The Turkish Model for Transition to Nuclear Power

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Centre for Economics and Foreign Policy Studies

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THE TURKISH MODEL FOR TRANSITION TO NUCLEAR ENERGY

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

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Introduction

In the last fifty years, interest towards nuclear energy fluctuated significantly. In the US, nuclear plants were first constructed in the 60s and the first half of the 70s, whereas the construction of new nuclear power plants stopped almost completely in the 80s. More generally, a significant number of developed countries have stopped investing in new nuclear power plants since three decades. Almost all of the nuclear power plants constructed in the last decade are located in Japan, South Korea, China and India.

There are many reasons for nuclear power plants to lose favor in the 80s. First and foremost among these were concerns about the safety of nuclear power, stemming from the nuclear accidents in Chernobyl and Three Mile Island. The inability to find a permanent and safe solution for storing nuclear waste and increased public awareness about environmental issues and nuclear arms in Europe and the US have led to the emergence of a political and social opposition against nuclear technology. Finally, economic reasons also contributed to the loss of appeal of nuclear energy. While costs of nuclear power plants turned out to be much higher than expected, coal and natural gas prices have either decreased or increased slowly particularly in the 80s and 90s and therefore thermal power plants based on coal or natural gas have become more attractive..

Nuclear power has recently made a comeback. One of the reasons is the increase in the efficiency of existing nuclear plants. The increase in the cost of natural gas improved the commercial feasibility of nuclear power plants. Similarly increases in the prices of fossil fuels have made investments in new nuclear plants more attractive. Another important factor is global warming and climate change policies. While nuclear power generation does directly lead to carbon emissions, believed to cause global warming, coal and natural gas plants produce carbon dioxide.

Another reason for the renewed interest towards nuclear energy concerns the concepts of “energy security” or “energy independence”. In Europe and Turkey, this concept is generally used in the context of reducing dependence on Russian natural gas. Concerns about dependence on natural gas imports were heightened particularly in 2009, when Russia stopped supplying natural gas to Ukraine. Not only Europe, but countries such as Japan, India and China have also considered nuclear plants as an alternative to generating power from natural gas and envisaged a decrease in natural gas imports.

Turkey’s interest in nuclear energy has also followed a similar path. In order to meet the increasing domestic demand for energy and reduce dependency on energy imports, various initiatives were undertaken in the past to build the country’s first nuclear power plant. For example, in the beginning of the 70s, a decision was taken to build a pressurized heavy water nuclear reactor with 400 MWe capacity. In 1974, Akkuyu was selected following surveys as a suitable location for the future plant, and in 1976, it was declared a nuclear site. The first tender for the construction of the nuclear plant was opened in 1977, but a financial agreement could not be reached with Swedish ASEA-ATOM, the only company to submit an offer. In the wake of the political and economic crises of the period, the investment was shelved.

In 1982, the nuclear project was once again revitalized and offers were received from international companies. A preliminary understanding was reached in 1985 with the Canadian company Atomic Energy of Canada Limited. However, this venture was also cancelled because of a dispute concerning purchasing guarantees. A new and eventually tender unsuccessful was opened for Akkuyu once more in 1996.

With the continuous increase in Turkey’s demand for energy, initiatives to build a nuclear power plant were given a new boost in the past decade. Following the failure of a new tender process in 2008 the investment model was changed to a Build Own Operate (BOO) scheme. An agreement was reached with Russia in 2010 and the “Agreement between the Governments of the Republic of Turkey and of the Russian Federation for Cooperation on the Establishment and Operation of a Nuclear Power Plant at Akkuyu in the Republic of Turkey”, signed in May 2010, was ratified by the Parliaments of both countries. As a result , a nuclear power plant consisting of four reactors with a total capacity of 4800 MWe will be built at Akkuyu. In accordance with the agreement, the technology and financing for the project will be supplied by the Russian side. In return the Turkish side gave a fixed price purchasing guarantee for a share the electricity produced by the Akkuyu plant. The plant is expected to start generating power by 2019.

These concrete steps towards a transition to nuclear power brings underlines the need for reviewing the country’s nuclear policies. This study does not aim to support or oppose nuclear energy. As a matter of fact, there are differences of opinion among the authors contributing to this study about the expediency of nuclear energy for Turkey.

This study focuses on the principal aspects of nuclear energy and the Akkuyu project. The first Section reviews the risks of nuclear energy and evaluates Turkey’s capacity to manage these risks. The second Section reviews past and prominent nuclear accidents. In Section Three, 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. In Section Four, the investment model foreseen for the construction and operation of the Akkuyu plant is examined. In Section Five, Turkey’s security and non proliferation policies are examined from a perspective of a country intent on transitioning to nuclear power.

This study has been prepared under the coordination of EDAM Chairman Sinan Ülgen, with contributions by Prof. Dr. İlhan Or and Assoc. Prof. Dr. Gürkan Kumbaroğlu from Boğaziçi University, Prof. Dr. Hasan Saygın, Deputy Chancellor of Istanbul Aydın University and Assoc. Prof. Dr. İzak Atiyas from Sabancı University. EDAM employees Ahu Yiğit, Evrim Görmüş and Aaron Stein have also contributed. This study has been financed by a grant from the Hewlett Foundation, California, USA.

Section I

A Study on the Security and Safety Aspects of Switching to Nuclear Power in Turkey

I

Prof. Dr. İlhan Or – Prof. Dr. Hasan Saygın - Sinan Ülgen

Executive Summary

Nuclear technology is a highly sophisticated and complicated technology. Moreover, the risks associated with nuclear power plants have also potentially such catastrophic and irreversible consequences that their management requires sophisticated techniques and skills. These risks are to be separated into four broad categories according to the IAEA:

- Safety related risks,
- Production/operational risks,
- Commercial/financial risks,
- Strategic risks .

All individuals and organizations engaged in activities related to nuclear power should adopt and behave according to a well established "Safety Culture'. Their personal dedication and accountability will have an important bearing on the safety of nuclear power plants.

The conversion of the senior management of all concerned organizations to this safety culture should be the starting point; safety matters should get their full attention. In this regard, the highest level affecting nuclear plant safety is the legislative level, at which the national policy and basis for safety culture is set. The formulation and enforcement of organizational policies and practices molding the environment and fostering attitudes conducive to safety, is the primary responsibility of the top management of involved organizations. They should institute such practices in accordance with their organization's safety policy and objectives.

Additionally, all stakeholders should strive for excellence in matters affecting nuclear safety by maintaining a questioning attitude and a rigorous, communicative and prudent approach.

The main challenges concerning Turkey's ability to fulfill the requirements for ensuring a safe transition to nuclear power can be summarized as follows:

- The human resources gap.

As a country that has had no experience in managing a large scale nuclear power capacity, Turkey currently lacks the human resources to carry out effectively the state's regulatory functions in particular concerning safety issues. Obviously this is a problem common to many states transitioning to nuclear power. The solution requires the adoption of a long term human resources development policy that would for instance involve a much closer and comprehensive cooperation with the IAEA in the area of professional training. The EU's TAIEX program can also be invoked to allow for twinning programs between the domestic regulatory institution and EU member states' nuclear authorities. For the short term however, state authorities may decide to seek international expertise in order to undertake the safety analysis for the Akkuyu project.

- The regulatory gap.

Turkey has not a sufficiently developed and sophisticated legal and regulatory framework for the regulation of nuclear power plant facilities and activities and for the clear assignment of responsibilities. An independent regulatory body to oversee the transition to nuclear power has not yet been setup. Likewise an effective risk management system for ensuring nuclear power plant safety has not yet been fully established.

- The technological gap.

The chosen reactor model for Akkuyu, the VVER-1200 has not yet entered into operation anywhere in the world . Its versions of are currently under construction at two sites in Russia. The VVER-1200 is a third-generation technology and may be considered as safer than the world's current fleet of reactors, but this has not been demonstrated since it exists only on paper. VVER-1200 has evolved from the older VVER-1000 type reactors. Since many unproven features are introduced, it has not been demonstrated in the field and with an operational track record that its safety measures are fully adequate. So, there is neither satisfactory background information relating to the design, construction, commissioning, operation, decommissioning and dismantling of VVER-1200 nor any other sufficient evidence that is required to support its safety assessment. This uncertainty leads to increased safety risks and makes safety management much more difficult.

- An unproven "Safety Culture"

The government, energy administrators, the regulatory body, developers and operators have to prioritize above all the promotion of a safety culture. The fact that "safety and quality have higher priority than costs and schedule" needs to be demonstrated in,

- choice of qualified subcontractors;
- state-of-the-art tools and methods;
- uncompromising compliance with the agreed requirements;
- walk downs by the management.

More fundamentally, an attitude of constructive skepticism is to be nurtured at every level of each institution (regulatory, operator, developer, sub-contractor) involved in nuclear energy. Workers should be encouraged to question authority, to challenge the established rules and practices and report potential safety concerns to their supervisors. A significant challenge in countries transitioning to nuclear power will be the establishment of such an environment. This observation is of particular relevance to Turkey where the cultural traditions may work against such an approach which necessarily implies a healthy challenge to authority.

In light of the above, the following recommendations can be highlighted.

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The best way to ensure a safe transition to nuclear energy in Turkey is the establishment of a competent, independent institutional capacity with sufficiently well endowed human resources that can effectively oversee this process. It is not realistic to expect Turkey to develop the needed human resources and to setup the cultural, institutional and legal infrastructure in the short term. There may be a need therefore for existing institutions to seek third party international assistance to overcome the bottleneck of human resources in the short term. In the medium term, an ambitious human resources development strategy should be adopted and a cooperation with international organisations such as the IAEA for professional training should be envisaged.

On the other hand, there are still significant deficiencies in the institutional setup for guaranteeing the required level of safety. There is still no independent nuclear regulatory authority. This task is currently being performed by TAEK. Given that TAEK is also the operator of research reactors, the requirement for the safety authority to be fully independent from the operators has clearly not been fulfilled. Moreover recent administrative and legal measures which have greatly undermined the independence of regulatory institutions in Turkey are likely to handicap the objective of fully fulfilling the safety standards in the transition to nuclear power. In particular in a model where in the future the state can become a financial stakeholder, the independence of the regulatory institution from the government is an essential feature that can allow the regulatory authority to insist on safety requirements reducing the profitability of the investment or to resist pressures from the government to unduly accelerate the construction of the nuclear power plant.

At the beginning, it would be useful to focus the competence of the human and administrative capacity on a single nuclear technology. It may not be realistic to expect an emerging nuclear state to acquire the competence to fully monitor and regulate the transition to many different nuclear technologies. Given that according to the intergovernmental agreement with Russia, the technology chosen for the Akkuyu nuclear power plant is a pressurized water reactor, choosing the same technology for the second nuclear power plant would put less pressure on the regulatory capacity. That may be the reason why, in the negotiations with the government of Japan, the Turkish side stated its preference for a pressurized water reactor rather than a boiling water reactor.

In addition, Turkey should be ready to rely on the procedure of "peer reviews" in addition to its own internal regulatory capacity that will be gradually built up. That would enable for instance the IAEA to assess whether the Turkish legislation and regulatory framework is sufficient to allow a safe and secure transition to nuclear power. Similarly this approach would allow the independent and separate testing of a new nuclear power plant before its entry into operation by the World Association of Nuclear Operators, the umbrella organisation of the nuclear power plant operators in addition to the tests conducted by the national authorities. The willingness of Turkey to participate in the stress tests for nuclear power plants held by the EU should be a welcomed as a positive step.

A more regular and comprehensive communication strategy with the public at large focusing on the adopted safety and security measures would be helpful in defusing the polarisation surrounding the transition to nuclear power. The legitimate concerns of the Turkish public opinion on the safety of nuclear power can only be addressed with such a long term, comprehensive and realistic approach to strategic communications.

As stated in the other working papers in this compilation, the Akkuyu Project does not constitute a replicable blueprint for Turkey's transition to nuclear power. Key features such as the sharing of investment risks, the agreement on the electricity price and on spent fuel management preclude this project from becoming a replicable model. However the Akkuyu investment will force Turkey to setup the necessary institutional and human infrastructure for a safe and secure adoption of nuclear power. This requirement should be among the priority goals of the Turkish government intent on implementing an ambitious strategy for nuclear power.

1 Introduction

Nuclear technology is a highly sophisticated and complicated technology. Moreover, the risks associated with nuclear power plants have also potentially such catastrophic and irreversible consequences that their management requires sophisticated techniques and skills. Nuclear power plants are considered such critical infrastructures that their incapacitation or destruction would have a debilitating impact on national and economic security, public health, and safety (Simion and Popescu 2011). The countries using nuclear power technology have therefore spent a lot of efforts for identifying and implementing the appropriate measures to eliminate or reduce the risk impact involved in their operations. In the era of global terrorism, growing terrorist threats to nuclear power plants have made management of the safety and security related risks much more difficult.

In this study different risks entailed in nuclear energy, together with the general strategies to mitigate them, are analyzed to help the elaboration of a national strategy particular to Turkey for the proper management of the security and safety risks.

2 Classification and Management of Risks

In the current global energy environment, efficiently and safely use of nuclear power needs to take many different dimensions of risks into consideration. A new risk management approach integrating management of design/production, safety related and economic risks have therefore come to the fore.

Different disciplines have their own more specific definitions of risk which reflects a different disciplinary focus on parameters and consequences. For instance, a nuclear safety analyst focuses on nuclear safety related risks and is interested in satisfying the frequency of radioactive release established by institutional and regulatory goals. A financial analyst focuses on financial risks and is interested in the potential that the cost of the investment will or will not be recovered over the life of the investment. For plant operation, the relevant risk is that the installation and operation of the new system may introduce operational difficulties or benefits. The project manager focuses on the budget and schedule risks is interested in if the project will be completed or not on schedule and within budget along with the associated cost impacts.

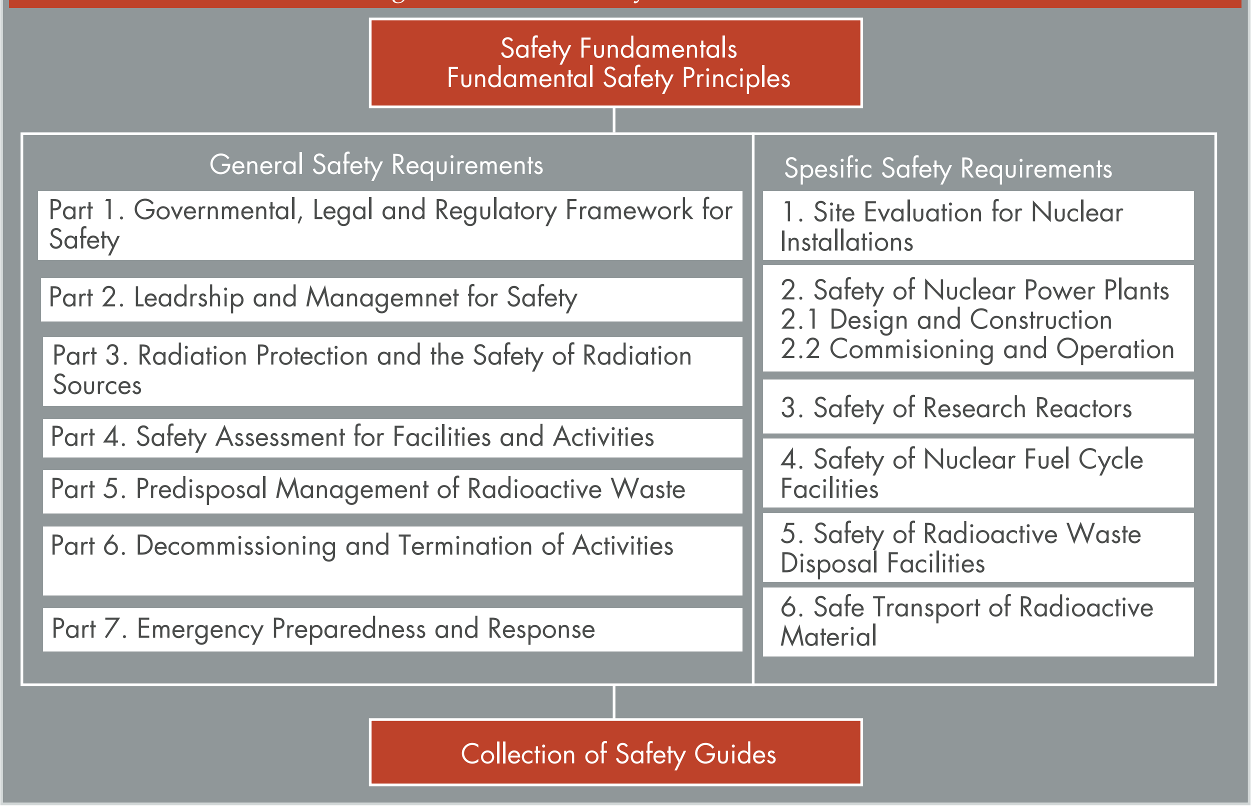
Risk associated with the nuclear industry can result from many sources like design/production processes, operation processes, training processes, social responsibility (including communication with the public), external influences (natural disasters, terrorist attacks, and economic factors), and financial processes etc. These risks are to be separated into four broad categories according to the IAEA:

- Safety related risks,
- Production/operational risks,
- Commercial/financial risks[1],
- Strategic risks .

3 Safety Related Risks

The IAEA has developed a set of safety standards, comprising Safety Fundamentals, Safety Requirements and Safety Guides. The IAEA's safety standards are not legally binding on Member States but may be adopted by them, at their own discretion, for use in national regulations in respect of their own activities. International conventions and the IAEA safety standards, appropriately supplemented by industry standards and detailed national requirements, establish a consistent and comprehensive basis for the proper protection of people and the environment against radiation risks.

Figure 1: IAEA's Safety Guides Collection



1- Commercial and financial risks are covered in a separate working paper by İzak Atiyas.

3.1 Fundamental Safety Principles

The term 'Safety' used in the IAEA safety standards includes the safety of nuclear installations, radiation safety, the safety of radioactive waste management and safety in the transport of radioactive material; it does not include non-radiation-related aspects of safety. Safety is concerned with both radiation risks under normal circumstances and radiation risks as a consequence of incidents, as well as with other possible direct consequences of a loss of control over a nuclear reactor core, nuclear chain reaction, radioactive source or any other source of radiation. Safety measures include actions to prevent incidents and arrangements put in place to mitigate their consequences in case of failure.

In the IAEA's Publication entitled Safety Fundamentals, the following principles are highlighted:

3.1.1 Prime responsibility for safety

It must rest with the person or organization responsible for facilities and activities that give rise to radiation risks an operating organization or to an individual, known as the licensee. The licensee retains the prime responsibility for safety throughout the lifetime of facilities and activities, and this responsibility cannot be delegated. It is responsible for: establishing and maintaining the necessary competences; providing adequate training and information; establishing procedures and arrangements to maintain safety under all conditions; verifying appropriate design and the adequate quality of facilities and activities and of their associated equipment; ensuring the safe control of all radioactive material that is used, produced, stored or transported; ensuring the safe control of all radioactive waste that is generated.

3.1.2 Role of the government

For ensuring safety, an effective legal and governmental framework, for the regulation of facilities and activities that give rise to radiation risks and for the clear assignment of responsibilities, including an independent regulatory body, is to be established and sustained. The government is responsible for the adoption within its national legal system of such legislation, regulations, and other standards and measures as may be necessary to fulfil all its national responsibilities and international obligations effectively, and for the establishment of an independent regulatory body. Government authorities have to provide for control over sources of radiation for which no other organization has responsibility, and radioactive residues from some past facilities and activities. The regulatory body has to have adequate legal authority, technical and managerial competence, and human and financial resources to fulfil its responsibilities; be effectively independent of the licensee and of any other body, so that it is free from any undue pressure from interested parties; set up appropriate means of informing parties in the vicinity, the public and other interested parties, and the information media about the safety aspects (including health and environmental aspects) of facilities and activities and about regulatory processes; consult parties in the vicinity, the public and other interested parties, as appropriate, in an open and inclusive process.

3.1.3 Leadership and management for safety

Effective leadership and management for safety are established and sustained in organizations concerned with, and facilities and activities that give rise to, radiation risks. Leadership in safety matters has to be demonstrated at the highest levels by means of an effective management system integrated all elements of management so that requirements for safety are established and applied coherently with other requirements. It has to ensure the promotion of a safety culture, the regular assessment of safety performance and the application of lessons learned from experience.

3.1.4 Justification of facilities and activities

For facilities and activities to be considered justified, the benefits that they yield must outweigh the radiation risks to which they give rise. For the purposes of assessing benefit and risk, all significant consequences of the operation of facilities and the conduct of activities have to be taken into account.

3.1.5 Optimization of protection

Protection must be optimized to provide the highest level of safety that can reasonably be achieved. To determine whether radiation risks are as low as reasonably achievable, all such risks, whether arising from normal operations or from abnormal or accident conditions, must be assessed using a graded approach, a priori and periodically reassessed throughout the lifetime of facilities and activities.

3.1.6 Limitation of risks to individuals

Measures for controlling radiation risks must ensure that no individual bears an unacceptable risk of harm. The doses and radiation risks must be controlled within specified limits. Because dose limits and risk limits represent a legal upper bound of acceptability, they are insufficient in themselves to ensure the best achievable protection under the circumstances. Both the optimization of protection and the limitation of doses and risks to individuals are therefore necessary to achieve the desired level of safety.

3.1.7 Protection of present and future generations

People and the environment, present and future, must be protected against radiation risks. Since radiation risks may transcend national borders and may persist for long periods of time, as well as current consequences, the possible consequences in the future, of current actions have also to be taken into account in judging the adequacy of measures to control radiation risks. In this context, safety standards must apply not only to local populations but also to population remote from facilities and activities; subsequent generations have to be adequately protected without any need for them to take significant protective actions. Additionally, radioactive waste must be managed in such a way as to avoid imposing an undue burden on future generations; that is, the generations producing the waste have to seek and apply safe, practicable and environmentally acceptable solutions for its long term management. The generation of radioactive waste must be kept to the minimum practicable level by means of appropriate design measures and procedures, such as the recycling and reuse of material.

3.2 Accident Prevention

The most harmful consequences come from the loss of control over a nuclear reactor core, nuclear chain reaction, radioactive source or other source of radiation. As in all serious risk management systems, the basic principle in nuclear safety should be the prevention of accidents, particularly any which could cause severe core damage.

