity, China has become of the countries where nuclear energy production has been increased very rapidly since mid 2000s. One of the most important reasons for tending towards nuclear energy is the rapidly increasing energy demand and the concerns relating to environmental

15_ http://thediplomat.com/2012/02/18/south-korea-nuclear-challenge

16_ "Nuclear waste disposal issue to make it hard to add nuclear reactors" Korea Economic Daily, September 18, 2012, http://english.hankyung.com/news/apps/news.view?c1=06&nkey=201209181808101

17_ For instance, due to a failure in the power plant named Kori 1 in February 2012, the plant was closed down for 12 minutes the manager of the power plant had not reported to NSSC for a period of one month. NSCC initiated an investigation upon the surfacing of this case and the manager of the company Korea Hydro and Nuclear Power (KHNP), that operated nuclear power plant resigned in April 2012 (http://www.world-nuclear-news.org/C_Kim_resigns_over_Kori_1704121.html). Due to the failures in October 2012, 2 more power plants were closed down (http://www.nuclearpowerdaily.com/reports/S_Korea_shuts_down_two_nuclear_reactors_999.html).

18_ http://www.eia.gov/countries/cab.cfm?fips=CH pollution. The goal of the government is to reach a nuclear power plant capacity of nearly 70 GW by the year 2020. There are 15 nuclear power plants in China as of 2012. The overall capacity of 30 power plants currently under construction amounts to nearly 33 GW; this means nearly half of the overall new capacity currently under construction across the world.

After the Fukushima accident which occurred in March 2011, the Chinese government began revising safety regulations and suspended the permission for new constructions until these revisions are completed. The revision process was completed at the end of 2011. The State Council adopted in May 2012 its safety plan to be applied in all power plants. Hence, the construction of new power plants is expected to be resumed.[19]

China does not have a long history in terms of interest for nuclear energy. The Chinese government approved the first project on nuclear energy in 1972. But, nuclear energy was not regarded a serious alternative even in those years. The main reason for this lack of interest was related with the large coal reserves in the country. The China National Nuclear Corporation, CNNC began the construction of the first local power plant in 1985 in Qinshan. This power plant began to operate in 1994 (Xu, 2008). As a result of the severe power cuts in the southern regions of China, two power plants were constructed with the French company Framatome in the region of Daya Bay and they began also began to operate in 1994. No other power plants were opened until 2002. In the meantime, China became a member of IAEA in 1984. Two years after, IAEA opened two centers in order to raise nuclear energy experts in China. China signed agreements with countries such as Denmark, Sweden, Finland and Norway for nuclear technology sharing and education. A total of 11 power plants began to operate in 6 regions until 2007.

The importance placed for nuclear energy increased significantly in 2000s. According to Xu (2008), this was due to 4 main reasons. Firstly, a highly significant increase occurred in energy consumption in 2000s. This led to severe supply deficits in many regions of China. Secondly, China's own energy resources began to be insufficient. In fact, China became a net oil importer in 1993 and a net coal importer since 2003. Thirdly, it is stated that coal reserves may be depleted within 25 years (Xu, p. 1199). Maybe, most importantly, coal-based electricity production led to very severe environmental problems. It is indicated that environmental pollution gives rise to very significant economic losses and that according to the World Bank data these losses reach 8 percent of the national income. Especially environmental pollution issues and increasing energy demand made nuclear energy be regarded as a serious alternative.

In fact, in the Medium and Long Term Nuclear Energy Development Plan adopted by the State Council in 2006, it was proposed to transform the role assigned for nuclear energy in economic development from "medium" to "active". In 2008, the nuclear energy development was raised from "active development" to aggressive development" (Zhou et. al., p. 772). Power plant constructions gained momentum as of mid 2000s. Eight out of 12 power plants that began to operate between 1990 and the first half of 2000s were based on foreign designs, while the share of Chinese power plants among those currently under construction is rising.

19_ Ibid.

The energy policy in China has a fragmented structure (Zhou et. al). There is a major impact of energy companies on the policy making process. For instance, the Ministry of Electric Power was abolished in 1996 and the State Power Corporation was established for the purpose of continuing the production of electricity. Administrative and regulatory functions were transferred to much smaller administrative units in time. Similar developments took place also in the field of nuclear energy. In 1980s, the Second Ministry of Machine Building which had made the first nuclear bomb in China was converted to the Ministry of Nuclear Energy. In 1999, China National Nuclear Company was established and affiliated with CNNC. China Atomic Energy Authority, CAEA, was established in the same year to function in affiliation with the Science Technology and Industry Commission for National Defense (first CSTIND, and consequently SASTIND[20]). As the importance of nuclear energy increased, the nuclear unit operating under SATINFD was moved to the newly established Nuclear Energy Office (NEB), operating under the National Development Reform Commission (NDRC). NDRC operates in affiliation with the State Council[21] and is the most competent body for Chinese economy.

The State Council is the highest policy unit in China. All policies, 5-year plans, as well as the rules relating to the implementation of nuclear energy projects are under the responsibility of the State Council. NDRC reports to the State Council. Five-year plans are prepared by NDRC. The choice of projects in the field of nuclear energy is made by NDRC. NEB prepares the nuclear development plans and manages the restructuring in the energy sector where necessary. It is indicated that CAEA manages especially the researches relating to nuclear technology and identifies the policies and arrangements relating to nuclear technology (Zhou et al. p. 774). CAEA also conducts the international cooperation on nuclear energy in China. The National Nuclear Safety Administration, NNSA) is the agency responsible for issuing licenses to nuclear power plants and regulating and supervising nuclear power plant operations and reports to the Ministry of Environmental Protection.

There are three public companies working in the field of nuclear energy: CNNC, China Guangdong Nuclear Power Corporation (CGNPC) and China Power Investment Corporation (CPIC). Among these, the most critical player is CNNC, because this company is also the owner of all nuclear construction companies. It is stated that these three companies are in a fierce competition in order to grab market share and cooperate very rarely in areas such as technology, strategy, management and similar topics (Zhou et. al. 774).

NDRC is placed at the center of the decision making process with regard to nuclear energy. When formulating its policies regarding nuclear energy, NDRC mostly bases itself on research centers, universities and establishments such as CNNC that are within the nuclear industry. NDRC submits to the State Council the policies formulated in this manner with regard to nuclear energy so that the Council may take its final decision.

During the decision process, local administrations play a major role especially in the selection of location. The central government decides on the selection of some projects, but local administrations have been competing for attracting new projects

20_ SASTIND- State Administration of Science Technology and Industry for National Defense.

21_ The State Planning Commission, with its previous name.

in recent years. In fact, three nuclear operators generally begin to prepare power plant projects together with local governments. In order to a project to receive a license, the establishment should obtain three different permits from NSAA. The first of these is regarding the selection of location. In order to receive this permit, the establishment submits to NSAA a safety report about the choice of location and an environmental impact report. A pre-feasibility report is also presented to NDRC. Upon the acceptance of the project by the State Council and the receipt of the first permit for the choice of location, a permit should be obtained for construction. In order to obtain this, the establishment submits an environmental impact assessment report relating to the construction process, a quality control report and a safety report. The third permit is issued at least 12 months before the refueling. The operation permit is issued 12 months after the first refueling.

Observers underline the fact that the Chinese government has been placing a major importance to the safety issue especially pursuant to the Chernobyl accident of 1986 (Zhou et. al., Kadak 2006). It is stated that no major safety issue has been faced so far. The inspection of safety is performed by CAEA and NNSA and the general opinion is that this inspection is in line with international standards. However, there are still major deficiencies in the legal and regulatory framework relating to nuclear energy. First of all there is not a fundamental framework law on nuclear energy. The State Council has issued three regulations regarding the management and safety implementations of civil nuclear establishments, the control of nuclear materials and emergency measures in case of accidents. The existing secondary regulation and standards are compliant with the standards determined by IAEA and the French and American authorities. Yet, NNSA, which is the main regulatory and supervisory authority, is not an independent organization. In bureaucratic hierarchy, when nuclear energy companies are directly under the State Council, NNSA reports to the Ministry of Environmental Protection. In other words, under bureaucratic hierarchy, NNSA is at a weaker position compared to the companies they inspect. NNSA does not have its own research and development unit. Therefore, for instance, it does not have a standard development capacity in cases not covered by the existing safety rules. More importantly, the number of experts working in NNSA is very limited. In this case, nuclear energy program develops very rapidly and the capacity of NNSA to conduct the relevant inspection when new power plants are established will remain highly limited. Furthermore, according to the assessment in the study by Zhou et. al., the decision making process relating to nuclear energy is not a transparent process. The criteria on which the decisions are made are not clear. Conflicts of interest may occur during the decision making processes.[22]

## *3.5. India*

India has a history of half a century in nuclear energy. The construction of nuclear power plants started in 1964 and the first two power plants began in 1969.[23] As of 2010, there are twenty nuclear reactors in the country and five reactors are currently under construction. Nuclear energy is regarded as an important component of the national development strategy. One year after gaining

22_ For instance, the persons involved in the Project preparation phase may also be included into the assessment process (Zhou et. al. p. 780)

23_ IAEA Country Profiles: India http://www-pub.iaea.org/MTCD/publications/PDF/CNPP2011_CD/countryprofiles/India/India2011.htm independence in 1947, the Atomic Energy Commission, AEC was established for the development of atomic energy in the country. The Department of Atomic Energy, responsible for nuclear technology and researches in the country and reporting directly to the Prime Ministry, was established in 1954.