The first means of preventing accidents should be to strive for such high quality in design, construction and operation of the plant and make sure that deviations from normal operational states are infrequent. In order to prevent any such deviation from developing into accidents, safety systems attached to extensive process controls and monitoring systems should be deployed. Safety systems make use of redundancy and diversity of design and the physical separation of parallel components, where appropriate, to reduce the likelihood of the loss of a vital safety function. Capability for automatic initiation of corrective action, periodic inspections and tests, inquisitive and careful staff, are other key measures to be taken in the prevention of deviations from developing into accidents.

Additionally, Probabilistic Safety Assessment (PSA) methodologies should be widely deployed to better analyse and evaluate safety critical plant systems, structures, components diversity and redundancy needs. Deployment of PSA methodologies requires, i) extensive historic data regarding past failures and near failures in similar systems, ii) physical, mathematical and simulation models regarding reliability and routine safe operations, iii) event trees, fault trees focusing on trigger-failure-response-impact chains.

The primary means of preventing and mitigating the consequences of accidents remains the proper application of the 'defence in depth' concept.

3.3 Establishment and Promotion of Defense in Depth Strategy

The "Defense In Depth" concept is centered on several levels of protection including successive barriers preventing the release of radioactive material to the environment. The concept includes protection of the barriers by averting damage to the plant and to the barriers themselves. It includes further measures to protect the public and the environment from harm in case these barriers are not fully effective.

When this concept is properly applied, it ensures that no single human or equipment failure would lead to harm to the public, and even combinations of failures that are only remotely possible would lead to little or no harm. Defence in depth also helps to establish that the three basic safety functions (controlling the power, cooling the fuel and confining the radioactive material) are preserved, and that radioactive materials do not reach people or the environment.

As most risk response strategies, the defence in depth strategy is twofold: first, to prevent accidents and second, if prevention fails, to limit the potential consequences of accidents and to prevent their evolution to more serious conditions. Special attention is paid to hazards that could potentially impair several levels of defence, such as fire, flooding or earthquakes.

All the levels of defence should be available at all times that a plant is operating at normal power. System design according to defence in depth also includes process controls that notice and track minor, tolerable failures or abnormalities, in order to interfere if they show signs of developing into serious abnormal conditions or accidents.

Table 1: Some Classic Levels of Defense in Depth

Levels	Objective	Essential Means
Level 1	Prevention of abnormal operation and failures	Conservative design and high quality in construction and operation
Level 2	Control of abnormal operation and detection of failures	Control, limiting and protection systems and other surveillance features
Level 3	Control of accidents within the design basis	Engineered safety features and accident procedures
Level 4	Control of severe plant conditions, including prevention of accident progression and mitigation of the consequences of severe accidents	Complementary measures and accident management
Level 5	Mitigation of radiological consequences of significant releases of radioactive material	Off-site emergency response

3.4 Accident Mitigation

The principle aim in mitigation is to substantially reduce the effects of an accidental release of radioactive material through well and thoroughly planned in-plant and off-site measures. Accident mitigation provisions are of three types, namely, accident management, engineered safety features and off-site countermeasures.

Accident management includes pre-planned and ad hoc operational practices, with the primary objective of restoring the plant to a safe state with the reactor shut down, continued fuel cooling ensured, radioactive material confined and the confinement function protected. In such circumstances, engineered safety features, including physical barriers, would act to confine any radioactive material released from the core so that discharges to the environment would be minimal.

Off-site countermeasures should also be planned and made available, in order to compensate for the possibility that safety measures at the plant might fail. In such a case, the effects on the surrounding population or the environment should be mitigated by protective actions (such as sheltering, distribution of protective equipment or evacuation of the population) and by prevention of the transfer of radioactive material to humans by food chains and other pathways.

3.5 Siting Issues and Related Risks

Siting issues and related risks include,

- External Factors Affecting the Plant;
- Radiological Impact on the Public and the Local Environment;
- Feasibility (and Applicability) of Emergency Plans;
- Ultimate Heat Sink Provisions.

All such risks are shared by the nuclear facility developer, operator and the Turkish State. The related responsibilities of the operator and the developer in responding to the hazards and needs originating from or related to the siting decisions are discussed in following sections. Nevertheless, since it is the Turkish State, which is the primary decision maker in the designation of the site, she cannot avoid sharing the related risks. Additionally, since the realization of such risks will necessarily impact the Turkish State (especially regarding power supply shortfalls, unreliable operations, undesirable environmental and health impacts) and possibly the local and global environment, generation of sound siting options, their careful evaluation, comparison (especially regarding the factors outlined below) and final selection should be done carefully and systematically.

The primary external factors that must be considered in the strategic site selection decisions are potential natural and human made hazards. Natural hazards include geological and seismological characteristics and the potential for hydrological and meteorological disturbances of candidate sites. Human made hazards include those arising from nearby chemical installations, the release of toxic and flammable gases.

The possible transport of radioactive material to humans, animals and vegetation is the key issue regarding the radiological impact on the public and the local environment. Since, air, food chains and water supplies provide the pathways, site characteristics to be investigated are those, which can influence the pathways. In this regard, physical characteristics such as topography, meteorology and hydrology; environmental characteristics such as prevailing vegetation type and animal life; the use of land and water resources; and the population distribution around the site should be considered in siting decisions.

The site selected for a nuclear power plant must be compatible with and allow for the external and internal countermeasures that may be necessary to limit the effects of accidental releases of radioactive substances. In this regard, the suitability of the selected site regarding, i) accessibility and speedy inbound transportation of heavy equipment/emergency teams and outbound transportation of victims (even under potential road, port and airport damage), ii) availability of back-up transmission lines and water sources and/or geographical conditions that will not hinder speedy repair of damaged delivery systems associated with such utilities, iii) availability of suitable areas for storage of emergency equipment and basic supplies, sheltering the victims, delivery of healthcare, should be considered.

The site selected for a nuclear power plant should have a reliable long term heat sink that can remove energy generated in the plant after shutdown, both immediately after shutdown and over the longer term. It should also be considered that extreme hazards such as earthquakes, floods and tornadoes could threaten the availability of the ultimate heat sink unless adequate design precautions are taken.

3.6 Design Issues and Related Risks

In dealing with design issues and related risks special consideration should be given to the following aspects,

- **Plant Process Control Systems and Preservation of Control Capability:** Plant design should allow for routine and continuous control of normal operation and anticipated operational occurrences so that plant and system variables remain within predefined and clearly identified operating ranges (this reduces the frequency of demands on the safety systems). In this regard, important plant neutronic and thermal–hydraulic variables should have assigned operating ranges, trip set points and safety limits to be automatically maintained in the operating range by feedback systems (acting on electrical and mechanical controls when variables begin to depart from the operating range). Additionally, the design of the control room should be such that it would remain habitable under normal operating conditions, anticipated abnormal occurrences and all potential accidents.

- **Automatic Safety and Shutdown Systems:** Automatic systems should be designed such that they would safely shut down the reactor, maintain it in a shut down and cooled state, and limit any release of fission products that might possibly ensue, if operating conditions were to exceed predetermined set points. Additionally, such safety shutdown systems should be independent in function from the reactivity control systems used for normal operation of the reactor.

- **Reactor Core Integrity:** It is of utmost importance that the core should be designed to have high mechanical stability and tolerate a wide range of anticipated variations in operational parameters. The core design should be such that the expected core distortion or movement during an accident would not impair the effectiveness of the reactivity control or the safety shutdown systems or prevent cooling of the fuel.

- **Reactor Coolant System Integrity:** Codes and standards for nuclear vessels and piping should be supplemented by additional measures for this key sub-system. Additionally, multiple inspections (deploying ultrasonic, radiographic and surface methods) should be conducted during and after fabrication and installation of the system. Hydraulic overpressure testing to pressures well above those expected in operation should be done before the system is made radioactive. Furthermore, in-service inspection of the primary coolant system should be made possible (because of the great reliance placed upon coolant retention and the environmental conditions to which this system is exposed for a long period of time).

- **Radiation Protection in Design:** The design should ensure that all plant components containing radioactive material are adequately shielded and that the radioactive material is suitably contained.

- **Reliability Targets:** High reliability of safety systems and functions should be pursued by design through specific reliability targets that are set to ensure performance on demand and operation throughout the required duration of performance. Reliability theory, applications and probabilistic methods should be deployed in determining the reliability required of safety systems and functions.

- **Dependent Failures:** Loss of safety functions due to damage to several components; systems or structures resulting from a (internal or external) common cause should be avoided as much as possible through design provisions. Primary methods and principles to be deployed for this purpose are, i) physical separation by barriers or distance, ii) protective barriers, iii) redundancy linked with diversity, iv) qualification to withstand the damage. Seismic events should receive special attention owing to the extent to which they can trigger multiple failures.

- **Equipment Qualification:** The effects of ageing on normal and abnormal functioning should be considered in design.

- **Protection Against Power Transient Accidents:** The stable and flexible operation (i.e. safe and reliable insertion and withdrawal of) and automatic control of shim, control and safety rods should be designed in the most safety conscious way possible.

- **Normal and Emergency Heat Removal Systems:** Heat transport systems are should be designed for highly reliable heat removal in normal operation and under emergency or accident conditions. Additionally, provision should be made for alternative means to restore and maintain fuel cooling under accident conditions, even if normal heat removal fails or the integrity of the primary cooling system boundary is lost.

- **Start-up, Shutdown and Low Power Operation:** These situations are by definition "transient states" and, as such, require special care. Components, structures, and systems used during start-up, low power and shutdown operations should be designed to prevent the occurrence of abnormal conditions nor accidents during those operations.

- **Confinement of Radioactive Material:** The plant should be designed to be capable of retaining the bulk of the radioactive material that might be released from fuel, for the full range of accidents considered in the design. Special systems providing a confinement function have the following common features. A structure encloses the region into which radioactive material from fuel, consisting principally of fission products, could be released in the event of the loss of fuel integrity. Confinement may be effected by making the structure so strong that when it is sealed it can withstand a high internal pressure. It is then called a containment structure. The containment structure usually has a subsystem that completes the sealing process on demand, and other subsystems protecting the structure. Together these constitute a containment system. Confinement may be effected by equipping the structure with devices that permit pressure due to an accident to be relieved to the exterior while ensuring that the bulk of any radioactive material released from fuel is retained, e.g. on filters. The structure maintains its integrity in both the short term and the long term under the pressure and temperature conditions that could prevail in design basis accidents. Openings and penetrations, when they have been secured, and other singular points in the structure are designed to meet requirements similar to those for the structure itself so that they do not render it vulnerable as potential pathways for the release of radioactive material. If analysis shows that residual reactor heat could lead to an increase of atmospheric temperature inside the containment and thereby generate a pressure threatening the integrity of the structure, provision is made for the removal of this heat.

- **Monitoring of Plant Safety Status:** Parameters to be monitored in the control room should be selected, and their displays are arranged, to ensure that operators have clear and unambiguous indications of the status of plant conditions important for safety, especially for the purpose of identifying and diagnosing the automatic actuation and operation of a safety system or the degradation of defence in depth.

- **Station Blackout:** Nuclear plants should be so designed that the simultaneous loss of on-site and off-site AC electrical power (a station blackout) will not soon lead to fuel damage. Additional electrical power generating sources (e.g. connection to a hydroelectric power station or installation of gas turbine generators) should be used to improve the response to station blackout.

- **New and Spent Fuel Storage:** Plant designs should provide for the handling and storage of new and spent fuel in such a way as to, i) avoid (accidental or deliberate) unauthorized retrieval, ii) ensure protection of workers, iii) prevent the release of radioactive material, iv) ensure the uninterrupted servicing of their environmental needs (such as cooling, hydration etc.).

- **Plant Physical Protection:** The design and operation of a nuclear power plant should provide adequate measures to protect the plant from damage and to prevent the unauthorized release of radioactive material arising from unauthorized acts by individuals or groups, including trespass, unauthorized diversion or removal of nuclear materials, and sabotage of the plant.

On the other hand, the scarcity of Nuclear Power Plants orders in the last two decades (especially in Western Europe and North America) have led many nuclear facility developers to minimize their design staffs (many of the experts who did the design of the current plants have already retired). So, recruiting and training adequate design staff may be a critical issue for the developer, especially if this activity is delayed to the aftermath of signing a contract on a new plant. Additionally, today new type of competence is needed for new technologies such as digital I&C (interface and control) systems. Thus, a good company name earned in the past is no guarantee for success but more important is the experience and competence of individuals actually assigned to the project. This issue led to significant time delays in the design and construction of the Olkiluoto 3 Plant in Finland, since the staff of developer Areva had been strongly reduced from the time of earlier construction. Especially the number of designers was too small for immediate start of detailed design. On the other hand, Areva had competent management and large economic resources to cover this weakness in a relatively short time and gained the capability for relatively fast restart of nuclear build. Nevertheless, at the time of signing the contract the design was still in a conceptual stage and the parties involved did not really recognize how much additional work was needed to complete it. The necessity of recruiting and training hundreds of designers and the inadequate completion of design and engineering work prior to start of construction contributed to delays (Laaksonen 2011).

Additionally, todays third generation plants are larger and more complex than the plants built before, while most nuclear facility developers feature leaner organizations, bringing about the necessity of decentralizing (subcontracting) many design tasks (subcontracting design tasks within a certain supply project seems to be a common practice, especially in the various steps of I&C design process). Design work is most difficult to coordinate if certain parts of the design are done in different companies. Lack of communication among designers can lead to mismatches within safety systems. If design work is conducted by different organizations and in different places (or even in different countries), arrangements for good coordination and communication among the designers is essential for a successful outcome. It is also necessary that designers communicate with those who make probabilistic safety analysis of design output.

In theory all such risks are supposed to be assumed by the nuclear facility developer. However, the realization of such risks will necessarily impact the Turkish State (especially regarding construction/installation delays, power supply shortfalls, unreliable future operations, undesirable environmental impacts, unsatisfied customers and local communities) and possibly the local and global environment. Accordingly, all designs must be clearly documented, well understood and agreed upon by all stakeholders. In any case, since it is the design that defines the product and service, overall and all detailed designs (prepared by the developer in consultation with the Turkish State) need to be explicitly approved by the State. So, it is of utmost importance that, the relevant agencies of the Turkish State be able to study and confirm the overall and detailed designs. In this regard, the personnel, equipment, training needs of the national agency empowered to study, suggest changes and approve the design should be meticulously addressed by the Turkish State.

3.7 Licensing and Regulatory Issues and Related Risks

Licensing and regulatory risks are triggered by,

- Environmental impact study (EIS) findings;
- Various municipality and TAEK (the Turkish Atomic Energy Board) licensing procedures related with the construction and operation of nuclear facilities;
- Various MENR (the Ministry of Energy and National Resources) and EPDK (Energy Market Review Board) licensing procedures related with the operation of nuclear facilities;
- Various International (primarily IAEA driven) conventions and suggested procedures related with the operation of nuclear facilities;
- Any possible licensing procedures regarding the importation and exportation of radioactive material (importation of nuclear fuel and exportation of nuclear waste).

In general, in any closely regulated sector, the licensing and regulatory framework ought to ensure that regulatory decisions are, i) predictable, ii) stable, iii) timely, iv) nationally coordinated, v) internationally aligned. Predictable means that the major requirements that an applicant has to fulfill must be clear in advance, set forth in clear rules and regulations (license being duly granted if the applicant fulfills these requirements). Stable means that once regulatory decisions are made, they are not altered afterwards (unless substantial new information shows that additional measures are necessary to ensure safety). Timely means that licensing and regulatory decisions are made within a pre-defined timescale. Nationally coordinated means that there should be an effective coordination between sectoral licensing and all the other different authorization procedures needed for the facility's operation (for example environmental authorization). Internationally aligned means that, as far as possible, regulatory decisions should reflect the multinational practices regarding the deployment of such facilities. Unfortunately, as illustrated below, these principles may not be followed in the nuclear power generation sector.

Firstly, it should be highlighted that safety regulations regarding nuclear power generation facilities are subject to frequent changes and more often than not get more stringent (at local, national and international levels), with the latest set of regulations and requirements being forced open facilities in the development stage and even operational ones (the fact is that all regulations around the world change every time a minor or major accident occurs at some nuclear facility somewhere in the world). This situation is likely to lead to serious delays and cost overruns. In addition, the "politicization" of nuclear energy adds significant political risk through political interference or outright turnaround in government support for nuclear power after electoral changes (the recent decision by the USA Obama administration to reject the planned nuclear waste storage site at Yucca Mountain in Nevada, after 20 years of planning and at a cost of at least $9 billion, is illustrative of this). The long-term nature of a nuclear construction projects increases exposure to such regulation and/or political agenda change risks.

Stringent regulatory approach and inspections are needed to verify that new and complex manufacturing techniques and new types of equipment meet the specifications set by the designer and the regulatory body. Most of the new licensing frameworks feature a series of quantitative inspections and tests, which in turn introduce the potential for regulatory disruptions after a company has spent significant amounts of time and money (based on suddenly outdated regulations / requirements).

Another issue is that the licensing applications in the nuclear sector are non-standard (most regulatory authorities accept individual license applications before the designs on which they are based have been reviewed and certified). Accordingly, there is usually great uncertainty in the licensing process since individual application reviews are initiated before fundamental design issues are resolved.

Early contacts and communication between developers, operators and the regulatory body before the actual signing of the contract (i.e. during the bidding process) and during the design phase have been found to provide benefits for safety, quality and project implementation. Such contacts may provide useful insights to all parties, such as,

- possibility for early allocation of developer and regulatory resources to the safety assessment of alternative designs;
- identification of crucial safety issues before and during critical decisions;
- developer's consideration of the safety issues that the regulatory body may raise, and improved design or generation of additional safety evidence in parallel with the evaluation and licensing process.

In the case of the Olkiluoto 3 Plant in Finland, the early contacts between the developer and the STUK, led to the generation and consideration of a series of design changes which considerably improved the final design submitted for approval (Laaksonen 2011).

Additionally, the combined construction permit and operating license (COL) process being adopted by many countries and favored by the industry is not yet tested and may be open to challenge and interventions by nuclear energy opponents. Further delays may arise due to the increasing number of reactor designs that need to be approved/accepted at the national and international levels before they can be included or referenced in a COL application.

Even after the granting of construction and operation licenses, regulatory risks are considerable since the regulatory body can order (short or long) temporary shutdowns and even early retirement (permanent shut-down).

The experience of the regulatory body and the maturity of the regulatory framework are also important factors in this regard. In the case of the Olkiluoto 3 Plant in Finland, the nuclear facility developer and operator benefitted considerably from the European Utility Requirements (EUR) that had been developed as a joint work by the leading nuclear utilities in Europe, in more than 10 years' time (about 85 % of the technical requirements were taken directly from that document). The Finnish regulatory body, STUK, had staff of adequate size and experience for making the construction permit review in the planned time. It could rely on its own in-house competence for making safety assessment: reviewing the safety analysis and conducting evaluation of the design and the management systems of the involved parties. It had also staff for conducting inspection of structures and components. Furthermore, STUK had arrangements to request expert support from organizations that are able to conduct material testing and independent safety analysis. During a time span of more than 20 years, STUK had reviewed and assessed plans for modernization of operating plants. It had also contributed to several feasibility studies intended to start new construction. In such reviews it had gathered extensive knowledge on different Nuclear Power Plant designs (Laaksonen 2011).

These risks are also supposed to be assumed by the nuclear facility developer and operator; however, since the realization of such risks will necessarily impact the Turkish State (especially regarding construction/installation delays, power supply shortfalls, unreliable future operations, undesirable environmental impacts, unsatisfied customers and local communities), the developer and the operator should be strongly encouraged to carry out pre-studies regarding issues to be investigated by the various licensing authorities (for example, a comparative technical investigation of the municipalities construction rules and regulations regarding such facilities, , a comparative technical investigation of MENR's, TAEK's and EPDK's rules and regulations regarding the operation of nuclear facilities, an investigation of customs rules, regulations and procedures regarding the importation and exportation of radioactive material).

It is likely that in some cases there will not be full agreement (either because of possible explicit violations of existing rules/regulations/procedures or because of non-existent or unclear/vague rules and regulations). In such cases, i) the developer/operation should be induced to alter its technical plans and designed procedures to better agree with the existing rules and regulations, ii) the municipality, the MENR, the TAEK and/or the EPDK should be induced to change/expand their rules and regulations, iii) if various rules and regulations are unclear/vague regarding this new technology, the municipality, the MENR, the TAEK and/or the EPDK should be induced to clarify the existing rules and regulations or to issue additional new rules and regulations.

Regarding the direct responsibilities of the State, it should be kept in mind that, a preliminary condition for nuclear energy development in any country, is the existence of a clear, well-established regulatory framework, directly addressing the issues of,

i) Safety requirements and control;
ii) Reactor licensing;
iii) Site permits;
iv) Discharge authorizations;
v) Waste management and disposal;
vi) Decommissioning rules;
vii) Financing.

Accordingly, it is the State's responsibility to clarify the authority and responsibility of the various regulatory bodies related to nuclear energy and to strongly empower them in their related areas, to staff the regulatory bodies with sufficient manpower having the necessary expertise, to protect the regulatory bodies from adverse political influence by providing them sufficient independence and authority, to make sure the regulatory bodies have world standard, well-defined and well-established regulations, licensing and control procedures.

Additionally, national safety requirements need to be clearly specified as part of the licensing and regulatory framework (making safety requirements clearly understood to the developers and operators is needed to avoid uncertainties in licensing and regulatory oversight). Just making reference to the national requirements and the regulatory guides is not enough to ensure that requirements are correctly understood by developers and operators. In the case of the Olkiluoto 3 Plant in Finland, up-to-date requirements were available in STUK's regulatory guides; but evidently the developer did not fully understand their impact in the early stage of the project (Laaksonen 2011).

3.8 General Technical Principals

3.8.1 Proven Engineering Practice

This simple but extremely important principle states that nuclear power technology should be based on sound, well tested and experienced engineering practices, which should be accompanied by approved codes, standards and other appropriately documented statements.

Well-established methods of manufacturing and construction should be used; dependence on experienced and approved suppliers contributes to confidence in the performance of important components. The workforce should also be carefully screened, selected and trained.