The Atomic Energy Act, which was India's first law on atomic energy, was adopted in 1962. The Department of Atomic Energy Safety Review Committee, DAE-SRC was established for the safety reviews of the decommissioning and operating activities of the Tarapur Atomic Power Station (TAPS) and Unit-1 of the Rajasthan Atomic Power Station. In 1981, this committee proposed the establishment of the Atomic Energy Regulatory Board, AERB in its report entitled "Re-organization of the Inspection and Safety Functions" and AERB was established consequently (Comptroller and Auditor General of India CAGI 2012)

AERB has 10 main functions: the Board develops safety policies in the field of nuclear, radiological and industrial safety. Moreover, it also develops the safety codes, guides and positioning, construction, commissioning, operation and decommissioning standards of various types of nuclear and radiation plants. The board also grants approvals for positioning, construction, commissioning, operation and decommissioning of nuclear plants and ensures the fulfillment of inspection conditions. AERB should identify the accepted radiation exposure limits of workers and citizens and approve the release of radioactive materials at the accepted limit into the environment. AERB is also responsible for revising the emergency preparedness plans of nuclear and radiation facilities. The board should revise all educational programs relating to nuclear energy and prepare an academic program for the nuclear safety education of relevant personnel. Finally, AERB should ensure the development of researches on nuclear energy and continuously inform the public about radiological safety (CAGI, 2012).

The Board of Directors of AERB is composed of a chairman, four members and a secretary. The secretary is an employee of AERB, whereas the Board members are individuals who are government officials or persons providing service to academic institutions or national laboratories or persons who have retired from such institutions. The board is responsible to the Atomic Energy Commission, AEC and is supported by the Safety Review Committee for Operating Plants (SARCOP) and Safety Review Committee for Application of Radiation (SARCAR). SARCOP supervises and conducts the safety inspection of the nuclear power plants and other radiation facilities identified by the central government. SARCAR is the monitoring and advisory committee, reviewing the safety of the implementation of all radiation resources in AERB (CAGI, 2012).

AERB was recently inspected by the Comptroller and Auditor General of India, CAGI. The goal of the inspection was to assess whether AERB fulfills its responsibilities as a regulatory body and whether its legal status, authority and independence were in line with the standards of IAEA (CAGI, 2012).

According to the inspection report, an independent supervisory body should first of all be established by law and hold the power of making the final decisions within its sphere of influence. It should identify the standards within the sector where there is a regulatory body and establish the rules itself. It should be able to impose sanctions where the standards and rules it has established are not complied with.

The CAGI report placed a high importance to the independence of the regulatory authority. In the report reference was made to the report prepared by the independent research commission pursuant to the Fukushima accident and it was reminded that essentially the reason of accident was the fact that the regulatory authority in Japan was not independent and that there was collusion between the government, the regulatory authority and the operator.

The inspection report reached the conclusion that AERB, which is the regulatory and supervisory body with regard to nuclear energy in India, did not avail of the qualities of an independent regulatory body. CAGI reached this judgment due to the following reasons: First of all, AERB was established under the Atomic Energy Act. As it was established under this act, no special law was issued for the establishment of AERB. Thus, in the eyes of CAGI, AERB is regarded as an institution affiliated with the central government. The French and American examples were provided in the report in order to support this judgment: in France, the regulatory institution responsible for nuclear topics was established in 2006 under a special law, thus one of the abovementioned qualities of an independent inspection body was fulfilled. This is no different in the United States of America. In 1974, the Nuclear Regulatory Commission, which is the supervisory body in the country, was established with the Energy Organization Act. So, according to the report, the fact that AERB was not established with a special act as was the case of the supervisory bodies in France and the US prevents it from being independent.

Moreover, according to the report, no rule regarding nuclear energy was formulated by AERB in India. All of the rules were shaped by the Department of Atomic Energy. In fact, the opinion of DAE was consulted during the CAGI inspection: According to the explanation reflected in the DAE report, the power to establish the rules to maintain the purposes of the Atomic Act (1962) was anyhow assigned to the central government. As a result, AERB does not avail of the power to establish and shape the rules regarding nuclear and radiation safety. According to CAGI, it would be impossible to call independent a regulatory body that cannot establish its own rules. In addition to its inability to establish its own rules, AERB reports regularly to the Atomic Energy Commission which is a body affiliated with the central government. The Atomic Energy Commission is an agency with the responsibility to report to the Prime Minister.

AERB cannot be regarded as an independent institution also from the economic sense, because also the budget of AERB is shaped by the central government. AERB does not have a special budget. As a result, AERB is a supervisory organization which is position under the central government and cannot be independent because of these characteristics.

In addition of the issue of non-independence of the regulatory authority, the CAGI report also drew attention to other inadequacies. For instance, the IAEA safety standards require each country to establish a nuclear safety policy. According to the report, AERB did not establish such a policy although this task was assigned to it. In more concrete terms, as of 2012, AERB has not yet prepared 27 of the 168 codes and guidelines which it had committed to develop. Another example relates to the decommissioning of nuclear power plants. According to the report, in addition to the absence of a legal framework on decommissioning in India, AERB does not have any power besides for the preparation of advisory codes and guidelines. Although it has been 13 years since the publication of the guidelines about this topic by AERB, none of the nuclear power plants in the country have a decommissioning plan. Furthermore, the Atomic Energy Act does not include a specific provision regarding the establishment of a fund for the decommissioning of power plants. Therefore, no legal framework has been established in India with regard to decommissioning.

India's nuclear energy program seems to be inadequate in terms of transparency. According to Subarrao (2012), the public is not sufficiently informed about the nuclear energy program conducted in the country and many nuclear accidents were not disclosed to the public. For instance, a serious accident occurred in the Narora Atomic Power Station, NAPS on March 31, 1993. The accident was reported by a committee of AERB and the Nuclear Power Corporation of India Limited, NPCIL, but the report was never presented to the public (Subbarao, 2012). The collapse of the dome of the Kaiga Atomic Power Plant under construction in 1993 was one of the rare cases across the world. This accident, which could have led to a disaster if it had happened during the operation of the nuclear reactor, was investigated by AERB and NPCIL. The research results were not disclosed. Major damages occurred in the fire that broke out in the Kakrapar Atomic Power Station, KAPS, in 1991. The power plant was significantly damaged due to the flood of 1994. The public was never informed about the details of the safety problems in the power plant (Subbarao, 2012, pp. 11-18).

The absence of transparency on nuclear energy in India led to a lack of confidence for the public. The public displays a negative approach with regard to nuclear energy. Recently, during the construction of the Kudankulam Power Plant (2012), the inhabitants of this town and neighboring villages protested the power plant (Kudankulam Power Plant, 2012)[24] The inhabitants of the town expressed their concern about any accident that may occur and defended that as the power plant was located on the coast of the sea, this would have a negative impact on the fishing activities in the sea. A lawsuit was filed at the Supreme Court in order to prevent the operation of the power plant in 2012. The lawsuit petition referred to the unlawful deeds during the construction process of the Kudankulam power plant, mentioned that only 6 out of 17 additional measures proposed by AERB after Fukushima were implemented and included the claims about AERB's granting refueling approval despite this.[25] The history of the Kudankulam power plant is attracts attention also due to the fact that it displays the deficiencies of the inspection process in India. For instance, according to the agreement made with Russia in 1988, Russia was going to establish a power plant composed of two VVERS units with a power of 1000 MW, and the wastes were going to be transported to Russia. The environmental and location licenses of the project were obtained on the basis of this platform. Consequently, with an amendment made in 1989, it was decided to keep the wastes in India. Thereupon, while it was necessary to renew the environmental license in order to initiate the project, this

24_ Taken from the link:http://en.wikipedia.org/wiki/Nuclear_power_in_India; September 20, 2012.

25_ http://www.dianuke.org/koodankulam-documents-prashant-bhushans-note-in-the-supreme-court/

was not done, and the new environmental license was obtained after the initiation of the construction. Furthermore, still no decision is made about where the wastes will be stored. Moreover, no environmental approval was obtained for the major modifications in the project (e.g., renouncing the use of river water as cooling water and using desalinated sea water).

In addition to all these problems, it is also stated that the human resources in the country about nuclear energy is inadequate. The Nuclear Power Corporation Limited (NPCIL) trains the technicians, engineers and scientists that will be work in this sector in India. These trainings are provided in the nuclear training centers of NPCIL or in the DAE/BARC Training School (Jain, 2012). Although there are special schools and training centers in the country, some resources claim that the workforce in the country is not sufficiently qualified and that not even one expert works in same reactors (Subbarao, 2012, p.23). More importantly, the number of experts in AERB is limited and assistance is received from institutions such as DAE/BARC and DAE. It is highlighted that the experts working in these institutions will actually be loyal to DAE and not to AERB, which may overshadow independence.[26]

The CAGI report led to major repercussions in India. In the meantime, the Indian government took a series of steps for amending the regulatory framework. In the IAEA meeting held in September 2012, the Indian government declared that they would invite IAEA to assess the nuclear regulatory process in India.[27] The Integrated Regulatory Review Service (IRRS) provided by IAEA, comprises the assessment of a regulatory framework in a country on the basis of the IAEA standards and international agreements. Furthermore, the Nuclear Safety Regulatory Authority, NSRA Draft Law, aiming to establish a regulatory authority in the nuclear field, was presented to the parliament in September 2011. One of the most important criticisms regarding the draft law was the fact that the independence of the regulatory authority to be established was not ensured in line with international standards and insufficient importance was placed on transparency.[28]

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26_ A. Gopalakrishnan "the nuclear safety question" http://www.countercurrents.org/gopalakrishnan201211.htm December 20, 2011, accessed on October 8, 2012.