The issue of standardization needs special consideration. Standardization, on one hand, can offer economic advantages in both design and operation, and can promote more efficient operation (thus safety), through direct sharing of operating experience and common training. However, there is also a risk that standardization may lead to generic problems. This risk may be reduced by adopting the concept of evolutionary improvements in the design of standardized plants.

3.8.2 Quality Assurance

Quality assurance principles should be applied throughout activities at a nuclear plant as part of a comprehensive system to ensure with high confidence that all items delivered and services and tasks performed meet specified requirements.

Quality assurance practices cover, validation of designs; procurement; supply and use of materials; manufacturing and installation, inspection and testing methods; and operational and other procedures to ensure that specifications are met.

A key component of quality assurance is the documentary verification that tasks have been performed as required, that deviations have been identified and corrected, and that action has been taken to prevent the recurrence of errors. Resources, staff and equipment should be well provided for the work involved, which includes, quality control procedures with sampling of work products, observation of actual practices, witnessing of tests and inspections.

3.8.3 Peer Reviews

"Peer reviews" are site visits conducted by a team of independent experts for informal review purposes. These reviews are neither inspections nor audits against specified standards. Instead, they comprise a comprehensive comparison of the practices applied by organizations with existing and internationally accepted good practices, and an exchange of expert judgements. As such, they provide access to practices and programmes employed at plants performing well and permit their adoption at other plants.

3.8.4 Human Factors

The personnel engaged in activities bearing on nuclear plant safety are to be trained and qualified to perform their duties. The probability of human error in nuclear power plant operations should be be reduced as much as possible by i) promoting and encouraging the use of well defined, clear and sound decision making procedures, ii) by providing means for detecting and correcting or compensating for error.

The remedy is a twofold approach, through design, including automation, and through improved human performance, including the need to identify expected behaviours, to conduct pre-task reviews, to identify error-likely conditions and to discuss outcomes and responses.

3.8.5 Safety Assessment and Verification

“Safety assessment” involves activities undertaken to reveal any underlying design weaknesses and includes systematic critical review of the ways in which structures, systems and components might fail, and identifies the consequences of such failures. The results should be documented in detail to allow independent audit of the scope, depth and conclusions of the critical review.

Deterministic and probabilistic methods should be jointly used in evaluating and improving the safety of design and operation.

In the deterministic method, the hypothetical occurrence of a wide range of possible initiating events that could challenge the safety of the plant are individually assumed, and analysis is used to show that the response of the plant and its safety systems to such hypothetical occurrences satisfy predetermined specifications both for the performance of the plant itself and for meeting safety targets. Accepted engineering analyses are used to predict the course of events and their consequences.

Probabilistic analysis is used to evaluate the likelihood of any particular sequence and its consequences, and especially to identify the importance of any possible weakness in design or operation or during potential accident sequences that contribute to risk. The probabilistic method can be used to aid in the selection of events requiring deterministic analysis and the other way around.

3.8.6 Sharing of Operating Experience

Nuclear Power Generation facilities should ensure that operating experience and the results of research relevant to safety are exchanged, reviewed and analysed, and that lessons are learned and acted on.

The organization operating a nuclear power plant should maintain an effective system for collection and interpretation of operating experience, and should disseminate safety significant information promptly among its own staff and to other relevant organizations. Such safety significant information to be collected and disseminated should include, the root causes of accidents, events that may be regarded as precursors of accidents and actions taken to prevent any recurrence. The sharing of this data should be co-ordinated nationally and internationally.

3.9 Safety Culture

All individuals and organizations engaged in activities related to nuclear power should adopt and behave according to a well established “Safety Culture’. Their personal dedication and accountability will have an important bearing on the safety of nuclear power plants.

The conversion of the senior management of all concerned organizations to this safety culture should be the starting point; safety matters should get their full attention. In this regard, the highest level affecting nuclear plant safety is the legislative level, at which the national policy and basis for safety culture is set. The formulation and enforcement of organizational policies and practices molding the environment and fostering attitudes conducive to safety, is the primary responsibility of the top management of involved organizations. They should institute such practices in accordance with their organization's safety policy and objectives.

Additionally, all stakeholders should strive for excellence in matters affecting nuclear safety by maintaining a questioning attitude and a rigorous, communicative and prudent approach, especially regarding the following issues.

The characteristics of a good Nuclear Safety Culture:

- When any possible conflict in priority arises, safety and quality should take precedence over schedule and cost.
- Errors and near misses when committed should be seen not only as a matter of concern but also as a source of experience from which benefit can be derived.
- Individuals should be encouraged to identify, report and correct imperfections in their own work in order to help others, as well as themselves to avert future problems.
- Plant changes or activities should be conducted in accordance with procedures. If any doubt arises about the procedures, the evolution should be terminated by returning the plant to a safe and stable condition. The procedures should then be evaluated and changed if necessary before proceeding further.
- When problems are identified, the emphasis should be placed upon understanding the root cause of the problems and finding the best solutions without being diverted by who identified or contributed to the problem; the objective should be to find 'what is right' and not 'who is right'.
- The goal of supervisory and management personnel should be that every task be done right the first time. They are expected to accept and insist upon full accountability for the success of each work activity and to be involved in the work to the extent necessary to achieve success.
- Practices and policies should convey an attitude of trust and an approach that supports teamwork at all levels and reinforces positive attitudes towards safety.
- Feedback should be solicited from station personnel and contractors to help identify concerns, impediments and opportunities to improve. Management should reinforce an attitude of individual behavior that leads staff to identify problems promptly and fully.
- The organization should have a commitment to continuous safety improvement and to manage change effectively.
- Senior managers should prevent isolationism and encourage the establishment of a learning organization.
- Every individual, every supervisor and every manager should demonstrate personal integrity at every opportunity that arises during the lifetime of the nuclear power plant.

- Every plant change, every meeting and every safety assessment should be taken as an opportunity to teach, learn and reinforce the preceding characteristics and principles.

4 Production and Operational Risks

4.1 Development / Construction Issues and Related Risks

A primary safety requirement is that a nuclear power plant be manufactured and constructed according to the design intent. This can be accomplished by giving attention to a range of issues, from the broad aspect of accountability of the organizations involved to the diligence, competence and care of the individual workers. Additionally, construction should begin only after the operating organization and the regulatory organization have satisfied themselves by appropriate assessments that the main safety issues have been satisfactorily resolved and that the remainder are amenable to solution before operations are scheduled to begin.

Since the options available to the designers for modifying plant safety features become more restricted as construction proceeds, it is critically important to coordinate safety evaluation with manufacturing and construction to ensure that important safety options are not foreclosed. Additionally, the fact that quality standards are extremely high and related tolerance margins are severely limited in nuclear facility construction further complicates the issue. Checkpoints should be established during construction so that satisfactory preliminary design, final design, installation and verification of the adequacy of safety related equipment can be reviewed.

The plant manufacturers and constructors should discharge their responsibilities for the provision of equipment and construction of high quality by using well proven and established techniques and procedures supported by quality assurance practices.

Primary development / construction issues and related risks include,

- Faulty / substandard construction;
- Faulty / substandard equipment and wiring / piping acquisition and installation;

- Mismatch between equipment space and utility needs and space/utility availabilities;
- Faulty/substandard human/equipment interface and human work conditions;
- Insufficient redundancies or backups in critical equipment and wiring/piping;
- Construction delays and cost overruns due to complex and slower manufacturing and rework associated with the non-negotiable high quality standards;
- Non-availability of experienced (and safety/high quality conscious) workers, specialists, sub-contractors and suppliers;
- Possible accidents during construction, wiring and equipment installation and testing.

On the other hand, in the last two decades, many of the experienced nuclear equipment manufacturers have left the business, or they have lost experienced employees with specific skills. Accordingly, for most nuclear facility developers, it is necessary to create a new network of manufacturers and to teach them how to work in the nuclear business. For instance, the specific quality assurance requirements, regulatory control, inspections and audits conducted by several organizations, and requirements on safety culture are new for manufacturers. This issue led for instance to a range of problems for the developer Areva in the construction of the Olkiluoto 3 Plant in Finland, since at the start of the project it was found that many of the experienced nuclear manufacturers that had contributed to the earlier Areva projects had left the business. Areva had to find new subcontractors and to coach them in the nuclear manufacturing (Laaksonen 2011).

Additionally, new third generation plants are larger than the plants built before. Larger structures and components mean that there is a need to explore new limits of technology. In order to improve safety and reliability of plants, advanced new features and manufacturing technologies have been developed. It is important that appropriate research programs and qualification tests are conducted before manufacturing, installation and construction, in order to demonstrate that the new features and technologies actually meet their design targets. In the case of the Olkiluoto 3 Plant in Finland, before signing the main contract, neither the developer Areva, nor the operator TVO, adequately appreciated the importance of an experienced architect engineer and an experienced construction company for the success of the project. Furthermore, Areva was not adequately aware of her limited development capability and the actual status and needs of the available designs. Accordingly, the target set for the construction time was not realistic and the lack of experience in managing large and complex construction projects led to significant delays (Laaksonen 2011).

Furthermore, developers in the 1970´s and 1980’s had large experienced organizations, and they had comprehensive in-house capability for design and manufacturing, which reduced dependence on subcontractors and facilitated communications within the project organization. (in other words, management of the nuclear plant construction projects was thus more straightforward than today).

Today's business is based on long subcontractor (supply) chains that need to be well-managed.

In the light of the above discussions, deployment of established "supply-chain project management" concepts and principles during all stages of the construction becomes highly important. In this regard,

- the importance of proven experience from management of large projects should not be underestimated both at personal and organizational levels;
- the developer needs to have fair partnership with the sub-contractors. For contracting suppliers and sub-suppliers with no previous experience from the nuclear field, the developer needs to ensure that all relevant nuclear specific work practices are clearly brought out in each call for tender;
- regular meetings among the active representatives of the developer, operator and the regulatory body at project management level are an effective channel to transfer information and address concerns raised by any of the parties;
- basing the developer's project management team at the site and its continuous presence (as opposite to working mostly in home office abroad), could significantly improve common understanding of key issues,
- granting adequate decision making power to the project management and separation of contractual issues from project management facilitates timely and higher quality construction.

In the case of the Olkiluoto 3 Plant in Finland, the non-recognition of the developer and the operator of the importance of skills and experience to manage a major construction project led to a slow start in actual construction; additionally, developer's home office decisions turning down common expert views on technical issues (as formed in project meetings between all parties) have been found to be detrimental to smooth progress of project (Laaksonen 2011).

In theory all such risks are supposed to be assumed by the nuclear facility developer; however, since the realization of such risks will necessarily impact the Turkish State (especially regarding construction/installation delays, power supply shortfalls, unreliable future operations, undesirable environmental impacts, unsatisfied customers and local communities) and possibly the local and global environment, detailed and precise technical guidelines aimed at minimizing such risks must be prepared and agreed upon by all stakeholders. Additionally, the relevant regulatory agencies of the Turkish State ought to be able to administer periodic inspections throughout the construction and installation period to make sure that the guidelines, plans and schedules agreed upon are adhered to. Close regulatory oversight has been found to promote quality of construction in other nuclear facility development projects. For example, throughout the Olkiluoto 3 project in Finland, the frequent and multiple quality controls and safety inspections, carried out by the developer, the operator and the Finnish regulatory body, STUK led to the early detection of product deviations with high sensitivity. Nevertheless, a reluctance (due to economic pressures) for stopping the work and insisting necessary timely corrections has been observed in some situations, where just the developer and the operator were involved (Laaksonen 2011).

4.2 Operational Issues and Related Risks

Operational Risks include,

- Equipment/facility damage;
- Fire, explosion;
- Radioactive and/or non-radioactive material release;
- Immediate or delayed bodily injury or death of personnel;
- Immediate or delayed bodily injury or death in local community;

due to human error, equipment/wiring/piping failure, substandard fuel or other material or utility usage.

These risks are best managed by adhering to the risk culture and general safety principles discussed in Section 3 , while giving special attention to,

i) clear, well defined and proven operational and control procedures;
ii) high standards and screening in hiring and promotions;
iii) quality and maintenance level of all equipment (including spares, redundancies and emergency equipment),
iv) quality level of supplies and materials;
v) well designed and seriously implemented training programs;
vi) adherence to prescribed work and environmental conditions;
vii) scheduled and unscheduled inspections;
viii) high quality emergency training and frequent and serious exercises.

These risks are also supposed to be assumed by the nuclear facility developer and operator. However, the realization of such risks will necessarily impact the Turkish State and possibly the local and global environment (especially regarding power supply shortfalls, unreliable operations, undesirable environmental impacts, unsatisfied customers and local communities, hazardous consequences for the local and/or global community). Accordingly, detailed and precise technical guidelines and procedures aimed at minimizing such risks, as well as related contingency, emergency and recovery plans, must be prepared and agreed upon by all stakeholders. These guidelines, procedures and plans should clearly identify, critical redundant / spare equipment, emergency / intervention stockpiles and equipment, emergency / rescue teams, together with their qualifications and training programs. Additionally, the relevant regulatory agencies of the Turkish State ought to be able to administer periodic inspections throughout the operation period to make sure that the guidelines, procedures and plans agreed upon are adhered to. Furthermore, transportation, communication and utility (especially water and electricity) links to the facility should have sufficient resilience and spare capacity to allow for immediate emergency response to possible operational hazard realizations.

4.3 Natural Risks

Natural Risks include, earthquakes, hurricanes/storms and similar hazards. These risks are best managed by reviewing the long term history of the nuclear site (at least 200 years or more) for the worst realizations of such natural disasters and making sure that the nuclear facility, including all its equipment and utilities, are designed and built to withstand similar strength disasters. All possible scientific and engineering inspections that may help estimating the likelihood and impact level of such hazards (such as the determination of the closest geological fault line and soil conditions) should also be accomplished before the design and construction stages. The reliability of communication and supply channels of the facility and the analysis of their durability and resilience in case of the expected worst realization of a natural hazard should also be given full consideration and contingencies planned for. For instance, in relation to the construction in Akkuyu, the design of the nuclear power plant is to foresee resilience against an earthquake that is at least 50 basis points higher on the Richter scale than any previously recorded earthquake in the region. Thus the Akkuyu plant is expected to resist to an earthquake of at least 9 on the Richter scale.

Another critical issue is the precautions to be taken to avoid concurrent failure of operational and back up equipment because of the experienced natural disaster. Such concurrent failures may be almost impossible under normal conditions, but the very unusual circumstances created by the disaster may make such concurrent failures much more likely (such as the concurrent failure of all emergency power generators at the Fukushima Nuclear Facility because of the unexpectedly high tsunami).

These risks are also supposed to be assumed by the nuclear facility developer and operator and/or its insurer. However, the realization of such risks will necessarily impact the Turkish State and possibly the local and global environment. Accordingly, detailed and precise technical guidelines and procedures aimed at minimizing such risks, as well as related contingency, emergency and recovery plans, must be prepared and agreed upon by all stakeholders. These guidelines, procedures and plans should clearly identify, critical redundant / spare equipment, emergency / intervention stockpiles and equipment, emergency / rescue teams, together with their qualifications and training programs. Additionally, the relevant regulatory agencies of the Turkish State ought to be able to administer periodic inspections throughout the operation period to make sure that the guidelines, procedures and plans agreed upon are adhered to. Furthermore, transportation, communication and utility (especially water and electricity) links to the facility should have sufficient resilience and spare capacity to allow for immediate emergency response to possible natural hazard realizations.

4.4 Risks Associated with Decommissioning

“Nuclear Decommissioning” is the dismantling of a nuclear power plant and decontamination of the site to a state no longer requiring protection from radiation for the general public. The main difference from the dismantling of other power plants is the presence of radioactive material that requires special precautions.

Decommissioning involves many complex and lengthy administrative and technical actions. It includes all clean up of radioactivity and progressive demolition of the plant. Once a facility is decommissioned, there should no longer be any danger of a radioactive accident or to any persons visiting it. After a facility has been completely decommissioned it is released from regulatory control, and the licensee of the plant no longer has responsibility for its nuclear safety. The complexity and very long duration of the decommissioning period and related activities is better understood in term of its somewhat overlapping but distinct stages and alternatives (U.S. Nuclear Regulatory Commission, 2011).

The first alternative, DECON (decontamination / dismantlement as rapidly as possible after reactor shutdown to achieve termination of the nuclear license) is the decommissioning method in which the equipment, structures, and portions of the facility and site containing radioactive contaminants are removed or decontaminated to a level that permits the property to be released for unrestricted use shortly after cessation of operations. It is the only decommissioning alternative that leads to termination of the facility license and release of the facility and site for unrestricted use shortly after cessation of facility operations. DECON activities are expected to require about 9 years (or less for smaller facilities). Because DECON operations are expected to be completed within a few years of shutdown, radiation exposures to workers generally are higher than for decommissioning methods that allow for radioactive decay by delaying or extending the work over a longer period. DECON also requires larger commitments of money and waste disposal site space than do other decommissioning methods. The principal advantage of DECON is that the site is available for unrestricted use promptly. DECON, actually comprises four distinct periods of effort: i) pre-shutdown planning and engineering, ii) plant deactivation and preparation for storage, iii) plant safe storage with concurrent operations in the spent-fuel pool until the pool inventory is zero, iv) decontamination and dismantlement of the radioactive portions of the plant, leading to license termination.

The second alternative, SAFSTOR (a period of safe storage of the stabilized and defueled facility followed by final decontamination/dismantlement and license termination) is the decommissioning method in which the nuclear facility is maintained in a condition that allows the safe storage of radioactive components of the plant and subsequent decontamination to levels that permit release for unrestricted use. The first three stages of SAFSTOR are identical to those of DECON. The fourth stage is extended safe storage (50 years) with no fuel in the reactor storage pool, and the fifth stage is decontamination and dismantlement of the radioactive portions of the plant. The radioactive or contaminated material must be decontaminated and disposed of at a regulated disposal facility. Once residual radioactivity is at acceptable levels, the license will be terminated and the facility can be released for unrestricted use. After termination of the NRC license, disassembly or demolition of nonradioactive facilities would be performed at the owner's discretion. SAFSTOR was intended to maximize public safety while minimizing the initial commitments of time, money, radiation exposure, and waste disposal capacity. SAFSTOR may also have some advantage where there are other operational nuclear facilities at the same site or where a shortage of radioactive waste disposal capacity occurs. The disadvantages of SAFSTOR are that the site is unavailable for other uses for an extended time; maintenance, security, and surveillance are required until the final decontamination is complete; and few, if any, personnel familiar with the facility are available at the time of decontamination (up to 60 years after plant shutdown).

In the third alternative, ENTOMB (immediate removal of the highly activated reactor vessel internals for disposal and relocation of the remainder of the radioactively contaminated materials to the reactor containment building, which is then sealed) radioactive contaminants are encased in a long-lasting material, such as concrete. The entombed structure is maintained and surveillance is performed until the radioactivity decays to a level permitting release of the property for unrestricted use. ENTOMB also features five distinct stages of effort, the initial three stages being identical to those of DECON. The fourth stage is preparation for entombment, when all of the radioactive materials are consolidated within the containment building and entombed. The fifth stage is entombed storage for an extended time, between 60 and 300 years. ENTOMB is intended for use where the residual radioactivity will decay to levels permitting unrestricted release of the facility within reasonable time periods (100 years). However, a few radioactive isotopes produced in nuclear reactors have long half-life periods that prevent the release of the facilities for unrestricted use within the foreseeable lifetime of any man-made structure. In addition, the use of the ENTOMB alternative contributes to problems associated with increased numbers of sites dedicated to "interim" storage of radioactive materials for long periods of time.

Since nuclear power plants are designed for a 40 to 60-year operating life (older plants were designed for a life of about 30 years) decommissioning is an issue that does not get full consideration at the project approval and planning stages. However, every facility will have to face decommissioning sooner or later and related economic and social costs and risks may be staggering.

In USA estimates regarding costs of decommissioning average around $325 million per reactor (in 1998 $). Regarding some specific cases, In France, decommissioning of Brennilis nuclear facility, a fairly small 70 MW power plant, already cost 480 million euros (20 times the original cost estimate) and is still pending after 20 years. Despite the huge investments in securing the dismantlement, extremely hazardous radioactive elements leaked out into the surrounding lake.[2] In Germany, decommissioning of Niederaichbach nuclear facility, a 100 MW power plant, amounted to more than 143 million euros. In UK, decommissioning of Windscale nuclear facility, a small 32 MW power plant, cost 117 million euros. Further decommissioning cases are displayed in Table 2.

These cases give credence to the Greenpeace claim that the period while the plant is being decommissioned may be twice as long as the reactor's operating life, while routine decommissioning costs reaching $1000 per kilowatt (Greenpeace 2009). Actually, Greenpeace's concern is shared by many others and, as US Nuclear Regulatory Commission underlines in their 2011 Report , a prudent and sound measure regarding decommissioning is to require a nuclear power plant operator to establish or to obtain a financial mechanism (such as a trust fund or a guarantee

2- http://en.wikipedia.org/wiki/Brennilis_Nuclear_Power_Plant from its parent company) to ensure that there will be sufficient money to pay for the ultimate decommissioning of the facility, before a nuclear power plant begins operations.

Table 2 : Nuclear Facilities Already Decommissioned or in the Decommissioning Process

Country	Location	Reactor type	Operative life	Decommissioning phase	Dismantling costs
Canada (Québec)	Gentilly-1	CANDU-BWR 250 MWe	180 days (between1966 and1973)	"Static state" since1986	stage two: US $ 25 Million
Canada (Ontario)	Pickering NGS Units A2 and A3	CANDU-PWR 8 x 542 MWe	30 years (from1974 to 2004)	Two units currently in "cold standby" Decommissioning in 2012?	(calculated: $ 270–430/kWe)
USA	Fort St. Vrain	HTGR (helium-graphite) 380 MWe	12 years (1977–1989)	Immediate Decon	$ 195 Million
USA	Rancho Seco[7]	Multiunit: PWR 913 MWe	12 years (closed after a referendum in 1989)	SAFSTOR: 5–10 years completion 2018	$ 200–500/kWe)
USA	Three Mile Island 2	Multiunit: 913 MWe PWR	INCIDENT: core fusion (in 1979)	Post-Defuelling Phase 2 (1979)	$ 805 Million (estimated)
USA	Shippingport	(The first BWR) 60 MWe	25 years (closed in1989)	Decon completed dismantled in 5 years (first small experimental reactor	$ 98,4 Million
USA	Trojan	PWR 1.180 MWe	16 years (closed in 1993because nearby seismic fault)	SAFSTOR: (cooling tower demolished in 2006)	
USA	Yankee Rowe	PWR 185 MWe	31 years (1960–1991)	DECON COMPLETED – Demolished (greenfield open to visitors)	$608 Million; with $8 Million per year upkeep
USA	Maine Yankee	PWR 860 MWe	24 years (closed in 1996)	DECON COMPLETED – Demolished in 2004 (greenfield open to visitors)	$ 635 Million[
USA	Connecticut Yankee	PWR 590 MWe	28 years (closed in 1996)	Decon -Demolished in 2007 (greenfield open to visitors)	$ 820 Million
USA	Exelon - Zion 1 & 2	PWR - Westinghouse 2 x 1040 MWe	25 years (1973 – 1998) (Incident in proceedings, abandoned)	Safstor-EnergySolutions (opening of the site to visitors for 2018)	$ 900–1,100 Million (2007 dollars)

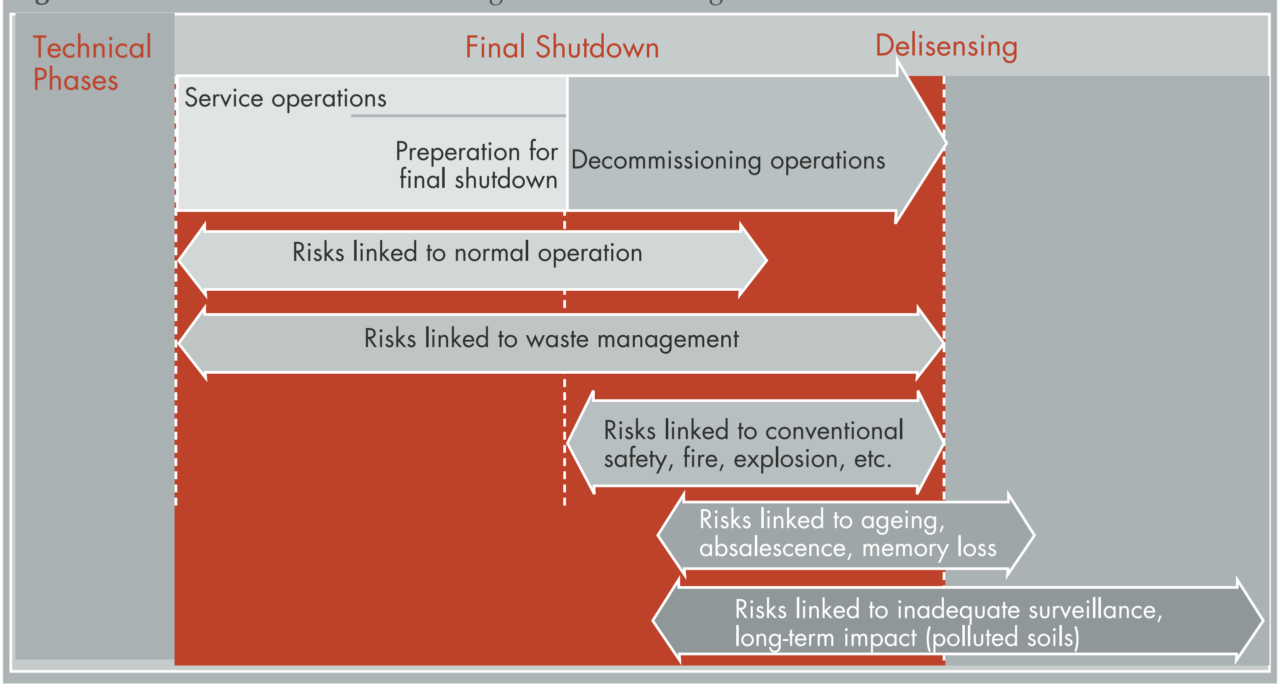
http://en.wikipedia.org/wiki/Nuclear_decommissioning

Naturally, just giving consideration to the financing of decommissioning does not eliminate the many risks associated with decommissioning. Figure 2 displays the main risks encountered when decommissioning a nuclear installation and the periods during which these risks are highest.

The risks involved in waste management and which concern safety or radiation protection (serious increases in the number of waste storage sites, storage of irradiating waste) are present throughout the phases in which large amounts of waste are being produced and therefore in particular during the decommissioning phase.

The risks present during operation of the installation change as decommissioning progresses. Even if certain risks, such as criticality, quickly disappear, others, such as those related to radiation protection (gradual removal of containment barriers) or conventional safety (numerous contractors working together, falling loads, work at height, and so on) gradually become more important. The same applies to the risk of fire or explosion (hot spot" technique used in cutting up the structures), as well as, for example, to the risks related to human and organizational factors (organizational changes in relation to the operating phase, frequent reliance on outside contractors).

Figure 2: Main Risks Encountered During Decommissioning



Decommissioning work of nuclear reactors often lasts for more than a decade. It follows on from an operating period that often lasts several decades. There is consequently a very real risk of all memory of the design and operation of the nuclear installations being lost. It is vital to be able to collect and thoroughly document the knowledge and memories of the staff involved in the operating phase, particularly as the traceability of the design and operation of the older installations is not always as thorough and reliable as might be desired. The length of the decommissioning operations also involves taking account of the risks inherent in the obsolescence of certain equipment (electrical or monitoring networks for example). Depending on the stage reached in the operations, risks linked to the potential instability of partially dismantled structures must also be taken into account.

The sometimes rapid changes in the physical condition of the installation and in the risks present raise the issue of ensuring that the means of installation surveillance are adequate and appropriate at all times. It is often necessary, either temporarily or permanently, to replace the centralized operational monitoring and surveillance systems with other more appropriate resources, such as "field" radiation monitoring or fire detection devices, located as close as possible to the potential source of risks. Constantly checking the adequacy of surveillance for the rapidly and significantly changing status of the installation is a difficult exercise, and there is a very real risk of failing to detect the onset of a hazardous situation."

In the Turkish case, risks associated with decommissioning and storage/removal of spent fuel are also the direct responsibility of the operator. However, the realization of such risks will necessarily impact the Turkish State, especially regarding safety and well-being of the local and national population, as well as the environment. Accordingly, detailed and long range plans and procedures aimed at minimizing such risks, as well as related contingency plans, must be prepared and agreed upon by all stakeholders. These plans and procedures should clearly be associated with specific decommissioning stages, and identify the size and location of long term hazardous/radioactive material storage/dump sites, together with assurances regarding their long term protection and containability.

However, at this point in time, there remains uncertainties regarding the sufficiency of the plans for financing the decommissioning and the related risk mitigation measures. The inter governmental agreement between Turkey and Russia specifies the operator as the party responsible for all decommissioning decisions and efforts, while allocating 0.0015 U.S.$ per kWh of electricity sold (from the nuclear facility to be developed and operated) to fund these efforts. The decommissioning strategies to be followed, the timing of specific decommissioning stages and/or the related decommissioning triggering mechanisms, related cost estimates and contingency plans are still areas that need to be addressed more thoroughly.

4.5 Risks Associated with Storage/Removal of Spent Fuel

As the Fukushima incident has demonstrated, another clearly identifiable risk area relates to the management of spent fuel. The overall risk can be separated in two sub categories. The first sub category relates to the temporary storage of the spent fuel within or near the nuclear power plant. The second sub category involves the long term storage of the spent fuel which involves the decision to reprocess (or not) the spent fuel. For the Akkuyu case, the long term challenge is addressed by the provision in the intergovernmental agreement between Turkey and Russia which envisages the spent fuel to be repatriated to Russia. The agreement specifies the operator as the party responsible for all spent fuel related storage, removal activities and related costs and risks Russia is in fact the only country in the world that will permanently take back the spent fuel. Other countries send back to the country of origin the high level toxic waste that will result from the reprocessing of the spent fuel.

As a result, for the Akkuyu case, the main risk relates to the temporary storage of the spent fuel within or near the nuclear facility. A related risk factor relates to the transport of the spent fuel to its country of permanent storage. More fundamentally, the amount, duration, location and methodology of temporary storage at the local site, the frequency, means and routing of the spent fuel from its temporary storage to its final destination in Russia, related contingency plans still need to be addressed.

However, as stated, the agreement with Russia for the Akkuyu nuclear power plant cannot provide a blueprint solution for dealing with the risks of spent fuel management. In other cases, the operator will not be able to give the guarantee for permanent storage of the spent fuel outside of Turkey. Therefore Turkish authorities intent on implementing an ambitious program for the development of civilian nuclear power will need to develop a national strategy to deal with the crucial issue of spent fuel management.

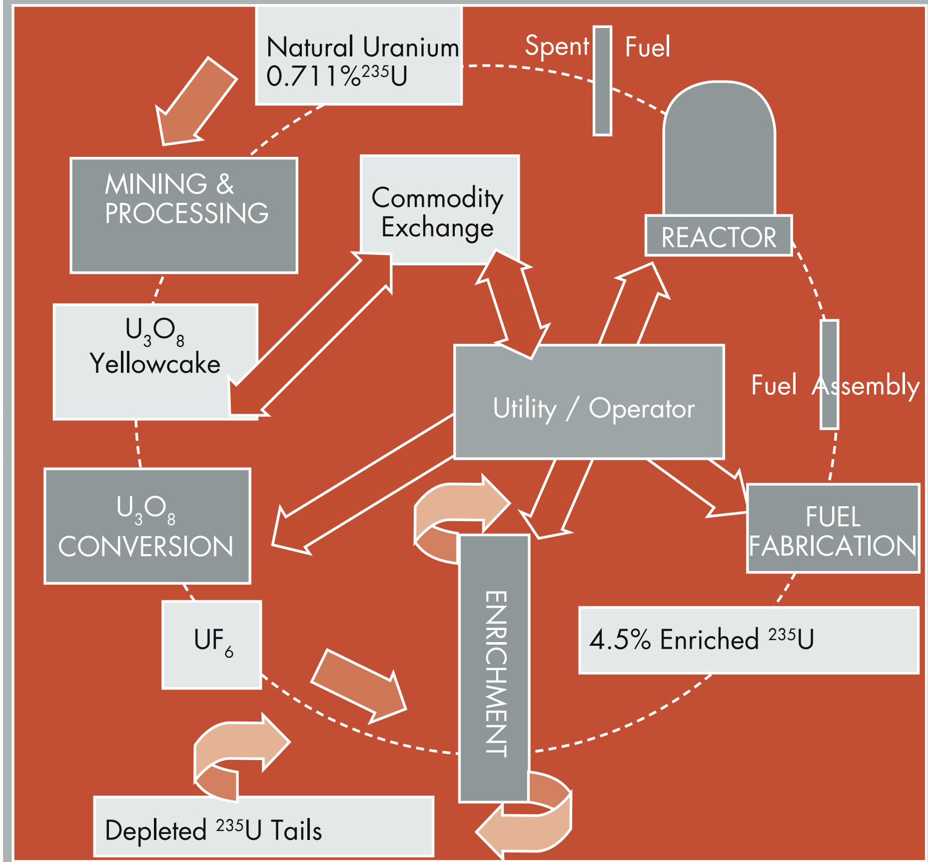
5 Strategic Risks

5.1 Supply Security Issues and Related Risks

Supply Security is primarily concerned with the sufficient availability of the appropriate nuclear fuel necessary for the continuous, safe and reliable operation of the facility at its design capacity.

Nuclear fuel is difficult to commoditize. Even if some quantity of low-enriched uranium is stockpiled at suitable locations, the fuel would need to be enriched/blended to the appropriate level and fabricated specifically for a designated nuclear reactor. Experts indicate that, even when the fabrication facility is immediately available (with no waiting time) and LEU being prequalified for the reactor, the time from enrichment to final fuel delivery could take nearly a year (a schematic illustration of the conceptual nuclear fuel cycle is displayed in Figure 3). A likelier scenario might be two years or more in some cases. Thus, supply assurance schemes limited to enriched uranium alone may be necessary but are insufficient. Furthermore, fuel fabricators tend to specialize, and alternative fabricators of the fuel assemblies will likely produce lower quality assemblies in terms of optimal performance and may not even be licensed to provide a certain "fuel assembly" (the final product). This highlights the importance of operators managing their commercial and political fuel risks by maintaining fuel stock inventory, using extended lead times for ordering, and assuring (if possible) some alternative sources (Decker and Kerjan 2007).

Figure 3: The Nuclear Fuel Cycle



Source:CRS

Nevertheless, many experts have noted that existing world market arrangements offer a very high standard of security of supply in all aspects of the nuclear fuel industry. In the history of the industry, there has never been a disruption of supply that has led to a loss of electricity generation. Several instances of major discontinuities in recent years have all been resolved with conventional market mechanisms (World Nuclear Association, 2006).

One major reason of this excellent track record is the fact that nuclear reactors operate without refueling for 12 to 18 months (thus securing months of electricity supply before halting), and if delivery of fresh fuel is delayed, a reactor can still be operated for 2-6 months beyond its scheduled shut down, at gradually lower power. Additionally, operators of nuclear power plants usually receive their full fuel reloads several months in advance of refueling, and the fuel supply inventories of material in process within the procurement chain amount to months of requirements. Thus nuclear power plants enjoy an electricity production autonomy and flexibility much greater than their conventional rivals (Euratom Supply Agency, 2005).

Accordingly, concerns regarding supply security of nuclear fuel is a recent subject. One major reason of this recent concern being the fact that primary production of natural uranium covers only 60% of world demand, while the remaining part coming from historical production (inventories and weapons dismantling) and from the re-enrichment of tails of depleted uranium resulting from the enrichment process (Euratom Supply Agency, 2005).

At 2005, an expert group was formed by the IAEA to summarize and report the proposals of different governments and to come up with a solution that would provide countries with assurance of civilian nuclear fuel supply and to assure non-proliferation (International Atomic Energy Agency, 2005).Since then, several proposals have been made regarding various aspects of assured nuclear fuel supply ranging from providing backup supplies through establishing low enriched uranium (LEU) stocks under IAEA auspices, to assurances by the nuclear industry and respective governments, to setting up international uranium enrichment centers.

Six States, comprising United States, France, Germany, Russia, UK, and Netherlands have suggested an assurance of enriched uranium supply so that if one supplier's delivery is disrupted due to political reasons unrelated to proliferation concerns, the remaining enrichers would collectively provide a substitute source of supply at market rates pending resolution of the disruption. Some in the international community suggested that the major enrichers should set aside some enriched fuel to backup the assurance.

In December 2, 2010, the first international nuclear fuel repository has opened at a uranium enrichment facility in Angarsk, Siberia. The fuel bank is holding 120 metric tons of low-enriched uranium with approval and oversight by the International Atomic Energy Agency.

However, it is unclear to what extent countries would need to forego enrichment and reprocessing to be eligible for the assurances. Additionally, "eligibility criteria" for nuclear fuel supply from such "fuel banks" are not very explicit and are open to political considerations, as illustrated by the following set of example criteria established by IAEA (IAEA Board of Governors, 2010).

LEU, as a mechanism of last resort, shall only be supplied to a Member State,

a. *that is experiencing a supply disruption of LEU to a nuclear power plant due to exceptional circumstances impacting availability and/or transfer and is unable to secure LEU from the commercial market, State-to-State arrangements, or by any other such means;*

b. *with respect to which the Agency has drawn the conclusion in the most recent Safeguards Implementation Report (SIR) that there has been no diversion of declared nuclear material and no issues relating to safeguards implementation in that Member State are under consideration by the Board of Governors;*

c. *that has brought into force a comprehensive safeguards agreement13 requiring the application of safeguards to all its peaceful nuclear activities and pursuant to which safeguards are to be applied to the LEU that is supplied through the IAEA LEU bank;*

d. *for which the Director General has concluded that the Member State fulfills the criteria listed in sub-paragraphs (a), (b) and (c) above.*

In light of the above discussions, a sound nuclear fuel supply assurance concept would be a "guarantee-in-depth" (somewhat analogous to "defence-in-depth" in reactor safety), consisting of three layers of guarantees (World Nuclear Association, 2006).

• Level I: Basic supply security provided by the existing world market (based on the strong multi-year performance record of the international market).

Forging diversified, long-term business relationships at reasonable price levels with suppliers is an integral part of this layer. Additionally, the "long term" aspect is important since it makes it easier for their suppliers to decide on new investments and/or secure the visibility and resilience of their own supplies.

- Level II: Collective guarantees by enrichers supported by governmental and IAEA commitments (to be invoked in the event of a disruption of normal commercial supplies for bilateral political reasons between an enricher and a customer State).
- Level III: Government stocks of enriched uranium product (EUP) (to be used as a last resort in the unlikely event that enrichers could not meet their backup supply commitments as embodied in Level II.

It should be emphasized that any arrangements for emergency or backup or guarantee supply arrangements ought to be used only as a last resort if existing market arrangements have failed, and not as a substitute for market supplies. Additionally, the triggering of emergency or backup or guarantee supply arrangements should be expected to be effective only in the event of a political disruption of the normal market for a reason other than a non-proliferation issues. In other words, any unilateral attempt by the customer State to fabricate its own nuclear fuel is likely to damage the first two layers of the supply guarantee system.

In the Akkuyu example, providing the necessary fuel and maintaining supply security is the direct responsibility of the Russian operator. However, the realization of such risks will necessarily impact the Turkish State, especially regarding power supply shortfalls and unreliable operations. Accordingly, detailed and precise plans and procedures aimed at minimizing such risks, as well as related contingency plans, must be prepared and agreed upon by all stakeholders. These plans and procedures should clearly identify, procurement sources, possible back-ups, target stockpile levels. If there are any plans to immediate or future manufacturing of some or all of the necessary fuel locally, details of that plan, regarding timing, investment, equipment, know-how and testing needs, as well as plans and procedures for obtaining international (IAEA) approval/endorsement, should be provided. Additionally, the relevant regulatory agencies of the Turkish State ought to be able to administer periodic inspections throughout the operation period to make sure that the fuel stockpile targets agreed upon are adhered to.

5.2 Terrorism Risks

It should be noted that nuclear plants already have extensive measures in place to prevent, withstand and, if necessary, mitigate the effects of a terrorist attack. Thus, in theory, they ought to be unattractive targets for sophisticated terrorists, reluctant to launch attacks that would likely fail. However, nuclear plants are, at the same time, very high-profile facilities and the general public is very sensitive to their well-being. Accordingly, even the slightest damage or its attempt would draw a lot of attention, thus, highly increasing the attractiveness of these facilities as targets of terrorist attacks. On the other hand, when some design characteristics (flaws) of nuclear facilities, which may make them more vulnerable to terrorist attack, were pointed out in the past, the authorities especially requested a "news-cap", to avoid (as they claimed) highlighting sensitive information that might be of use to terrorists. So, this issue deserves special, sensitive consideration.

Terrorism Risks include,

- Attempts to crash into the facility or into the spent fuel / waste storage areas by airplanes, helicopters, trucks, cars or fast boats (carrying explosive or flammable material, chemical and / or biological agents);
- Missile, bomb attacks to the facility or to the spent fuel / waste storage areas or to the power lines;
- Attempts to place and ignite explosives or flammable material, chemical or biological agents at the facility grounds or on to the outside surface of the buildings;
- Attempts to infiltrate the facility and place and ignite explosives or flammable material within the facility or within the spent fuel / waste storage areas;
- Attempts to infiltrate the facility and damage the equipment and / or the wirings;
- Attempts to disrupt the transportation of incoming or outgoing radioactive / toxic material with the aim of stealing radioactive material and / or spreading radioactivity.
- Attempts to infiltrate the power transmission system and damage the equipment and / or the wirings;
- Cyber attacks (primarily attempts to remotely seize and manipulate plant controls to cause an accident).

The above listed attempts may involve small or large external teams, suicide bombers, insider support, heavy equipment, little or extensive military style training.

At this point, it should be emphasized that the physical security of nuclear power plants and their vulnerability to deliberate acts of terrorism was elevated to a security concern following the attacks of September 11, 2001. Nuclear power plants were designed to withstand hurricanes, earthquakes, and other extreme events. But deliberate attacks by large airliners loaded with fuel, such as those that crashed into the World Trade Centre and Pentagon, were not analyzed when design requirements for today's reactors were determined including even third generation reactors. A taped interview shown September 10, 2002, on the Arab TV station al-Jazeera, containing a statement that Al Qaeda initially planned to include a nuclear plant in its list of 2001 attack sites. In light of the possibility that an air attack may penetrate the containment structure of a nuclear plant or a spent fuel storage facility, it is not impossible that such an event can be followed by a meltdown or spent fuel fire and widespread radiation exposure (Holt and Andrews 2007,Martin 2000).

Theoretically, an aircraft crash, a flood, a terrorist attack or disruption of energy supply as it was at Fukushima may also cause such an accident at a nuclear power plant. The European Commission has therefore called for comprehensive tests called as stress tests for which embrace both natural and manmade hazards, including effects of airplane crashes and terrorist attacks. All 143 nuclear power plants in the EU will be re-assessed using EU wide criteria (European Commission 2011).

Most of these risks are shared by the nuclear facility developer, the operator, its insurer and the State. The developer and the operator are primarily responsible for the safety and security of the facility grounds. The State is responsible for providing protection against airplane, helicopter, truck, car crashes, missile and long range bomb attacks, as well as preventing unauthorized groups from getting close to the site and responding to calls of security support from the site. Since the State has a direct responsibility in minimizing terrorism risks, and since the realization of such risks will necessarily impact the Turkish State and possibly the local and global environment detailed and precise plans, technical guidelines and procedures aimed at minimizing such risks, as well as related contingency, emergency and recovery plans, must be prepared and agreed upon by all stakeholders.

Regarding the State, these guidelines, procedures and plans should clearly cover,

i) No fly/sail and restricted fly/sail zones around the facility, as wells as how to monitor and enforce these restrictions and intervene if necessary; monitoring and intervention capability should cover manned or unmanned small, high speed, low flying bodies, as well as high speed boats;

ii) Restricted lands and roads around the facility, as well as how to monitor and enforce these restrictions and intervene if necessary;

iii) A nearby command and communication center with secure communication lines to the facility and sufficient security equipment, personnel (including armed tactical forces) and materials, safely stockpiled for immediate availability and deployment;

iv) Providing security support in the transportation of incoming radioactive fuel and outgoing radioactive/toxic wastes and spent fuel.

v) Contingency planning and capability for partial or full evacuation of the surrounding population out to 15 km. from the plant;

vi) Live training programs and exercises, as well as simulation based training and testing.