27_ India to ask IAEA for review of its nuclear regulatory process, http://zeenews.india.com/news/nation/india-to-ask-iaea-for-review-of-its-nuclear-regulatory-process_800611.html, September 19, 2012; accessed on October 8, 2012.

28_ For instance: Gopalakrishnan "Transparency in nuclear safety regulation", February 2, 2012, http://www.dnaindia.com/analysis/comment_transparency-in-nuclear-safety-regulation_1644896 Accessed on: October 8, 2012 and Gopalakrishnan "Breaking the stranglehold on the N-Safety regulator" http://www.dnaindia.com/analysis/comment_breaking-the-stranglehold-on-the-n-safety-regulator_1644897 Accessed on: October 8, 2012.

## 3.6. United Arab Emirates[29]

The interest of the United Arab Emirates (UAE) for nuclear energy is based on a study prepared by the Executive Affairs Authority of the country, analyzing the future of the country's energy supply. In this study the need to develop supply diversity, including nuclear energy, was highlighted. This study was followed by the study on the Policy of the United Arab Emirates on the Evaluation and Potential Development of Peaceful Nuclear Energy, named as the "White Book". The views of IAEA as well those of the US, France, Korea, Germany and Japan were consulted in the preparation of this study. The White Book published in 2008 highlights the following principles:

1) Commitment for operational transparency
2) Commitment for the prevention of proliferation
3) Commitment for the highest safety and security standards
4) Commitment for cooperating with IAEA for the implementation of a peaceful nuclear energy program and complying with IAEA's standards

The study also proposed concrete steps for the preparation of the relevant legal framework, international commitments and financial regulations. These steps also include the establishment of an independent regulatory authority and the formation of the legal infrastructure required for financial responsibility, spent fuel management and decommissioning. At the basis of the general approach lies the development of the nuclear energy program in line with the "Milestones" proposed by IAEA (2007) and the establishment of a Nuclear Energy Program Implementation Organization (NEPIO) to provide leadership to its implementation.

The White Book also determined certain points with regard to technology and the financing model. Thus, the technology preferred is the third generation light-water reactor, LWR technology. The financing model is the Build-Own-Operate (BOO) model and partnerships between the government and international investors are envisaged.

The White Book was followed with the study entitled "Roadmap for Success", prepared in line with the IAEA (2007) "milestones" approach, determining the details about the steps of the development of nuclear energy program. This study presented 4 options which were potentially acceptable in terms of technology. These were the Areva EPR, Westinghouse AP1000 models, Korea's KHNC APR1400 model and GE-Hitachi ABWR model.

One of the characteristics required by AEB in the project was the presentation of the quote as a whole under the responsibility of a single company, and not in the form of a consortium committing to undertake different aspects of the project. As a result of the negotiations made with construction companies, Korean KEPCO provided the most suitable quote for the demands of UAE. Hence, an agreement was signed between KEPCO and the Emirates Nuclear Energy Corporation in November 2010.

29_ The study of Ebinger et. al. (2011) was used in the preparation of this section.

Meanwhile, the Federal Authority of Nuclear Regulation, FANR, was established with a federal law issued in 2009 (Federal Law No. 6 of 2009 Regarding the Peaceful Uses of Nuclear Energy, hereafter referred to as the "UAE nuclear energy law"). FANR was established as an independent legal entity with an independent financial statement in the UAE nuclear energy law. In the law it was highlighted that FANR has full powers and administrative independence in its field of activity. FANR comprises a Board of 9 persons working a part-time basis. This board is appointed for a term of 3 years upon the decision of the Council of Ministers; this term may be renewed. The board selects a general manager. The general manager manages the two main departments of FANR, namely the Administrative Department and the Operational Department. In case of "mismanagement" by one of the Board members, he may be replaced by someone appointed in his place (Art. 13). The General Manager may be changed where this suitable for "public interest". Here, it may be underlined that the term "public interest" remains rather vague. The budget of FANR is composed of the resources provided by the government, the revenue obtained from the jobs performed and the "gifts, loans and donations" to be accepted by the Board, which "do not contradict the purposes of the authority".