Regarding the operator, these guidelines, procedures and plans should clearly cover,

i) Bomb, missile, airplane, truck crash resistant outer shell and spent fuel/waste areas;

ii) A system of road barriers to prohibit crashing/vehicle-bombing attempts by land vehicles;

iii) Protection against waterborne vehicles;

iv) Special considerations for the control room (to enable operators to safely shut down the plant following an explosive, biological or chemical attack); such as, heavy sealing and/or filtering, separate temperature control, availability of self-contained breathing apparatus; capability of reactor shut down from a location outside the control room;

v) Sound, vision and other systems to detect trespassers and monitor the safe operation of critical equipment;

vi) Equipment and animals to detect hidden explosive and/or flammable material;

vii) Size, equipment, supplies and capabilities of the security team (including well-defined physical fitness standards, minimum qualification scores for mandatory tests, requirements for on-the-job training);

viii) Frequency and content of routine inspections;

ix) Extensive screening and periodic security checks of the facility personnel (screening process should include, background investigation, psychological assessment, drug and alcohol screening, continuous behavioral observation);

x) Rigorous screening and security checking of all visitors;

xi) Safe communications with the State's command/security center;

xii) Reliable back-up power availability;

xiii) Extensive emergency response (especially equipment damage control, explosion, fire fighting, coordinated partial or full evacuation, back-up communication, medical) capabilities;

xiv) Multi layered, controlled and restricted access to sensitive areas within the facility;

xv) Inspection of all incoming supplies and material, as well as outgoing material;

xvi) Transportation security of incoming fuel and other critical supplies (vehicle types and sizes, size and effectiveness of the security detail, coordination with and requested coverage of the authorities, security of the schedules, routes and related communications);

xvii) Transportation security of outgoing spent fuel and other radioactive/toxic wastes (vehicle types and sizes, size and effectiveness of the security detail, coordination with and requested coverage of the authorities, security of the schedules, routes and related communications);

xviii) Security plans that describe how digital computer and communications systems and safety-related networks are protected from cyber attacks;

xix) Live training programs, exercises, as well as simulation based training and testing.

Additionally, the relevant regulatory agencies of the Turkish State ought to be able to administer periodic inspections throughout the operation period to make sure that the guidelines, procedures and plans agreed upon are adhered to. Furthermore, transportation and communication links to the site area should have sufficient resilience and spare capacity to allow for immediate additional emergency response to possible terrorist act realizations.

6 Considerations on Turkey's Management Capability of Safety Related Risks Associated with Nuclear Power

It can be said that nuclear power plants are the most sophisticated and complex energy systems ever designed. As happened at Three Mile Island in 1979, a malfunction may lead to another, and then to a series of others, until the core of the reactor itself begin to melt, and even the world's most highly trained nuclear engineers cannot know how to respond them (Cooke 2009). Recently the world witnessed that Japan, one of most technologically advanced countries was incapable of preventing and managing the nuclear accident in Fukushima. Since waste from nuclear power plants remains active for hundreds of thousands of years, nuclear power plant accidents pose most catastrophic threats for the global environment and public health. As a consequence, the operation of nuclear power plants carry heavy risks hence need sophisticated risk management. Assessing nuclear risks accurately and manage safely also needs use of sophisticated risk analysis and management techniques and human recourses with required high skills and expertise. The main challenges concerning Turkey's ability to fulfil the requirements for ensuring a safe transition to nuclear power can be summarized as follows:

- **The human resources gap.**

As a country that has had no experience in managing a large scale nuclear power capacity, Turkey currently lacks the human resources to carry out effectively the state's regulatory functions in particular concerning safety issues. Obviously this is a problem common to many states transitioning to nuclear power. The solution requires the adoption of a long term human resources development policy that would for instance involve a much closer and comprehensive cooperation with the IAEA in the area of professional training. The EU's TAIEX program can also be invoked to allow for twinning programs between the domestic regulatory institution and EU member states' nuclear authorities. For the short term however, state authorities may decide to seek international expertise in order to undertake the safety analysis for the Akkuyu project.

- **The regulatory gap.**

Turkey has not a sufficiently developed and sophisticated legal and regulatory framework for the regulation of nuclear power plant facilities and activities and for the clear assignment of responsibilities. An independent regulatory body to oversee the transition to nuclear power has not yet been setup. Likewise an effective risk management system for ensuring nuclear power plant safety has not yet been fully established.

The current regulatory framework for nuclear power consists of two laws, namely the Nuclear Law and the Law on TAEK, numbered 2690 and dated 9 July 1982; and implementing regulations (Martin 2000). The Law on the Construction and Operation of Nuclear Power Plants and Energy Sale, numbered 5710 ("Nuclear Law"), the first nuclear power law of Turkey, was enacted on 9 November 2007.

Numerous international agreements, both multilateral and bilateral, are also applicable in this context. Turkey has been a party to the Treaty on the Non-Proliferation of Nuclear Weapons (NPT) since 1980 and a member state of the International Atomic Energy Agency (IAEA) since 1957. Apart from the NPT, Turkey is a state party to the multilateral treaties given in Table 3 regulating various aspects of the peaceful use of nuclear power. The ratification process is ongoing for the Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management.

Table 3: International Agreements concluded by Turkey

Name	Signature Date	Ratification Date
Paris Convention on Third Party Liability in the Field of Nuclear Energy	29.07.1960	13.05.1961-10806
Protocol to Amend the Convention on Third Party Liability in the Field of Nuclear Energy of 29 July 1960	28.01.1964	13.06.1967-12620
Treaty on the Non-proliferation of Nuclear Weapons (NPT)	28.01.1969	28.11.1979-16823
Agreement Between the Government of the Republic of Turkey and the IAEA for the Application of Safeguards in Connection with NPT	30.06.1981	20.10.1981-17490
Protocol to Amend the Convention on Third Party Liability in the Field of Nuclear Energy of 29 July 1960, as Amended by the Additional Protocol of 28 January 1964	16.11.1982	23.05.1986-19115
Convention on The Physical Protection of Nuclear Material	23.08.1983	07.08.1986-19188
Convention on Early Notification of a Nuclear Accident	28.09.1986	03.09.1990-20624
Convention on Assistance in the Case of a Nuclear Accident or Radiological Emergency	28.09.1986	03.09.1990-20624
Joint Protocol Relating to the Application of the Vienna Convention and the Paris Convention	21.09.1988	19.11.2006-26351
Convention on Nuclear Safety	24.09.1994	14.01.1995-22171
Comprehensive Nuclear Test Ban Treaty	03.11.1999	26.12.1999-23918
Protocol Additional to the Agreement Between the Government of the Republic of Turkey and the IAEA for the Application of Safeguards in Connection with NPT	06.07.2000	12.07.2001-24460
Protocol to Amend the Convention on Third Party Liability in the Field of Nuclear Energy of 29 July 1960, as Amended by the Additional Protocol of 28 January 1964 and by the Protocol of 16 November 1982	12.02.2004	Awaiting ratification

Moreover, Turkey is still at the stage of establishing and updating its nuclear legislation by transposing in its national legislation the latest safety standards series issued by the IAEA.

Table 4: TAEK Regulations

Decree Pertaining to Issue of Licenses for Nuclear Installations,	RG[1] No: 18256 of 19.12.1983
Decree on Radiation Safety,	RG No: 18861 of 07.09.1985
Regulations on Physical Protection of Special Nuclear Materials,	RG No:16702 of 20.07.1979
Regulations on Radiation Safety	RG No: 23999 of 24.03.2000
Regulations on Nuclear Materials Accounting and Control	RG No: 23106 of 10.09.1997
Regulations on Safe Transport of Radioactive Materials,	RG No: 23106 of 10.09.1997
Regulations on the Establishment and Working Procedures of Nuclear Safety Advisory Committee,	RG No: 23106 of 10.09.1997
Regulation on Operating Organization, Personnel Qualifications and Licensing of Operating Personnel for Research Reactors,	RG No: 25973 of 21.10.2005
Regulation on Basic Requirements of Quality Management for Safety in Nuclear Installations,	RG No: 26642 of 13.09.2007
Regulation on Nuclear Safety Inspections and Enforcements,	RG No: 26642 of 13.09.2007
Regulation on Export Permit for Nuclear and Nuclear Dual Use Goods,	RG No: 26642 of 13.09.2007
Regulation on Specific Principles for Safety of Nuclear Power Plants,	RG No: 27027 of 17.10.2008
Regulation on Design Principles for Safety of Nuclear Power Plants,	RG No: 27027 of 17.10.2008
Regulation on Nuclear Power Plant Sites,	RG No: 27176 of 21.03.2009
Regulation on Specific Principles for Safety of Research Reactors,	RG No: 27144 of 17.02.2009
Regulation on Incident Notification and Reporting for Research Reactors,	RG No: 27144 of 17.02.2009
Regulation on Records and Reports for Research Reactors,	RG No: 27144 of 17.02.2009
Regulatory Documents Approved by TAEK: - A Guide on Fire Protection in Nuclear Power Plants - A Guide on External Man-Induced Events in Relation to Nuclear Power Plant Design - A Guide on the Earthquake Related Subject Requested in the Issuance of Limited Work Permit and Site License, 1989. - A Guide on Seismic Design and Qualification of Nuclear Plant Facilities, 29.5.1996-47 - A Guide for the Establishment and Implementation of a Quality Management System for the Safety in Nuclear Installations - A Guide for Document and Records Control for the Safety in Nuclear Installations - Guide for Acceptance Inspection and Testing for the Safety in Nuclear Installations	

- The technological gap.

The chosen reactor model for Akkuyu, the VVER-1200 has not yet entered into operation anywhere in the world. Its versions of are currently under construction at two sites in Russia. The VVER-1200 is third-generation technology and may be considered as safer than the world's current fleet of reactors, but this has not been demonstrated since it exists only on paper. VVER-1200 has evolved from the older VVER-1000 type reactors. Since many unproven features are introduced, it has not been demonstrated in the field and with an operational track record that its safety measures are fully adequate. So, there is neither satisfactory background information relating to the design, construction, commissioning, operation, decommissioning and dismantling of VVER-1200 nor any other sufficient evidence that is required to support its safety assessment. This uncertainty leads to increased safety risks and makes safety management much more difficult. In addition to the lack of experience; there is also a lack of documentation. For VVER-1200, the necessary tools for carrying out the safety assessment are not fully available including the necessary safety analysis computer codes and methods providing information on the safety margins. It is not possible to properly make safety assessments for VVER-1200 without having access to these tools, documentation including detailed technical description and to the preliminary safety analysis. This situation creates an important weakness in nuclear safety assessments and hence increases risks related to nuclear safety.

- An unproven "Safety Culture"

The government, energy administrators, the regulatory body, developers and operators have to prioritize above all the promotion of a safety culture. The fact that "safety and quality have higher priority than costs and schedule" needs to be demonstrated in,

- choice of qualified subcontractors;
- state-of-the-art tools and methods;
- uncompromising compliance with the agreed requirements;
- walk downs by the management.

More fundamentally, an attitude of constructive skepticism is to be nurtured at every level of each institution (regulatory, operator, developer, sub-contractor) involved in nuclear energy. Workers should be encouraged to question authority, to challenge the established rules and practices and report potential safety concerns to their supervisors. A significant challenge in countries transitioning to nuclear power will be the establishment of such an environment. This observation is of particular relevance to Turkey where the cultural traditions may work against such an approach which necessarily implies a healthy challenge to authority.

In light of the above, the following recommendations can be highlighted.

The best way to ensure a safe transition to nuclear energy in Turkey is the establishment of a competent, independent institutional capacity with sufficiently well endowed human resources that can effectively oversee this process. As set out in the analysis by Izak Atiyas in this compilation of working papers, the investment model for the Akkuyu Project incentives the investor for cost cutting as a result of the fixed price guarantee for the purchase of electricity. While the core responsibility for managing risks associated with the design, construction, operation and decommissioning of the nuclear power plant as well as other risks such as natural disasters, terrorism, supply security and spent fuel management lies with the operator, the public at large will be significantly affected by the mismanagement of these risks. The regulatory capacity will have to shoulder the burden of ensuring the safety of nuclear power.

It is not realistic to expect Turkey to develop the needed human resources and to setup the cultural, institutional and legal infrastructure in the short term. There may be a need therefore for existing institutions to seek third party international assistance to overcome the bottleneck of human resources in the short term. In the medium term, an ambitious human resources development strategy should be adopted and a cooperation with international organisations such as the IAEA for professional training should be envisaged.

There will be a need a) to incentivize the employment of a sufficient number of Turkish technical personnel in the nuclear power plants under construction and eventually under operation in Turkey ii) to establish a program of human resources training with international organisations such as the IAEA iii) to establish a program of exchange with other states experienced in nuclear power plant operations to allow Turkish technical experts to be trained at these facilities iv) to promote cross border inter-university cooperation that would allow Turkish universities to establish joint undergraduate/graduate level programs v) to mandate research institutions such as TÜBİTAK to support international research projects on nuclear power plant technology, operation and monitoring vi) to ensure with administrative and financial measures that the potential nuclear safety authority is endowed with the necessary and competent human resources.

On the other hand, there are still significant deficiencies in the institutional setup from the standpoint of guaranteeing the required level of safety. There is still no independent nuclear regulatory authority. This task is currently being performed by TAEK. Given that TAEK is also the operator of research reactors, the requirement for the safety authority to be fully independent from the operators has clearly not been fulfilled. Moreover recent administrative and legal measures which have greatly undermined the independence of regulatory institutions in Turkey are likely to handicap the objective of fully fulfilling the safety standards in the transition to nuclear power. In particular in a model where in the future the state can become a financial stakeholder, the independence of the regulatory institution from the government is an essential feature that can allow the regulatory authority to insist on safety requirements reducing the profitability of the investment or to resist pressures from the government to unduly accelerate the construction of the nuclear power plant. Rules regarding the employment, promotion and renumeration of the staff of the nuclear safety authority should be based on merit. New mechanisms to enable the employment of the existing limited number of experienced and competent nuclear experts in the regulatory authority should be designed.

At the beginning, it would be useful to focus the competence of the human and administrative capacity on a single nuclear technology. It may not be realistic to expect an emerging nuclear state to acquire the competence to fully monitor and regulate the transition to many different nuclear technologies. Given that according to the intergovernmental agreement with Russia, the technology chosen for the Akkuyu nuclear power plant is a pressurized water reactor, choosing the same technology for the second nuclear power plant would put less pressure on the regulatory capacity. That may be the reason why, in the negotiations with the government of Japan, the Turkish side stated its preference for a pressurized water reactor rather than a boiling water reactor.

In addition, Turkey should be ready to rely on the procedure of "peer reviews" in addition to its own internal regulatory capacity that will be gradually built up. That would enable for instance the IAEA to assess whether the Turkish legislation and regulatory framework is sufficient to allow a safe and secure transition to nuclear power. Similarly this approach would allow the independent and separate testing of a new nuclear power plant before its entry into operation by the World Association of Nuclear Operators, the umbrella organisation of the nuclear power plant operators in addition to the tests conducted by the national authorities. The willingness of Turkey to participate in the stress tests for nuclear power plants held by the EU should be a welcomed as a positive step.

A more regular and comprehensive communication strategy with the public at large focusing on the adopted safety and security measures would be helpful in defusing the polarisation surrounding the transition to nuclear power. The legitimate concerns of the Turkish public opinion on the safety of nuclear power can only be addressed with such a long term, comprehensive and realistic approach to strategic communications.

As stated in previous sections, it is important for the company responsible for the construction of the nuclear power plant, the operating company, the nuclear safety authority, the local population as well as all relevant stakeholders to fully internalize the required safety culture in order to reduce the risks related to the construction, operation and decommissioning of nuclear power plants. The main elements of this safety culture are i) fight against fatalism, ii) a questioning attitude towards complex technologies iii) the full implementation of all relevant rules and procedures and the ability to show initiative in case of perceived violations iv) drawing the right lessons from all unwanted situations, realized risks and accidents small and big v) challenging even the more established procedures with a view to improve them. The right approach to this type of safety culture can only be gained by a wholesale change in societal behavior supported by large scale education and effective media campaigns.

It should be recalled that the intergovernmental agreement contains scant provisions about the risks related to supply security, spent nuclear fuel and plant decommissioning. There is a clear need for a clarification by the public authority about the risk elimination and mitigation strategies that will be adopted to address these risks that currently fall under the responsibility of the operator.

As stated in the other working papers in this compilation, the Akkuyu Project does not constitute a replicable blueprint for Turkey's transition to nuclear power. Key features such as the sharing of investment risks, the agreement on the electricity price and on spent fuel management preclude this project from becoming a replicable model. However the Akkuyu investment will force Turkey to setup the necessary institutional and human infrastructure for a safe and secure adoption of nuclear power. This requirement should be among the priority goals of the Turkish government intent on implementing an ambitious strategy for nuclear power.

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Section II

Major Nuclear Accidents and Their Implications for the Evolution of Nuclear Power

II

Prof. Dr. Hasan Saygın

Executive Summary

Nuclear disaster is a disaster deeply affecting people physically, mentally, emotionally, economically and genetically, altering and damaging genes to cause serious effect to generations to come. Some serious nuclear power plant accidents including the Three Mile Island accident (1979) Chernobyl disaster (1986), and now Fukushima I nuclear accidents (2011) strongly affected on the development of nuclear power and the evolution of reactor technology. The first serious accident in the world and still being the worst nuclear accident in the West, occurred in the pressurized water reactor at the Three Mile Island facility in Pennsylvania in 1979. The Three Mile Island accident was a significant turning point in the global development of nuclear power. The number of reactors under construction was increasingly rising every year in the period 1963–1979. Following the accident, the number of reactors under construction in the U.S. rapidly declined. . Globally, the cessation of increase in nuclear power plant construction came with the more catastrophic Chernobyl disaster in 1986 Chernobyl's accident was a turning point for the nuclear power industry worldwide. According to World Association of Nuclear Operators (WANO), "It demonstrated clearly that nuclear power was not safe enough." After decades of inertia following the accidents at Three Mile Island and Chernobyl nuclear power has been making a comeback due to serious concerns about climate chance and energy dependency. Industry representatives have started assert that the needs of an energy-hungry world have made a massive expansion of nuclear power inevitable. Since the early 1980s, many nations utilizing nuclear power have overseen and regulated nuclear safety. Industry has been working on the development of so-called inherently safe reactors. Advanced (Generation III and III+) reactors have been developed in this period. Newer advanced reactors are inherently safer and more fuel efficient. They have simpler designs which reduce capital cost. As a result, the nuclear industry has in recent years been attempting a resurgence. The Fukushima accident occurred at just the moment. As a result a reassessment of the safety of nuclear power is underway in many countries that had opted for nuclear power.

1 Introduction

Nuclear disaster is a disaster deeply affecting people physically, mentally, emotionally, economically and genetically, altering and damaging genes to cause serious effect to generations to come. Some serious nuclear power plant accidents including the Three Mile Island accident (1979) Chernobyl disaster (1986), and now Fukushima I nuclear accidents (2011) strongly affected on the development of nuclear power and the evolution of reactor technology (IAEA 2009).

The first serious accident in the world and still the worst nuclear accident in the West, occurred in the pressurized water reactor at the Three Mile Island facility in Pennsylvania in 1979 (Teeghman). It was rated a level five by the INES. The Three Mile Island accident was a significant turning point in the global development of nuclear power. The number of reactors under construction was gradually rising every year in the period 1963–1979. Following the accident, the number of reactors under construction in the U.S. rapidly declined. Many similar Babcock and Wilcox reactors on order were canceled; in total, 51 American nuclear reactors were canceled from 1980–1984. Globally, the cessation of increase in nuclear power plant construction came with the more catastrophic Chernobyl disaster in 1986. The Chernobyl accident was a turning point for the nuclear power industry worldwide. According to World Association of Nuclear Operators (WANO), "It demonstrated clearly that nuclear power was not safe enough." The association points out that the accident "caused such a negative opinion of nuclear energy that, should such an accident occur again, the existence and future of nuclear energy all over the world would be compromised".[1]

Since the early 1980s, many nations utilizing nuclear power have overseen and regulated nuclear safety. Industry has been working on the development of so-called inherently safe reactors. Advanced (Generation III and III+) reactors have been developed in this period Newer advanced reactors are inherently safer and more fuel efficient. They have simpler designs which reduce capital cost.

After decades of inertia following the accidents at Three Mile Island in 1979 and Chernobyl in 1986 nuclear power has been making a comeback due to serious concerns about climate change and energy dependency. The industry has in recent years been attempting a resurgence. The Fukushima accident occurred at just this juncture. It has now been revealed as the worst since Chernobyl and perhaps the worst in history. The designers of reactors at Fukushima in Japan did not anticipate that a tsunami generated by an earthquake would disable the backup systems that were supposed to stabilize the reactor after the earthquake.

The nuclear power industry has improved the safety and performance of reactors, and has proposed new safer (but generally untested) reactor designs but there is no guarantee that the reactors will be designed, built and operated correctly. The extraordinary events at Fukushima in the past few months have led to major activity in assessing their implications for other countries. The accident demonstrated existence of serious problems in nuclear reactor technology once again.[2]

1- http://clonemaster.homestead.com/files/cancel.htm

2- "50 Years of Nuclear Energy", IAEA. http://www.iaea.org/About/Policy/GC/GC48/Documents/gc48inf-4_ftn3.pdf. Retrieved December 29, 2008.

Following these accidents all nuclear utilities reviewed their own reactor designs and operations to determine what changes should be undertaken in the light of the experience.

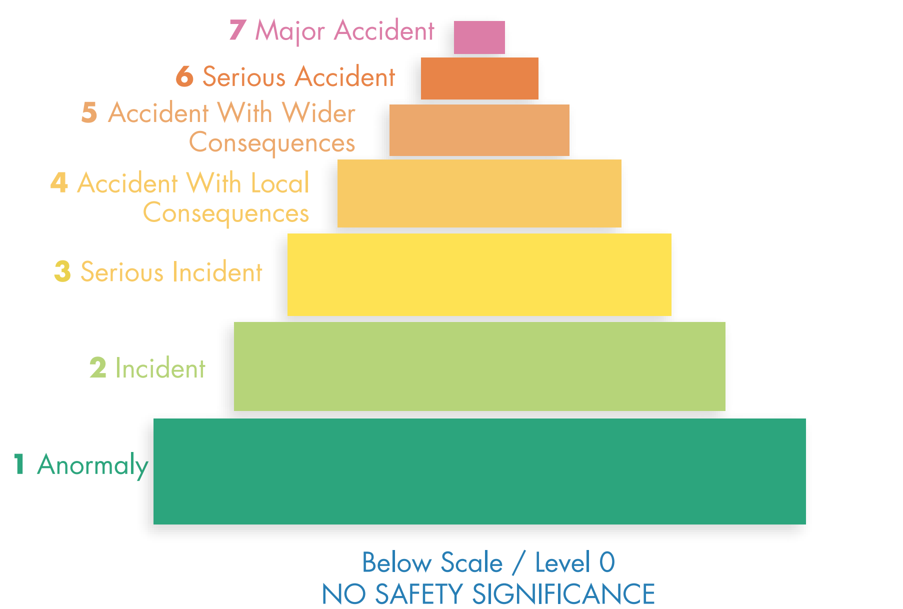
In this study, the biggest nuclear reactor accidents and their implications for the evolution of nuclear technology have been reviewed.

2 The Biggest Nuclear Accidents

The International Atomic Energy Agency (IAEA) defines the nuclear and radiation accident/disaster as "an event that has led to significant consequences to people, the environment or the facility by includes lethal effects to individuals, large radioactivity release to the environment, or reactor core melt without considering whether it is accidental or planned, whatever the form and cause".

IAEA uses the International Nuclear and Radiological Event Scale (INES) to assess the severity of nuclear accidents according to their impacts. It was introduced to enable prompt communication of safety significance information in case of nuclear accidents. The scale is logarithmic and each increasing level represents an accident approximately ten times more severe than the previous level (IEAE 2009).

Figure 1: Hierarchy of nuclear events on INES



Level 7 represents major accidents described by a major release of radioactive material with widespread health and environmental effects requiring implementation of planned and extended counter measures. A major accident is an event resulting in an environmental release corresponding to a quantity of radioactivity radiologically equivalent to a release to the atmosphere of more than several tens of thousands of terabecquerels of 131I. This corresponds to a large fraction of the core inventory of a power reactor, typically involving a mixture of short and long lived radionuclides. With such a release, stochastic health effects over a wide area, perhaps involving more than one country, are expected, and there is a possibility of deterministic health effects. Long-term environmental consequences are also likely, and it is very likely that protective action such as sheltering and evacuation will be judged necessary to prevent or limit health effects on members of the public. There have been two level 7 accidents up to now: Chernobyl and Fukushima accidents (IAEA 2009).

Level 6 represents a serious accident described by an impact on people and environment with significant release of radioactive material likely to require implementation of planned countermeasures. A serious accident is an event resulting in an environmental release corresponding to a quantity of radioactivity radiologically equivalent to a release to the atmosphere of the order of thousands to tens of thousands of terabecquerels of 131I. With such a release, it is very likely that protective action such as sheltering and evacuation will be judged necessary to prevent or limit health effects on members of the public. Only one an accident classified on this level occurred up to now: the Kyshtym Accident (IAEA 2009).

Level 5 represents accidents with wider consequences. Their impact on people and environment is described by limited release of radioactive material likely requiring implementation of some planned countermeasures and several deaths from radiation. Its impacts on radiological barriers and control is described by severe damage to reactor core and hence release of large quantities of radioactive material with a high probability of significant public exposure, possibly arising from a major criticality accident or fire (IAEA 2009).

The terminology of “Accidents with wider consequences” is used for events resulting in an environmental release corresponding to a quantity of radioactivity radiologically equivalent to a release to the atmosphere of the order of hundreds to thousands of terabecquerels of 131I. The Windscale fire (UK - 1957) and the Three Mile Island accident (US - 1979) fall under scale 5 nuclear power plant accidents (IAEA 2009).

Table 1: The INES scale by the International Atomic Energy Agency

INES

THE INTERNATIONAL NUCLEAR AND RADIOLOGICAL EVENT SCALE

GENERAL DESCRIPTION OF INES LEVELS

INES Level	People and Environment	Radiological Barriers and Control	Defence-in-Depth
Major Accident Level 7	• Major release of radioactive material with widespread health and environmental effects requiring implementation of planned and extended countermeasures.		
Serious Accident Level 6	• Significant release of radioactive material likely to require implementation of planned countermeasures.		
Accident with Wider Consequences Level 5	• Limited release of radioactive material likely to require implementation of some planned countermeasures. • Several deaths from radiation.	• Severe damage to reactor core. • Release of large quantities of radioactive material within an installation with a high probability of significant public exposure. This could arise from a major criticality accident or fire.	
Accident with Local Consequences Level 4	• Minor release of radioactive material unlikely to result in implementation of planned countermeasures other than local food controls. • At least one death from radiation.	• Fuel melt or damage to fuel resulting in more than 0.1% release of core inventory. • Release of significant quantities of radioactive material within an installation with a high probability of significant public exposure.	
Serious Incident Level 3	• Exposure in excess of ten times the statutory annual limit for workers. • Non-lethal deterministic health effect (e.g., burns) from radiation.	• Exposure rates of more than 1 Sv/h in an operating area. • Severe contamination in an area not expected by design, with a low probability of significant public exposure.	• Near accident at a nuclear power plant with no safety provisions remaining. • Lost or stolen highly radioactive sealed source. • Misdelivered highly radioactive sealed source without adequate procedures in place to handle it.
Incident Level 2	• Exposure of a member of the public in excess of 10 mSv. • Exposure of a worker in excess of the statutory annual limits.	• Radiation levels in an operating area of more than 50 mSv/h. • Significant contamination within the facility into an area not expected by design.	• Significant failures in safety provisions but with no actual consequences. • Found highly radioactive sealed orphan source, device or transport package with safety provisions intact. • Inadequate packaging of a highly radioactive sealed source.
Anomaly Level 1			• Overexposure of a member of the public in excess of statutory annual limits. • Minor problems with safety components with significant defence-in-depth remaining. • Low activity lost or stolen radioactive source, device or transport package.

NO SAFETY SIGNIFICANCE (Below Scale/Level 0)

Table 2: Nuclear events according to their ratings on INES (IAEA 2009).

	People and Environment	Radiological Barriers and Control	Defence-In-Depth
7	*Chernobyl, 1986* — Widespread health and environmental effects. External release of a significant fraction of reactor core inventory.		
6	*Kyshtym, Russia, 1957* — Significant release of radioactive material to the environment from explosion of a high activity waste tank.		
5	*Windscale Pile, UK, 1957* — Release of radioactive material to the environment following a fire in a reactor core.	*Three Mile Island, USA, 1979* — Severe damage to the reactor core.	
4	*Tokaimura, Japan, 1999* — Fatal overexposures of workers following a criticality event at a nuclear facility.	*Saint Laurent des Eaux, France, 1980* — Melting of one channel of fuel in the reactor with no release outside the site.	
3	*No example available*	*Sellafield, UK, 2005* — Release of large quantity of radioactive material, contained within the installation.	*Vandellos, Spain, 1989* — Near accident caused by fire resulting in loss of safety systems at the nuclear power station.
2	*Atucha, Argentina, 2005* — Overexposure of a worker at a power reactor exceeding the annual limit.	*Cadarache, France, 1993* — Spread of contamination to an area not expected by design.	*Forsmark, Sweden, 2006* — Degraded safety functions for common cause failure in the emergency power supply system at nuclear power plant.
1			Breach of operating limits at a nuclear facility.

Level 4 represents accidents with local consequences. Acidents with local consequences is a term employed for events resulting in an environmental release corresponding to a quantity of radioactivity radiologically equivalent to a release to the atmosphere of the order of tens to hundreds of terabecquerels of 131I. Level 4 accidents are Tokaimura Accident in Japan and Saint Laurent des Eaux Accident in France (IAEA 2009).

The biggest five nuclear reactor accidents on INES are therefore as follows:

- **Chernobyl Accident (Level 7)**

The accident at the Chernobyl Nuclear Power Plant in Northern Ukraine is the most severe accident in the history of the peaceful use of nuclear energy. The Reactor experienced a steam explosion and fire that caused a meltdown, releasing massive quantities of radioactive material. The explosion occurred at the building housing reactor No 4 and blew open the roof of the building causing radioactive material to escape into the air. As a result of this accident the fourth unit of the reactor was fully destroyed. A significant fraction of the reactor core inventory was released and contaminated areas of Belarus, Ukraine and the Russian Federation.

The total activity of all radionuclides that escaped from the active core of the reactor during 10 days after the explosions is assessed as approximately 1019 Bq. There were widespread health and environmental effects. The radiation from Chernobyl Nuclear Power Plant affected many people in and around the power plant and even many parts of Europe. As a result, the city of Chernobyl was largely abandoned, the larger city of Pripyat was completely abandoned, and a 30 km exclusion zone was established (IAEA 2009, Teeghman; Malko).

- **Fukushima Nuclear Accidents (Level 7)**

The accident occurred due to a series of events beginning on 11 March 2011. Major damage to the backup power and containment systems caused by an earthquake and tsunami resulted in overheating and leaking from some of the Fukushima I nuclear plant's reactors. Each reactor accident was rated separately; out of the six reactors, three were rated level 5, one was rated at a level 3, and the situation as a whole was rated level 7. An exclusion zone of 20 km was established around the plant as well as a 30 km voluntary evacuation zone.

- **Kyshtym Accident (Level 6)**

It occurred at Mayak, Soviet Union, 29 September 1957. A failed cooling system at a military nuclear waste reprocessing facility caused a steam explosion that released 70–80 tons of highly radioactive material into the environment. Impact on local population is not fully known. This is the only accident to go over 5 on the scale besides Chernobyl and Fukushima (IAEA 2009).

- **Three Mile Island accident (Level 5)**

The accident occurred Three Mile Island Unit 2 (TMI-2) Nuclear Power Plant near Middletown, Pennsylvania (United States), 28 March 1979. A combination of design and operator errors caused a gradual loss of coolant, leading to a partial meltdown. Radioactive gases were released into the atmosphere. It was the most serious in U.S. commercial nuclear power plant operating history, although it led to no deaths or injuries to plant workers or members of the nearby community(IAEA 2009; Teeghman).

- **Windscale fire (Level 5)**

The accident occurred in United Kingdom on 10 October 1957. Annealing of graphite moderator at a military air-cooled reactor caused the graphite and the metallic uranium fuel to catch fire, releasing radioactive pile material as dust into the environment (IAEA 2009; Teeghman).

Following the accidents all nuclear utilities reviewed their own reactor designs and operations to determine what changes should be undertaken in the light of the experience. Since the TMI-2 Accident in 1979, a great deal of research has been conducted to gain an understanding of severe accident phenomena and to reduce the numerous uncertainties inherent in the severe accident phenomena of nuclear power plants (USNRC, 1980) .A major objective in reactor design is to provide the capability to withstand a wide range of postulated events without exceeding specified safety limits. Assessment of the consequence of hypothetical loss of coolant accident in primary circuit is an essential element to address fulfilment of acceptance criteria.

A more detailed analysis of the Chernobyl, Fukushima and Three Mile Island accidents which remain the three biggest accidents in the 50-year history of nuclear power generation is provided in the next sections.

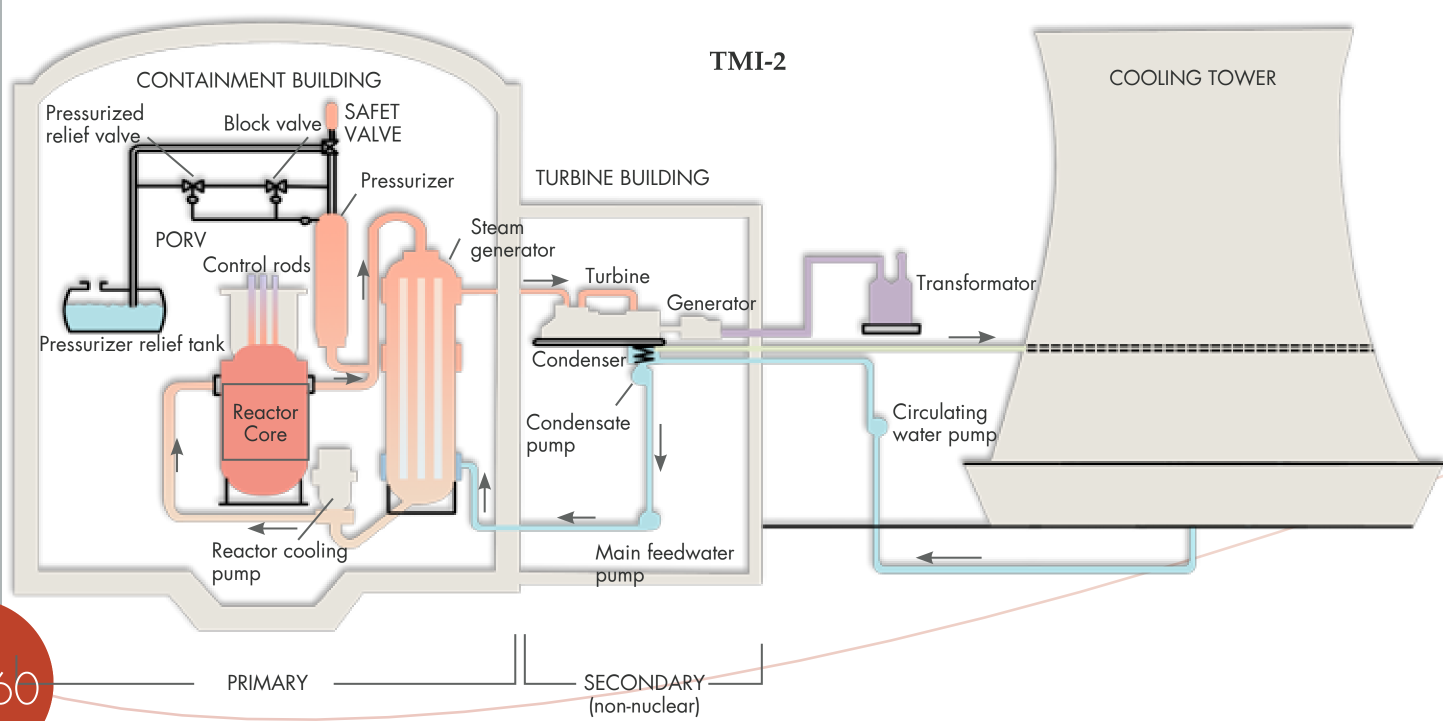
3 The Three Mile Island Accident

3.1 Three Mile Island Reactor –General Features

Three Mile Island Unit 2 (TMI-2) is owned by First Energy Company of Akron which was damaged during an accident Technology in 1979 and never reopened.

Figure 2: Three Mile Island Nuclear Power Plan

Figure 3: Schematic representation of Three Mile Island Nuclear Power Plant



TMI-2 is a pressurized water reactor (PWR) with a thermal power of 2,720 MWt designed by Babcock and Wilcox (Henry 2007). A PWR combines the efficiency of high temperature operation and the safety of a closed system by enclosing the reactor's core in a high-pressure tank filled with continuously re-circulated water. Because the water is under high pressure about 150 atmospheres, its temperature can rise above 300 °C without boiling. The reactor coolant pumps circulate this heated water through the steam generators. Here heat is transferred to cool water circulating in a much lower pressure secondary system. The heated water in this secondary at turns to steam at lower pressure and drives turbines, which drive electric generators. The large quantities of heat produced within the closed reactor system can only be removed by generation of steam in the secondary system.

Although the water in the core of the reactor must not be allowed to boil, only the water in the "pressurizer" tank is allowed to boil. The water circulating in the closed primary system is permitted to turn to steam here. There must always be a "head" of steam in the upper part of the pressurizer tank, for it is by enlarging or shrinking this head of steam (with electric heaters or water sprays) that the operators control the pressure in the reactor as well.

TMI-2 has a reactor containment, a concrete shield around and over the reactor vessel. The containment, or reactor building, is a steel lined, cylindrical concrete structure with a volume of approximately 2 million cubic feet. This building is designed to contain a pressure of at least 55 psi.

3.2 The TMI-2 Accident : Sequence of Events

The Three Mile Island Accident was a partial core meltdown in Unit 2 (Henry 2007; Castleberry; Sehgal 2006; Mitchell and Frampton 1980; Frogatti 2005). On March 28, 1979, in the hours preceding the accident, the TMI-2 reactor was running at 97% of full power, while the companion TMI-1 reactor was shut down for refuelling. The chain of events leading to the core meltdown began at 4 after midnight[3]:

- In TMI-2's secondary loop, one of the three main water/steam loops in a pressurized water reactor, workers were cleaning a blockage in one of the eight condensate polishers (sophisticated filters cleaning the secondary loop water), when the pumps feeding the polishers stopped for reasons still unknown.
- When a bypass valve did not open, water stopped flowing to the secondary's main feedwater pumps, which also shut down.
- Since the flow of the water stopped, the temperature inside the reactor core increased. This caused the water inside the reactor to expand, increasing the pressure inside the pressurizer to 2200 psi, 100 psi more than the normal. This in turn caused the reactor to shut down automatically.
- Within eight seconds, control rods were inserted into the core to halt the nuclear chain reaction. However, the radioactive fission products still produce heat so the temperature and pressure started to rise. To reduce the pressure, the valve on the pressurizer, called the pilot-operated relief valve (PORV), opened. Up to this time, everything operated as designed.

After that an extraordinary sequence of events started:

- The PORV valve should have closed when the pressure decreased by a certain amount, as it was supposed to about 10 seconds later. But it did not. The accident was now underway.
- The operators thought that the relief valve had shut because instruments showed them that a "close" signal was sent to the valve. In reality the PORV was stuck open. Unfortunately, the operators not have an instrument indicating the valve's actual position.
- With the valve open, steam and water escaped the pressurizer; this water flowed into a drain tank. This implies a Loss of Coolant Accident.
- Responding to the loss of cooling water, the emergency feed pump should be automatically activated for pumping Emergency Injection Water (EIW) to keep the water flowing to turbine. It would send about 1000 gallons of water per minute into the reactor core. However it did not. That pump was tested 42 hours prior and was functional. However, to perform the test a valve should be closed

3- See NRC Press conference on the Three Mile Island accident www.nrc.gov/reading-rm/doc-collections/fact-sheets/3mile; NRC Technical Education Center Reactor Concepts Guidelines Pressurized Water Reactor Systemshttp://www.nrc.gov/reading-rm/basic-ref/teachers/04.pdf; World Nuclear Association, Three Mile Island Accident, http://www.world-nuclear.org/info/inf36.html; http://www.threemileisland.org/science/what_went_wrong/index.html; http://www.threemileisland.org/downloads/354.pdf;http://americanhistory.si.edu/tmi/tmi03.htm; http://americanhistory.si.edu/tmi/03-01.htm; NRC: Three Mile Island – Unit 2 ". http://www.nrc.gov/info-finder/decommissioning/power-reactor/three-mile-island-unit-2.html.

and then open again. Apparently the workers performing the test had forgotten to open the valve, so the emergency pump did not work and water did not flow.

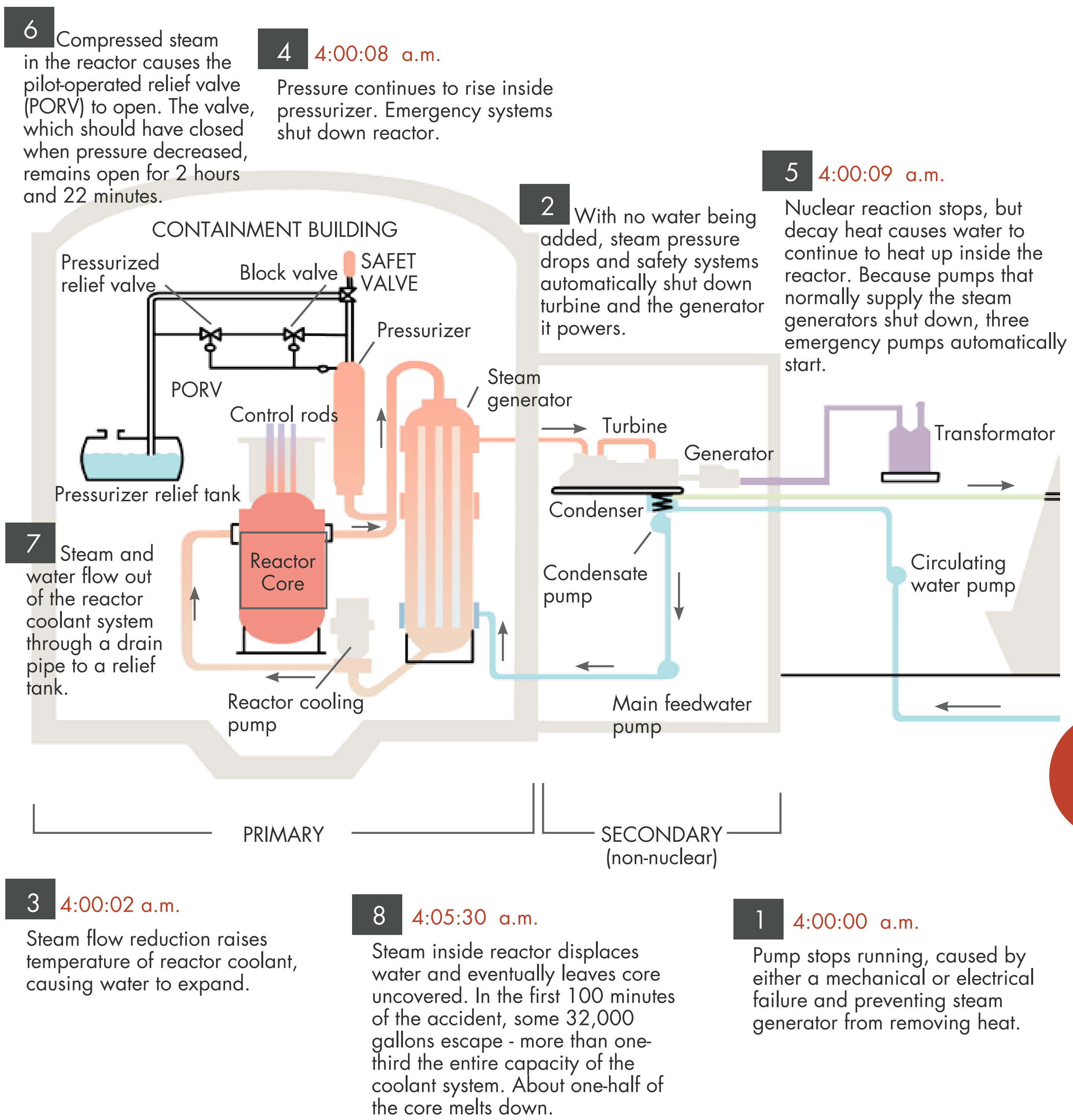
- The reactor was now losing water and getting hotter and hotter. With the loss of water (and no air or steam in the pressurizer) the pressure dropped.
- When the pressure dropped, some of the water in the reactor turned to steam. This had two major consequences; first it forced water into the pressurizer and filling that completely, and second, steam rather than water surrounded some of the reactor fuel. Steam does not conduct heat as well as water, so the fuel pellets heated up.
- In case of an accident, a nuclear power plant has tanks of water with pumps that can quickly introduce water to cool the reactor. One of these automatically started. This was noted by the operators, but then they looked at the indicators for the pressurizer telling them that the pressurizer was full of water (which it was because of the steam in the reactor core area).
- There was no instrument that showed the level of coolant in the core. Operators judged the level of water in the core by the level in the pressurizer, and since it was high, they assumed that the core was properly covered with coolant. Remembering earlier occasions when these emergency pumps had come on without reason, they saw no reason to add water. On the contrary, the violently boiling water created the appearance of the pressurizer becoming filled with water, a condition that the operators have been trained to prevent.
- The operators therefore turned off the pumps and prevented the water inflow. After that the situation went from bad to worse.
- About 100 minutes after the accident started, steam bubbles appeared in the coolant pumps, causing them to vibrate.
- Fearing a complete failure of these pumps, the operators turned them off.
- With no water flowing into the reactor and water and steam escaping the reactor, large portions of the reactor core became uncovered.
- With no water to remove the heat, the fuel pellets started to melt, resulting in a partial meltdown.
- Finally, one operator surveyed the data and concluded that the PORV was open, so at 6:18 a.m., they closed the valve and then introduced water into the reactor, thus ending the immediate emergency.