In 2008, the White Board also envisaged the establishment of the nuclear energy company of UAE, named the Emirates Nuclear Energy Corporation, ENEC. ENEC was established in 2008. Its main responsibility was to undertake the ownership and operation of the power plants to be established in Abu Dhabi and to cooperate with foreign investors in the field of nuclear energy as the investment company of the Abu Dhabi government both in the domestic and foreign markets.

Based on the statements summarized above with regard to the management method of FANR, it may be said that the decision making process of FANR is independent, but independence is not achieved in terms of the administration and the budget. The noticeable aspect in the approach of UAE to nuclear energy is the preliminary preparation made the transition to nuclear energy production, rather than the characteristics related with the independence of FANR. A policy was developed before the any actual attempt, consequently the main steps relating to the development of the program were formulated, potential alternatives were presented and the negotiations with potential suppliers were initiated pursuant to this preliminary preparation phase.

# 4- The Situation in Turkey

The reason that the safety issue stands out within the regulatory framework with regard to nuclear energy is certainly the potential danger posed for the society by nuclear power plant activities. In case of an accident, not only the owners of the power plant, but also the surrounding community would incur a serious damage. In other words, a failure in the activities related to the production of nuclear energy has the potential of generating negative externality and serious damages for the society. This externality is not something that may be handled with market mechanism and the safety issue arises because of this reason. Actually, from this respect, the nuclear sector is principally not different from other sectors or activities subjected to market malfunctions. The real difference lies at the dimension of potential damage.

In many areas where market mechanism does not function properly, state intervention is generally organized through administrative authorities. In fact, the regulatory and supervisory activities in areas such the implementation of the competition policy, banking, energy, electronic communication and market economy are performed by relatively independent administrative authorities in Turkey. The independence here is certainly not absolute. First of all, the activities of such type of authorities are restricted by the main laws of the relevant institution or of the sector which they are inspecting. There is  an overall consensus that the responsibility and power of establishing sectoral policies do not belong to the regulatory authority; policy formation is the responsibility of the political authority, such as the relevant ministry. However, the quality of the regulatory framework within these limits is closely associated with how independently the regulatory authority may take decisions. In the decisions it takes, the regulatory authority is expected to be independent from the political authority and the companies or operators it is assigned to inspect. In order for the regulatory authority to be independent in its decisions, a series of institutional measures have been envisaged in international literature, including the folllowing:

1) The political authority cannot intervene directly in the decisions of the regulatory authority; for instance, it should not have the power to annul or amend the decisions
2) The chairman and/or board members of the regulatory authority, in other words persons with the power to take a regulatory decision, should be appointed for  fixed term and cannot be removed from office except for under extraordinary circumstances such as disease or misuse of authority
3) The budget of the authority should not be directly under the control of the political authority and should have its own sources of income (such as special taxes)

Certainly, being independent does not mean not being inspected or not being accountable. One of the measures ensuring accountability is to subject the decisions of the regulatory authority to judicial review (appeal). In Turkey this function is generally fulfilled by the Council of State.  The second measure is to subject the budget and performance of the regulatory authority to audit. For instance, the regulatory authority may be accountable to the Parliament or the relevant parliamentary commission each year and its budget may be inspected by the Council of State on behalf of the Parliament.

Another institutional measure required for ensuring accountability is transparency. As specified at the beginning of this study, transparency requires the decisions, the decision making process and the decision making logic to be transparent. This requires the justifications of the decisions and the technical details playing a role in decision making to be open to the public.

We would like to remind the fact that the regulations and inspections to be implemented with regard to the issue of nuclear safety will mostly contradict the interests of the political authority and the establishment being regulated and inspected. Naturally, the risk perception of the regulatory authority will be different from that of the political authority and/or the establishment. The regulatory authority should not take into account the reflection of safety related interventions on other areas. For instance, the delays to arise during the construction of the power plant due to safety inspection may directly increase the costs or lead to setbacks in the supply of electricity. Both contradict the short term interests of both the political authority and the establishment. Likewise, intervening inthe failures that may occur when the power plant begins to operate and to stop electricity production for example due to this reason may damage the interests of the political authority and/or the establishment. It is for this reason that as demonstrated by international experience, one of the most important threats standing in front of ensuring safety in nuclear energy is the weakness of the regulatory and supervisory authority, and even worse, when it is in collusion with the nuclear power plant operator. It is lessons drawn from this experience that lie behind the prominence of the measures aimed at ensuring the independence and transparency of the regulatory authority in the field of nuclear energy.