However, between the time that the operators shut off the pumps and the closing of the valve the core was uncovered, enough to cause some fuel to melt. In fact, at the time of the accident, nobody thought that a major portion of the fuel melted. When the reactor was opened months later, they were surprised to find that about 60% of the core actually melted.

Figure 4 : Sequence of events for the TMI-2 accident

THE ACCIDENT AT TREE MILE ISLAND

On March 28, 1979, Three Mile Island secured its place in history as site of the worst commercial nuclear power accident in the nation's history. Like an automobile engine with a hole in its radiator, the Unit 2 reactor overheated when an emergency release valve opened, then failed to close. The mechanical problem was made worse when a control room operator failed to identify the problem and correct it. The result was a partial meltdown of the reactor's core. Unit 2, which has not operated since the accident, is in "monitored storage". It is scheduled to be decommissioned and decontaminated in september 2014. Here's a look at what happened during the accident.



Source: Nuclear Regulatory Commission, Report of the President's Commission on the Accident at Three Mile Island

3.3 Lessons Learned From TMI-2 Accident

The TMI partial meltdown, which was the worst accident at an American commercial nuclear power plant, both altered nuclear regulation policies in the United States and shook the public's confidence in nuclear technology.

The accident was attributed to mechanical failure and operator confusion. The reactor's other protection systems also functioned as designed. The emergency core cooling system would have prevented any damage to the reactor but for the intervention of the operators (World Nuclear Society 2011).

NRC's regulations and oversight became broader and more robust, and management of the plants was scrutinized more carefully. The problems identified with the help of the careful analysis of the events have led to permanent and sweeping changes in how NRC regulates its licensees – which, in turn, has reduced the risk to public health and safety. Some of the major changes which have occurred since the accident are as follows:

- Upgrading and strengthening of plant design and equipment requirements. This includes fire protection, piping systems, auxiliary feedwater systems, containment building isolation, reliability of individual components (pressure relief valves and electrical circuit breakers), and the ability of plants to shut down automatically;
- Identifying human performance as a critical part of plant safety, revamping operator training and staffing requirements, followed by improved instrumentation and controls for operating the plant, and establishment of fitness-for-duty programs for plant workers to guard against alcohol or drug abuse;
- Improved instruction to avoid the confusing signals that plagued operations during the accident;
- Enhancement of emergency preparedness to include immediate NRC notification requirements for. plant events and an NRC operations center that is staffed 24 hours a day. Drills and response plans are now tested by licensees several times a year, and state and local agencies participate in drills with the Federal Emergency Management Agency and NRC;
- Establishment of a program to integrate NRC observations, findings, and conclusions about licensee performance and management effectiveness into a periodic, public report;
- Regular analysis of plant performance by senior NRC managers who identify those plants needing additional regulatory attention;
- Expansion of NRC's resident inspector program – first authorized in 1977 – whereby at least two inspectors live nearby and work exclusively at each plant in the U.S. to provide daily surveillance of licensee adherence to NRC regulations;
- Expansion of performance-oriented as well as safety-oriented inspections, and the use of risk assessment to identify vulnerabilities of any plant to severe accidents;

- Strengthening and reorganization of enforcement as a separate office within the NRC;
- The establishment of the Institute of Nuclear Power Operations (INPO), the industry's own" policing" group, and formation of what is now the Nuclear Energy Institute to provide a unified industry approach to generic nuclear regulatory issues, and interaction with NRC and other government agencies;
- The installing of additional equipment by licensees to mitigate accident conditions, and monitor radiation levels and plant status;
- Employment of major initiatives by licensees in early identification of important safety-related problems, and in collecting and assessing relevant data so lessons of experience can be shared and quickly acted upon; and
- Expansion of NRC's international activities to share enhanced knowledge of nuclear safety with other countries in a number of important technical areas.

From the point of view of reactor design, the Three Mile Island accident demonstrated the importance of the inherent safety features. Despite the fact that about half of the reactor core melted, radionuclides released from the melted fuel mostly plated out on the inside of the plant or dissolved in condensing steam. The containment building which housed the reactor further prevented any significant release of radioactivity (World Nuclear Society).

After the TMI-2 accident, the safety performance concerns were with the severe accident safety, i.e. the prevention and mitigation of these accidents. This has been formalized into the programs of Severe Accident Management at most of the light water reactor plants. Severe accident research results have lead to back fits and accident management actions and procedures, which have enhanced the safety of the plants, or provided the rationale for deliberate decisions of not requiring any back fits or SAM measures (Sehgal 2006).

4 The Chernobyl Accident

The accident at the Chernobyl NPP in April 1986 was the product of a flawed Soviet RBMK reactor design coupled with serious mistakes made by the plant operators, as a direct consequence of Cold War isolation and the resulting lack of any safety culture. The Chernobyl Nuclear Power Plant lying about 130 km north of Kiev, Ukraine, and about 20 km south of the border with Belarus, consisted of four nuclear reactors of the RBMK-1000 design, with Units 1 and 2 constructed between 1970 and 1977, while Units 3 and 4 of the same design were completed in 1983. The RBMK design involved in the 1986 Chernobyl disaster had several significant shortcomings.

The initials RBMK (reaktor bolshoy moshchnosty kanalny) are a Russian acronym which translates roughly as "reactor cooled by water and moderated by graphite". It describes one of the two types of reactors the Soviets have built for power production, the other being similar to the United States pressure vessel reactor. The RBMK type is the older of the two designs. It is very different from western type power reactor designs, as it derived from a design principally for plutonium production and was intended and used in Russia for both plutonium and power production. This type of reactors were constructed and operated only in the USSR (NUREG 1987, Smolensk NPP 2008).

The first RBMK (Leningrad NPP) was put into the commercial operation in November 1974. Before the accident an additional 14 RBMK reactors were put into operation. Thus at the time of the Chernobyl accident, 15 RBMK reactors were in operation in the USSR. RBMK reactors were built in pairs, with two units occupying opposite sides of a single building complex. Reactors of the first two units of the Leningrad, Chernobyl and Kursk NPPs belong to the first generation of RBMKs. The others are second generation of RBMKs. They were constructed by using the technical blueprint of the first RBMK reactor that was developed in 1960s. This means that all RBMKs had similar shortcomings and an accident similar to the Chernobyl accident could happen at each Soviet NPP with a channel-type reactor (Malko; World Nuclear Association,1986)[4]

4- http://thayer.dartmouth.edu/~cushman/courses/engs43/Chernobyl.pdf

4.1 Main Reasons for the Accident

4.1.1 Design flaws

The Chernobyl reactors had several dangerous properties that contributed to the accident. The the most important ones are as follows (Malko;Howieson 1989; IAEA 1992; Denton 1987)[5].

- **Positive void coefficient**

In almost all reactors, the multiplication factor and hence the reactor power is decreased when temperature increases. This is a basic safety feature found in most Western reactors. Water acts as both coolant and moderator in LWR's so that a loss of coolant also stops the fission reaction. In the RBMK, the moderator is solid graphite and the water coolant acts as a poison. That means that the presence of water absorbs neutrons and slows the reaction. If coolant is lost or is converted to steam, reactor power may increase. This is known as a positive void coefficient and it represents a serious design flaw. Under certain operating conditions, the power can increase uncontrollably until the reactor disintegrates. This is what happened at Chernobyl. The term 'positive void coefficient' is often associated with RBMK reactors. Although the void coefficient is only one contributor to the overall power coefficient of reactivity, it is the dominant component in RBMK reactors. At the time of the accident at Chernobyl, the void coefficient of reactivity was so positive that it overwhelmed the other components of the power coefficient and the power coefficient itself became positive. When the power began to increase, more steam was produced, which in turn led to an increase in power. The additional heat resulting from the increase in power raised the temperature in the cooling circuit and more steam was produced. More steam means less cooling and less neutron absorption, resulting in a rapid increase in power to around 100 times the reactor's rated capacity. The value of the void coefficient is largely determined by the configuration of the reactor core. In RBMK reactors, an important factor affecting this is the operating reactivity margin.

- **Operating reactivity margin**

Although the definition is not precise, the operating reactivity margin (ORM) is essentially the number of 'equivalent' control rods of nominal worth remaining in the reactor core. The operators at Chernobyl seemed to believe that safety criteria would be met so long as the lower limit for the ORM of 15 equivalent rods was adhered to, regardless of the actual configuration of the core. The operators were not aware of the 'positive scram' effect where, following a scram signal, the initial entry of the control rods actually added reactivity to the lower region of the core .

The ORM could have an extreme effect on the void coefficient of reactivity, as was

5- World Nuclear Association, http://www.world-nuclear.org/info/inf31.html; NRC Tchernobil Nuclear Power Plant Accident Press Conference http://www.nrc.gov/reading-rm/doc-collections/fact-sheets/chernobyl-bg.html;http://users.owt.com/smsrpm/Chernobyl/RBMKvsLWR.html the case for the core configuration of Chernobyl 4 in the run-up to the accident. Unacceptably large void coefficients were prevented for initial cores by increasing fuel enrichment levels, with the excess reactivity balanced by fixed absorbers. However, with increasing fuel burn-up, these absorbers could be removed to maintain the fuel irradiation levels - shifting the void coefficient in the positive direction and increasing the sensitivity of the coefficient to the extent of insertion of the control and protection rods.

- **Control rod insufficiency**

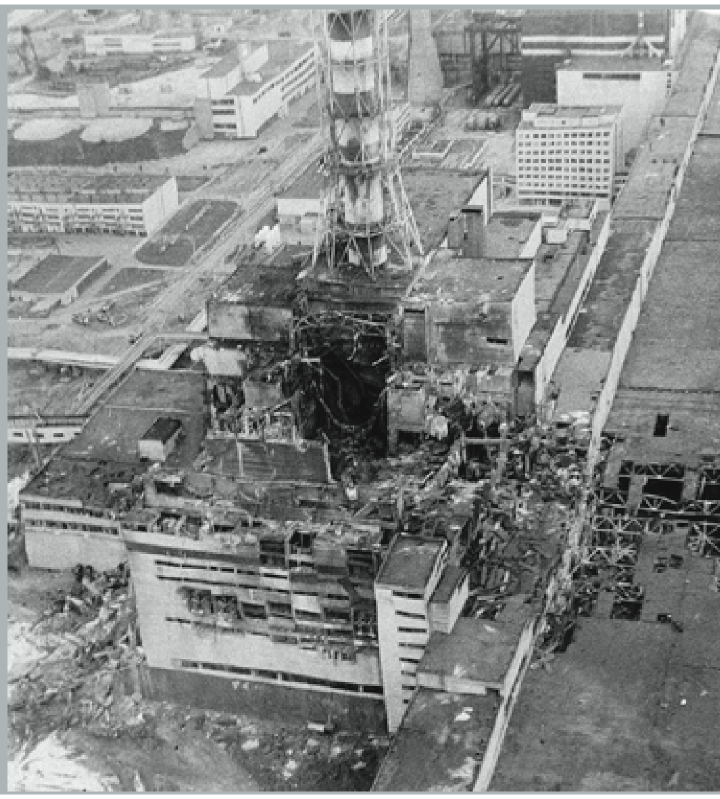
When the operators noticed the sharp increase in power they attempted to insert the control rods into the core. This did not help because:

- The rods could not move fast enough.
- The lower part of each rod was made not of boron carbide, but graphite. This was because when the rods were retracted the empty space was filled with water which acts as a poison, thus decreasing the effect of retracting the rods. This was not desirable, so a graphite rod was attached to the bottom of each control rod to keep the water out.

When the operators started to push the control rods back in, the boron carbide parts were completely clear of the core. Below the graphite part was a column of water. Inserting the rods initially had the effect of pushing the water away which meant decreasing the amount of poison which meant increasing k.

The intense heat deformed the core and the control rods stuck before they could be completely inserted.

Figure 5: Chernobyl NPP after the Accident



- **Lack of containment**

RBMK reactors do not have a containment structure, a concrete and steel dome over the reactor itself designed to keep radiation inside the plant in the event of such an accident. The Chernobyl plant was built without containment shells. In other reactors, the containment shell will keep almost all radioactive material from spreading in case of an accident. Strong concrete buildings surround most Western reactors. Unit 4 didn't have anything like that. If it did, radiation might not have leaked into the environment.

- **Graphite Moderator**

The graphite blocks are also flammable at high temperatures. A number of Soviet citizens died in the process of putting out the fire caused by the explosion. iodine, strontium and caesium were scattered over a wide area. the graphite blocks used as a moderating material in the RBMK caught fire at high temperature as air entered the reactor core, which contributed to emission of radioactive materials into the environment.

4.1.2 Operator errors

According to the Soviet participants of the Post-Accident Review Meeting in Vienna severe violations made by the personnel of the Unit 4 of the Chernobyl NPP on 25-26 April 1986 were the main reasons of the Chernobyl accident. These identified violations were as follows:

- operation of the reactor at a very low operative reactivity surplus (ORS),
- conducting of the experiment by the power below the level provided for test,
- blocking of the protection system relaying on water level and steam pressure in steam-separators,
- blocking of the protection system relaying on shutdown signal from two turbo-generators,
- connection of all the main circulating pumps to the reactor,
- switching off the emergency core cooling system.

The Sternberg commission however recognized only the first violation from the above list. It stated that in accordance with existing technological regulations the operator had to shut down the reactor already at 07hr 10 min on 25 April 1986. The power of the reactor was then 1,500 MW thermal and the OSR was 13.2rods. The existing technological requirements for operation of the Unit 3 and Unit 4 required the shutdown of the reactor when the operative reactivity surplus decreased to such value at such power level. The operator did not fulfill this requirement. However, the Sternberg commission stated that this violation could not initiate the accident or influence it. Records made by the operator in the operative logbook show that at 23 hr 10 min on 25 April 1986 the ORS value was 23 full rods. This means that in the period from 07 hr 10 min to 23 hr 10 min the reactor of the fourth unit was brought in accordance with technological requirements.

The accident would not have happened unless the operators had made several serious errors. First of all the test should have been aborted when things were not going as planned. The test was initiated with a number of safety systems turned off. The power level was lower than planned, increasing the importance of the positive void coefficient. The core was suffering from severe xenon poisoning, so the control rods had to be almost fully retracted, leaving too small a margin of safety. The operators seemed completely unaware of the fact that the effect of xenon poisoning would decrease rapidly, should the power level rise.

4.2 Chernobyl Conclusions

The Chernobyl accident resulted from a combination of external circumstances, engineering design flaws and errors made by badly trained operators. The test was started at extreme operating conditions. Closing the valve to the turbines increased boiling of the coolant. The positive void coefficient started a power excursion which accelerated when the poisoning of the core decreased as the flux increased. This could have been stopped by the control rods, had they not been too far out of the core, as well as badly designed. Instead, the control rods delivered the final blow. The fuel rods went white-hot and shattered. The hot fuel made the water dissociate into hydrogen and oxygen. The cooling system exploded from the pressure of the steam, then the hydrogen could react with the air outside and there was a chemical explosion.

The main reasons of the accident at the Chernobyl NPP were severe shortages of the design, sever infringements of the safety regulations for construction of the reactor as well as low safety culture in the USSR preceding the accident. These factors were responsible for various errors of the operators that tried to carry out the electromechanical experiment at the time of shutdown of the Unit 4 of Chernobyl NPP.

The reactor was brought by operators into unstable regime of operation in which a positive reactivity surge was introduced to the core. Possibly, the accident began from the boiling of water in some fuel channels in the lower part of the core because of a small temperature surplus. The pressing of the button AZ-5 by which all control and protection absorbing rods began to insert into the core increased the positive reactivity surge instead of decreasing it. This caused fission chain reactions by prompt neutrons and uncontrolled excursion of the power. There is a high possibility that a number of explosions occurred in the core. One of these explosions was a nuclear explosion that destroyed the reactor of the Unit 4 of the Chernobyl NPP.

4.3 Post Accident Changes to the RBMK[6]

In light of the Chernobyl accident, modifications have been made to other RBMK reactors. reactors in the former Soviet Union. The following changes were implemented to improve operational safety:

6- World Nuclear Association “RBMK Reactors”, http://www.world-nuclear.org/info/inf31.html

- Reduction of the void coefficient of reactivity.
- Improvement of the response efficiency of the emergency protection system.
- Introduction of calculation programs to provide an indication of the value of the operating reactivity margin (ORM, i.e. the effective number of control rods remaining in the core) in the control room.
- Prevention of the emergency safety systems from being bypassed while the reactor is operating.
- In order to ensure adequate subcooling at the core inlet, the avoidance of modes of operation that cause a reduction in the departure from nuclear boiling (DNB) ratio of the coolant at the reactor inlet.

One of the most important post-accident changes to the RBMK was the retrofitting of the control rods. A graphite 'displacer' is attached to each end of the length of absorber of each rod (except for 12 rods used in automatic control). The lower displacer prevents coolant water from entering the space vacated as the rod is withdrawn, thus augmenting the reactivity worth of the rod. However, the dimensions of the rod and displacers were such that, with the rod fully withdrawn, the 4.5 m displacer sat centrally within the fuelled region of the core with 1.25 m of water at either end. On a scram signal, as the rod falls, the water at the lower part of the channel is replaced by the bottom of the graphite displacer, thus initially adding reactivity to the bottom part of the core. Following the Chernobyl accident, this 'positive scram' effect was mitigated by retrofitting the control rods so that, with the rods fully retracted, there would not be a region containing water at the bottom of the core.

In addition to the above changes, several further modifications have been implemented at RBMK plants. These measures consist of:

- Replacement of the fuel channels at all units (except Smolensk 3).
- Replacement of the group distribution headers and addition of check valves.
- Improvements to the emergency core cooling systems.
- Improvements of the reactor cavity over-pressure protection systems.
- Replacement of the SKALA process computer.

All reactors in Chernobyl are now shut down. Around 17 Chernobyl-type reactors are still in operation, the closest of which are two large reactors in Ignalina, Lithuania.

4.4 Implications for Western Reactors

As the RBMK reactors are very much different from anything in the West, there is very little to learn from the Chernobyl accident. An uncontrolled power increase like in Unit 4 is almost impossible in most other reactors. Also, almost all Western reactors have strong containment buildings. The accident at Three Mile Island has shown that even a partial meltdown of the core, although a financial disaster, need not be an environmental one.

5 The Fukushima Accident(s)

The Fukushima accident occurred following the 9.0 magnitude Tōhoku earthquake and resultant tsunami on 11 March 2011 in Ohkuma, Japan. It has been rated at the maximum level (Level7) on the INES, indicating an accident with large release of radioactivity accompanied by "widespread health and environmental effects", like Chernobyl.

However, there are very significant differences between Fukushima and Chernobyl. Briefly, the amount of the release (~10% of Chernobyl), the presence of the containment structures, the radionuclides released (mostly iodine and cesium isotopes vs. the entire core inventory), the physical form of the releases (mostly aqueous vs. volatile), the favorable currents and winds at the site, and the timing of the release with respect to population evacuation resulted in vastly smaller overall consequences (Buongiorno et al).