The following picture comes out when one considers Turkey's situation in light of these data: According to Provisional Article 1 of Law No. 5710, "TAEK shall continue to fulfill this function in line with the Turkish Atomic Energy Agency Law dated 9/7/1982, with no. 2690, until a new agency is established for fulfilling the duty of regulating and inspecting nuclear activities." Therefore, currently, the regulatory authority in the field of nuclear energy production is TAEK. There seems to be a consensus in Turkey on the view that TAEK does not bear the characteristics of an independent regulatory authority according to international norms. However, it appears like this consensus is formed because TAEK performs development activities and operates the reactor in addition to regulating and inspecting. So, according to this perception, the sole or the most important obstacle standing in front of the independence of TAEK is the development activities performed by TAEK. It would be beneficial to review the institutional characteristics of TAEK to show that this is not the case.

The institutional characteristics of TAEK were identified by Law No. 2690 issued in 1982. TAEK reports to the Prime Ministry. TAEK's Chairman is "selected by the Prime Minister and jointly appointed by decree" (Article 5). As indicated above, one of the internationally accepted prerequisites of enabling the regulatory authority to act independently is the inability of the political authority to remove from office the persons who fulfill the duty of chairman. Generally, this institution is clearly stated in the relevant law. In fact, in Article 24 of the Law on the Protection of Competition, it is stipulated that "The Chairman and members of the Board shall not be removed from office due to any reasons prior to the completion of their term". However, as there is no such provision in the TAEK Law, TAEK's management is directly under the control of the Prime Minister.

Another element of regulatory independence relates to the distribution of the power of regulation and decision making. Autonomy requires that the decisions and the regulations of the administrative authority are made in an independent manner, and that especially the political authority should not be directly involved in this process. Yet, this is not the case for TAEK. For instance, many critical decisions, including the adoption of TAEK's regulations (TAEK Law, Art. 6/b/2), are taken by the Atomic Energy Commission (AEC). AEC is also the critical buyer in the licensing and inspection/license cancellation process. AEC, "under the Chairmanship of the President of TAEK, consists of the Vice Presidents, one member each from the Ministries of Defense, Foreign Affairs, Energy and Natural Resources and of four faculty members in the field of nuclear energy." (TAEK

Law, Art. 6/a). According to the referred article, the Prime Minister presides to the meetings of the Atomic Energy Commission where deemed necessary. All members are appointed by the Prime Ministry and, as in the case with the Chairman, there are no provisions to prevent the arbitrary removal from office of the members. In a way, the Commission functions as a sub-branch of the Prime Ministry. In this case, it is not in line with the principles of independence. [30]

Another dimension of regulatory autonomy relates with the financial resources of the authority. The main point here is the presence of mechanisms to prevent the full financial dependence of the agency to the political authority. For instance, the main income source of the Competition Authority "is composed of payments to be made at a ratio of four out of ten-thousand of the capital of all partnerships at the status of an incorporation or limited company to be newly established, and of the remaining part in case of capital increase (Law No. 4054, Art. 39/c). Thus, the Competition Authority holds a budget that is independent from the budget of the Ministry to which it reports. Yet, the budget of TAEK is fully dependent on the budget of the Prime Ministry and its real income is composed of the allowance to be allocated for TAEK in the budget of the Prime Ministry.

Another dimension of the regulatory independence relates with the inspection of the agency. It is preferred that the inspection of the agency is not conducted by an institution directly reporting to the political authority. For instance, the financial inspection of the Competition Authority is performed by the Audit Office. The Audit Office conducts its inspections on behalf of the Turkish Grand National Assembly. Yet, TAEK is under the inspection of the High Inspection Board (HIB) of the Prime Ministry in administrative and financial topics." (TAEK Law Art. 16). Moreover, TAEK may be inspected also by the inspectors of the treasury, upon the request of HIB and the approval of the Prime Minister. In other words, TAEK is dependent on the political authority also in the field of inspection.

In summary, TAEK is not independent not only because it performs development activities in the field of nuclear energy or because it operates the reactor; it also does not avail of other key legal and institutional characteristics of independence. The new authority to be established should avail of these characteristics of independence.

On the other hand, the presence of these legal characteristics in a regulatory authority does not guarantee actual or de-facto independence. These characteristics are required but are not sufficient. To give a very simple example: there is a considerable weight of the political authority in the process of appointing managers of any authority. In case the closeness to the political authority precludes the principle of merit in the management of the authority during the appointments, independence would de-facto receive a severe harm. According to the institutional characteristics of the country, various methods may be used by the political authority or the establishment under inspection for influencing the decisions of the regulatory authority.

Another measure aimed at ensuring the accountability of the regulatory authority, and thus the high regulatory quality, is transparency. Transparency may also play a role in ensuring de-facto independence. There are no provisions on transparency

30_ Ebinger et. al. (2011, s. 34) pinpoints to another potential conflict of interest: The duty of chairmanship of AEC, which is the duty of approving the regulations of TAEK is fulfilled by the Chairman of TAEK.

in the TAEK Law. The topic of transparency should be extensively tackled in the establishment law of the regulatory authority and measures should be adopted for ensuring that the agency conducts its regulatory activities in a transparent manner. First of all, transparency requires the publication of all documents relating to regulatory work on the website of the agency, but this is not sufficient. Decision making processes should also be transparent and the public should be enlightened about the justifications of the decisions adopted. The background research and technical reports used in the decisions should be open to the public. The right of the public to obtain information should be clearly defined and the regulatory authority should be required to provide this information (in a manner so as to prevent confidential information from being disclosed). Moreover, local information committees should be established by law as in France and it should be possible for these committees to obtain relevant information about safety.

In addition to the institutional elements discussed above, it is known that there are major deficiencies in terms of legislations and regulations in the legal and regulatory framework with regard to nuclear energy in Turkey.[31] For instance, there are major deficiencies in the legal and regulatory framework in Turkey about spent fuel and decommissioning of power plants. With regard to Akkuyu specifically, as the whole responsibility about these topics is assigned to the contractor company the problem appears to be solved at least in principle in the power plant, but the deficiencies in the legal framework still continue. The problem of nuclear waste is one of the most delicate topics in the development of nuclear energy. One of the important lessons to be drawn especially from the Korean experience is that governments are unwilling to take steps to solve this problem, that they display a tendency to delay the solution of the problem over a period of time while the solution of this problem in a competent nuclear energy policy should be taken up at the beginning. Likewise, there are serious ambiguities about financial liabilities and insurance.

Actually, these deficiencies reflect the presence of a larger and more fundamental problem. Turkey does not yet have an integrated policy with regard to nuclear energy.[32] First of all, the political authority has not yet presented a serious study comprising a critical analysis on whether the country need a nuclear power plant and discussing the benefits and costs of nuclear energy compared to its alternatives. The process of creating such a study should be in the form of a process where the views of the public are received and responses to these views are provided. After this stage, there is the need for a policy document indicating how the nuclear policy will be developed, how the relevant legal and regulatory infrastructure is to be formed, how the safety culture will be created and what type of steps are to be taken in topics such as spent fuel and decommissioning. These documents should be prepared in a participatory manner, the public should be informed, their views should be received and sufficient responses should be provided to these views.

Finally, another important factor impacting the quality of the regulatory framework relating to nuclear energy is the presence of adequate human capital.[33] Therefore, relevant planning should certainly be made, a pool with an adequate number of experts should be created and a human resources plan should be made for the

31_ For instance see Şirin (2010)

32_ There is a document entitled "Information on Nuclear Power Plants and the Nuclear Power Plant to Be Established in Our Country" on the website of the Ministry of Energy and Natural Resources. This document is far from being a "policy book".

33_ See Ebinger (2011) with regard to the education in the nuclear field.

relevant training of experts for this important element of the regulatory framework. In Turkey there are universities providing graduate and undergraduate education in the field of nuclear engineering. In case the right planning is made via this infrastructure, no major limitation should be expected with regard to human resources.

# 5- Conclusion and Recommendations

In this study, some characteristics that a regulatory authority to operate in the field of nuclear energy in Turkey should have were highlighted in light of international trends and country experiences. One of the most important purposes of the regulatory and supervisory work in the field of nuclear energy is to ensure that the activities related with the production of nuclear energy are conducted in line with internationally accepted safety standards. The standards in this field are determined by international agreements and the work of IAEA. Also the European Union began to produce its own directives with regard to nuclear safety. The whole set of these international rules constitutes one of the main elements of the laws and regulatory framework of nuclear energy.

The second main component of the legal and regulatory framework relating to nuclear energy is the regulatory framework established by each country. The establishment of an independent regulatory authority in the light of international experience has become one of the most important components of the country wide regulatory framework. The quality of the regulatory framework mostly depends on the degree of independence of this authority, their powers and the degree at which they conduct their activities; in short on the institutional and governance characteristics of the regulatory authority. International experience emphasizes specifically that the authority should be independent from the establishment under regulation and inspection during the decision making process. Another critical characteristic which is emphasized is the protection of transparency and the right of the general public to obtain information.

It is generally accepted that TAEK, which still functions as the regulatory authority in Turkey, is not yet an independent authority. The fact that TAEK is involved in nuclear energy development activities and operates a reactor is just one of the obstacles standing in front of its independence. In order to achieve independence, at least the decision making process of the regulatory authority should be protected from political impact, those serving in the decision bodies should not removed from office except for extraordinary cases and the control of the political authority over the budget of the regulatory authority should be reduced. In addition to such type of measures related to independence, it should be ensured that the work of the regulatory authority is transparent and observable. The topic of transparency should be included with detailed provisions in the law on the establishment of the regulatory authority and measures should be adopted for ensuring that the agency fulfills the regulatory activities in a transparent manner.

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