When the earthquake hits seven reactors at four nuclear power plants in the region were operating at the time and all shut down automatically. The operating units which shut down were Tepco's Fukushima Daiichi 1, 2, 3, Fukushima Daini 1, 2, 3, 4, Tohoku's Onagawa 1, 2, 3, and Japco's Tokai, total 9377 MWe net. Fukushima Daiichi units 4-6 were not operating at the time, but were affected, total 2587 MWe net (units 4-6). Onagawa 1 briefly suffered a fire in the turbine building, but the main problem initially centred on Fukushima Daiichi units 1-3. Unit 4 became a problem on day five. [7]

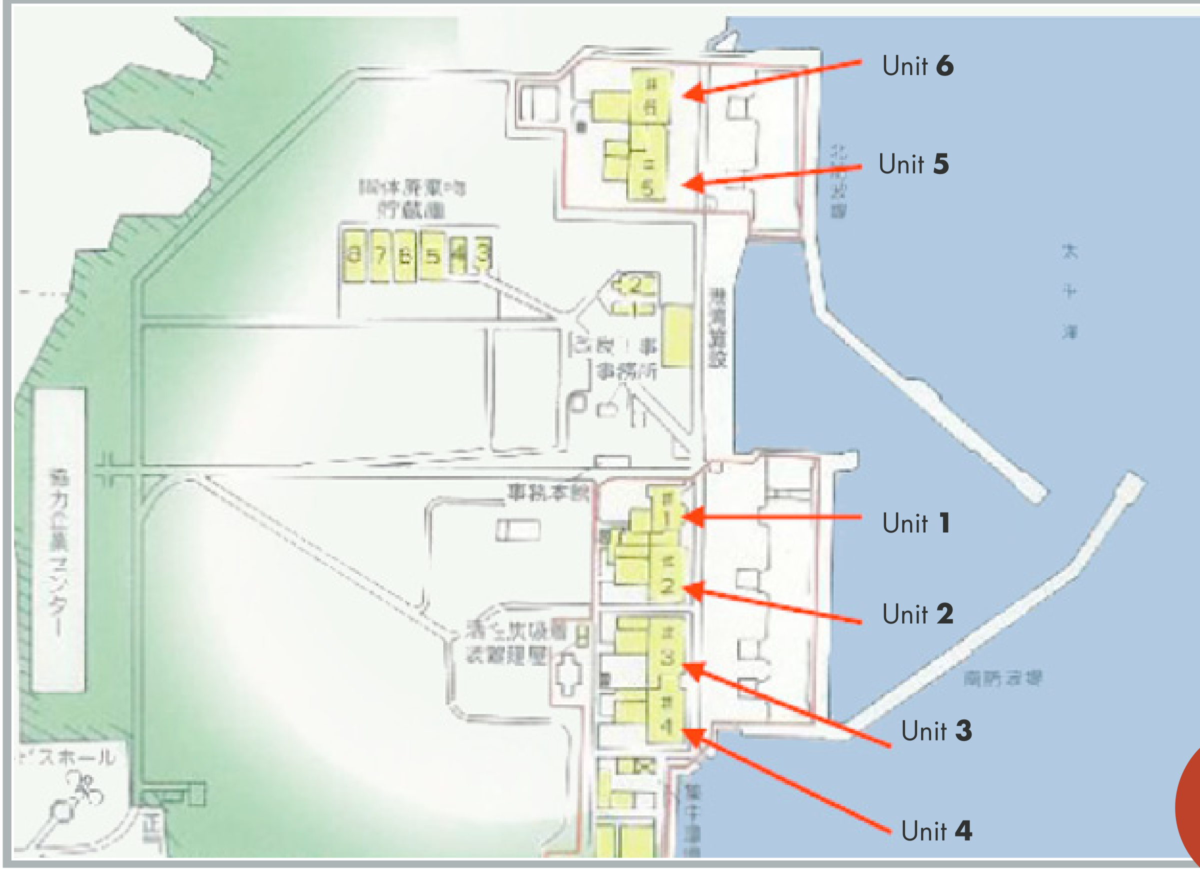
5.1 An Overview of the Fukushima Daiichi Nuclear Power Plant

Fukushima Daiichi NPP site has a nearly square shape and its area is approximately 1.47 million square meters. Since the commissioning of Unit 1 in April 1982, additional reactors have been constructed in sequence and there are four reactors now. The total power generating capacity of the facilities is 4.4 million kilowatts. [8]

7- World Nuclear Association,"Fukushima Accident 2011" http://www.world-nuclear.org/info/fukushima_accident_inf129.html; Report of the Japanese Government to the IAEA Ministerial Conference on Nuclear Safety "The Accident at TEPCO's Fukushima Nuclear Power Stations" , June 2011http://www.iaea.org/newscenter/focus/fukushima/japan-report/cover.pdf,

8- Report of the Japanese Government to the IAEA Ministerial Conference on Nuclear Safety "The Accident at TEPCO's Fukushima Nuclear Power Stations" , June 2011http://www.iaea.org/newscenter/focus/fukushima/japan-report/cover.pdf, The Fukushima Daiichi reactors are Boiling Water Reactors (BWRs) of an early (1960s) design supplied by GE, Toshiba and Hitachi, with what is known as a Mark I containment. Reactors 1-3 came into commercial operation 1971-75.

Figure 6: General Layout of Fukushima Daiichi NPP[9]

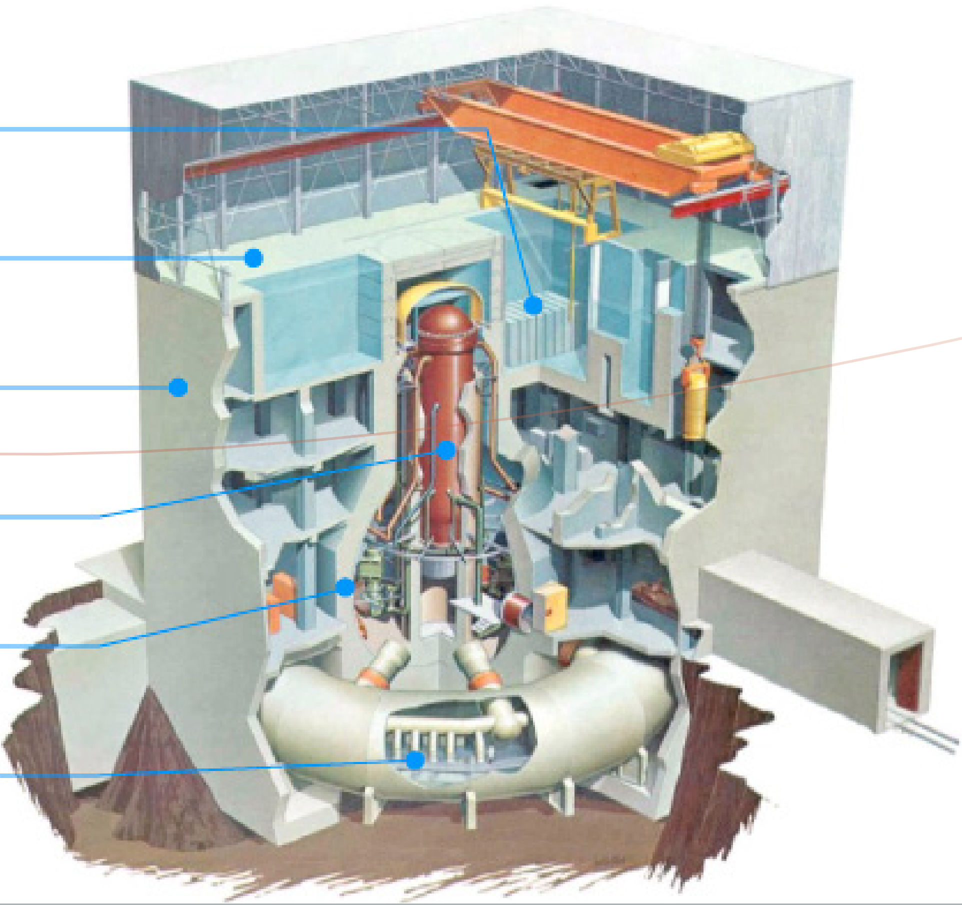


The BWR Mark I has a Primary Containment System comprising a free-standing bulb-shaped Primary Containment Vessel (PCV,-also known as drywell) of 30 mm steel backed by a reinforced concrete shell). PCV contains the reactor pressure vessel (RPV) and connected to a torus-shaped wetwell beneath it containing the suppression pool (with 3000 m^3 of water in units 2-5). The water in the suppression pool acts as an energy-absorbing medium in the event of an accident. The wetwell is connected to the dry containment by a system of vents, which discharge under the suppression pool water in the event of high pressure in the dry containment. The function of the primary containment system is to contain the energy released during any loss-of-coolant accident (LOCA) of any size reactor coolant pipe, and to protect the reactor from external assaults.[10]

9- Report of the Japanese Government to the IAEA Ministerial Conference on Nuclear Safety "The Accident at TEPCO's Fukushima Nuclear Power Stations" , June 2011http://www.iaea.org/newscenter/focus/fukushima/japan-report/cover.pdf,

10- World Nuclear Association,"Fukushima Accident 2011" http://www.world-nuclear.org/info/fukushima_accident_inf129.html

Figure 7: The BWR-3 Reactor[11]



5.2 Reasons for the Accident and Possible Corrective Actions for Current and Future NPP's.

The reasons for the accident and possible corrective actions for current and future plants were determined as follows (MIT 2011):

1. The loss of offsite power (due to the earthquake) and onsite AC power (due to the tsunami), combined with the rapid discharge of the DC batteries led to a complete station blackout, which in turn led to fuel overheating and damage.

Possible corrective actions for current plants

- The diesel generators, their fuel, and related switchgear could be housed in rooms at sufficiently high elevation and/or in water-proof rooms to preserve

11- Buongiorno and friends.

onsite AC power in case of tsunamis or floods.

- Utilities could maintain transportable diesel generators or gas-turbine generators (i.e. jet engines) that would be rapidly brought to the site (e.g. by air, road or water) to restore AC power.

Possible design improvements in future plants:

- A mix of passive and active safety systems may be desirable to defeat the station blackout scenario without relying on external intervention, by determining the right mix through analysis including risk assessment, taking into account also the possible failure modes of the passive systems upon occurrence of the initiating external event.

2. Deficient fuel cooling resulted in overheating of the fuel, enabling rapid oxidation and generation of large amounts of hydrogen, which ultimately led to the explosion/destruction of the reactor buildings at Units 1 and 3, and possibly fires at Unit 4. However, the exact mechanism of hydrogen accumulation in the reactor buildings has not been ascertained at this time.

Possible corrective actions at current and future plants:

- Venting of pressure vessels should be via strong pipes connected to the stack as currently a U.S. practice. Venting should be possible without power.
- Plants should have the air atmosphere in the pool areas more directly connected to the plant stacks. Also, fail-open (on power loss) louvers in the buildings could be used.
- More hydrogen recombiners (passive) and igniters (active) could be considered for small releases in the upper regions of a building, where hydrogen may accumulate. Also, catalytic recombiners could be used in the ventilation system and inside the containment where it is not already done now.
- Hydrogen flares for massive venting of containment gases could be explored.
- Use of materials that generate hydrogen upon oxidation with steam could be reduced or eliminated, e.g., replace Zircaloy cladding with less reactive metals, and ultimately a ceramic, such as SiC.

3. Due to the station blackout, the operators had to vent (vs cool) the containment to prevent containment over-pressurization. Some vented gases leaked into the reactor building, which had no ventilation (again due to the station blackout), resulting in hydrogen accumulation and ultimately explosion/destruction of the reactor buildings at Units 1 and 3.

Possible corrective actions at current plants

- The containment should be vented directly to the stack, when containment cooling is not available. A catalytic recombining system that automatically activates upon loss of power could also be explored.

Possible Future improvements:

- Use of passive containment cooling could eliminate the need for venting as a means to reduce containment pressure, when AC power is not available.
- Use of the filtered / vented containment concept (French-Swedish examples) could provide a balanced approach to controlling containment pressure and radioactivity releases to the atmosphere when containment cooling is not available.

4. The largest radioactivity releases from the Fukushima plant may be from the spent fuel pools. In the Spent Fuel Pools, the elevated location of the spent fuel pools exposed them to damage from hydrogen explosions in the reactor buildings at Units 1, 3 and possibly 4. The failure of spent fuel pool cooling may have caused the pool fire at Unit 4 and forced one-week-long unconventional cooling efforts (e.g. helicopters, water cannons). Earthquake-induced water leakage from the pools (not confirmed at this time) may have aggravated the situation.

Possible corrective actions at current plants:

- Spent fuel assemblies could be moved to dry storage as quickly as possible. Could redesign dry casks with a "top hat" chimney to enhance air cooling for the hotter fuel assemblies. However,

  (i) one must ensure the casks do not tip over due to an earthquake or hurricane / typhoon, if the casks are breached, radioactivity release is un-mitigated (unlike in pools where water provides some scrubbing effect),

  (ii) the decay heat in pools is dominated by recently-discharged fuel, so moving the older fuel to dry casks may not have that significant an impact on pool heat-up time in the event of an accident. These uncertainties make it unclear whether accelerated dry storage is actually preferable to other options, such as on-site spent fuel pools or centralized interim storage.
- Current spent fuel pools could be retrofitted with a passive cooling system that can survive the initiating external event.
- The policy on full core unloading into the pools during refueling shutdowns and spent fuel pool packing may have to be reviewed.

Possible future improvements:

- Spent fuel pools could be housed in containment-like structures separate from the reactor building. (Note that some PWR plants have spent fuel pools inside the actual containment.)
- Regional or national consolidated spent fuel interim storage facilities would reduce the spent fuel inventory at the plant, which in turn would reduce the source term in case of spent fuel pool accidents. Interestingly, Japan has recently completed a reprocessing plant at Rokkasho and in 10-15 years it is

likely that all their spent fuel will be shipped there rather than stay at reactor sites for long periods of time.

5. Due to this site's compact layout, problems at one unit created negative safety-related situations at adjacent units. The hydrogen explosion at Unit 3 disabled some fire pumps used for seawater injection at Unit 2. Also, it has been suggested that the fire/explosion at Unit 4 was caused by leakage of hydrogen released from Unit 3 through shared duct-work with Unit 4. Units 5 and 6, which are far from Units 1-4, were unaffected by the hydrogen explosions at Units 1 and single external event (the tsunami) disabled all 13 diesel generators at the station simultaneously. The Fukushima-Daini and Onagawa plants, both in the vicinity of Fukushima-Daichii, survived the earthquake and tsunami without major damage.

Possible actions at current plants:

- Layout diversity and separation at multi-unit sites could be enhanced. For example, at least one diesel generator room could be placed sufficiently above grade (for protection against tsunamis), and one below grade (for protection against plane crashes). Also, in future plants the administrative buildings and parking lots could be located between units to enhance physical separation between those units.

Possible future improvements:

- An obvious approach for future plants would be to choose sites away from highly seismic areas and coasts, to greatly reduce (and perhaps eliminate) the possibility of damage due to massive earthquakes, tsunamis and floods.
- It is noted that people tend to congregate near coasts and faults (river valleys); therefore, there are strong synergies between minimizing the probability of an adverse external event and maximizing the distance from densely populated areas. The vast majority of nuclear plants worldwide are already located away from highly seismic area except the plants in Japan, Taiwan and California. Higher expected ground motions in these regions is currently overcome by a more stringent seismic design of the plants located in these regions.
- The number of allowable units at a single plant site could be determined based on an analysis which accounts for the following, often conflicting, factors:

  (i) reduction of common cause vulnerabilities,

  (ii) availability of staff and resources to address a severe accident impacting all units simultaneously,

  (iii) high standardization (shared learning),

  (iv) shared equipment (with implications on both economics and safety),

  (v) low environmental impact of multi-unit cooling.

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Section III

The Economics of Nuclear Power in the Turkish Context

III

Assoc. Prof. Gürkan Kumbaroğlu

Executive Summary

The economics of nuclear power in the Turkish context is evaluated in this paper with particular focus on the Turkish Agreement with Russia to construct a four-unit plant with a total installed capacity of 4,800 MW in Akkuyu. In May 2010, Russia and Turkey signed an agreement that a subsidiary of Russia's state-owned atomic power company Rosatom would build, own, and operate a power plant at the Akkuyu site, on Turkey's Mediterranean coast, comprising four VVER units of 1,200 MW installed capacity each. The first unit is expected to enter service in 2019 with the other three coming online subsequently. The Turkish Electricity Trade and Contract Corporation (TETAS) has guaranteed the purchase of 70% power generated from the first two units and 30% from the third and fourth units over a 15-year power purchase agreement at an average price of 12.35 US cents per kWh excluding VAT.

The average wholesale electricity price in 2010 is calculated as 9.38 US ¢/kWh. When compared with the Akkuyu agreement prices for 2010 in real terms, it is seen that the wholesale price is about 60% higher than the highest price estimate for the Akkuyu agreement (Low discount rate scenario 5.84¢/kWh). The discrepancy is significantly higher (284%) for the high discount rate/low price scenario.

Considering the fact that the agreement refers to a price that is the average of a price for the period 2020-2035 and therefore almost two decades ahead, it appears to be an economically advantageous deal for Turkey (in the sense that the agreed-upon average purchase price can be expected to be considerably lower than end-use electricity prices by that time) provided that safety measures and regulations related to the construction, operation and maintenance of the reactor as well as related to waste transport and management activities are all well defined and provide convincing confidence and reliability regarding the risk of an accident and nuclear leakage. In addition, the project company is to transfer 15 % of its profits to the Turkish Treasury after the end of the purchasing commitment.

If the deal would have been possible without an intergovernmental agreement, as a stand-alone commercial agreement at the same terms, is rather questionable considering the economics and all the risks taken up by the Russian party. Other aspects such as the strong bilateral cooperation in the energy sector between Russia and Turkey and the promotion of Russian nuclear technology in new emerging markets might have been influential factors that contributed to this agreement. If Turkey is to have a nuclear future as envisaged in long-term official energy strategy, the agreement seems to be a good starting point economically as long as the possibility of leakage and a severe nuclear accident are excluded, waste management poses no concern, and the necessary regulatory and controlling mechanisms can be put in place successfully. The economics of a non-nuclear future, on the other hand, together with its feasibility and sustainability, is being discussed worldwide more extensively after the Fukushima accident.

1 Introduction

The economics of nuclear power in the Turkish context is evaluated in this paper with particular focus on the Turkish Agreement with Russia to construct a four-unit plant with a total installed capacity of 4,800 MW in Akkuyu. It should be stressed that this study does not provide an attempt to question the decision of installing Turkey's first nuclear power plant, but to elaborate on various aspects of this decision in relation to international standards and experience in order to better understand its implications for the country. In accordance with this aim, a comprehensive economic evaluation is presented in the following.

First, international experience regarding the cost of nuclear power generation worldwide is reviewed based on historically available data. Next, issues related to the economics of power generation implied by the Turkish Agreement with Russia are evaluated in comparison with international experience. Subsequently, the anticipated impact of nuclear power on electricity supply & prices in Turkey is discussed based on official supply / demand projections. The final section summarizes most important findings and concludes the study.

2 The Cost of Nuclear Power Generation - Worldwide

2.1 Investment Costs and Factors Affecting Recovery

The up-front expenditures of a nuclear power plant investment related to all planning, engineering, construction and licensing activities, must be recovered during the operation phase and are spread over the economic lifetime of the plant for capital recovery and added in annualized form to other annual costs of operation, maintenance etc. Since the fixed costs are to be recovered over the plant's lifetime generation, a lifetime capacity factor affects the recovery, in addition to assumptions of economic life and discount rate. All these issues are elaborated in this section.

2.2 Overnight Capital Costs

In addition to the bare cost of constructing a plant, usually identified as engineering-procurement-construction, investment costs of a nuclear power plant also include the cost of land, cooling infrastructure, administration and associated buildings, site works, switchyards, project management and licenses as well. This definition confirms with what is referred to as *overnight capital cost*. In the World Nuclear Association's recent report (WNA, 2011a) nuclear overnight capital costs are quoted from mid-2008 vendor figures to be just over $3000/kW for Advanced Boiling Water Reactor (ABWR) type reactors, just under $3000/kW for Economic Simplified Boiling Water Reactor (ESBWR) type reactors and about $3000/kW for AP1000 (a trademark of Westinghouse Electric Company LLC) Pressurized Water Reactor (PWR) types. According to a recent OCED study (OECD, 2010), the overnight capital costs (2008 values) ranged from US$ 1556/kW for Advanced Power Reactor (APR)-1400 type reactors in South Korea through $3009 for ABWR reactors in Japan, $3382/kW for Generation III+ reactors in USA, $3860 for the European Pressurized Reactor (EPR) at Flamanville in France to $5863/kW for EPR reactors in Switzerland, with world median $4100/kW. Belgium, Netherlands, Czech Rep and Hungary were all over $5000/kW. In China overnight costs were $1748/kW for Chinese Pressurized Reactor (CPR)-1000 (a Generation II+ pressurized water reactor) and $2302/kW for AP1000 type reactors. The overnight capital cost of a Russian Vodo-Vodyanoi Energetichesky Reactor (VVER)-1150 type reactor is given as $2933/kW.

The real investment cost, however, typically exceeds overnight capital cost due to the cost of financing and escalation in material and labour costs as has been experienced quite often recently (e.g. Romm, 2009; Kanter, 2009). According to a summary of cost estimates provided by Kennedy (2007), construction costs excluding Interest During Construction (IDC) are estimated at £ 500-1000/kW (2004 values), while they go up to £ 3000/kW (2004 values) with IDC. Drawing on largely unknown public records of French reactors, Grubler (2010) reveals specific reactor costs and their evolution over time, and finds substantial escalation of real-term construction costs. MIT (2009) estimates $4,200/kW for nuclear on average. This is in accordance with Joskow/Parson's (2009) assumption of $4,000/kW. The U.S. Department of Energy (2010), on the other hand, has a slightly higher estimate of $5,300/kW, which is in accordance with the result of a report published by the Moody's Investors Service (Moody's, 2007) that estimates the all-in cost of a nuclear generating facility at $5,000- $6,000/kW.

2.3 Capacity Factor

The capacity factor determines the amount of electricity produced and thus has a significant impact on unit generation costs. If the capacity factor is low, less electricity is produced and hence the investment costs, which are recovered over the lifetime power generation of the plant, are covered by a lower amount of production implying a higher unit cost. Since the fixed costs are to be recovered over the plant's lifetime generation, it is the lifetime capacity factor that is relevant for unit cost computations.

Joskow / Parsons (2009) found that U.S. nuclear plants have a lifetime capacity factor less than 80%. Their analysis at global level results in lifetime capacity factors at about 82 percent as of 2007. It is mentioned that only Finland has a fleet of nuclear plants with lifetime capacity factors greater than 90 percent, and only four other countries have fleets with lifetime capacity factors greater than 85 percent.

The MIT study "The Future of Nuclear Power" (MIT, 2003) employs 85% and 75% lifetime capacity factors in its base case scenario reflecting most reasonable estimates. However, in the 2009 update (MIT, 2009) it is mentioned that the fleet-averaged capacity factor since 2003 has been maintained at about 90%. In the update on the cost of nuclear power, an 85% capacity factor was assumed. The generic assumption of 85% has also been used in the OECD-study (OECD, 2010).

Koomey / Hultman's (2007) analysis on 99 nuclear reactors in the US reveals a median capacity factor of about 72% for earlier reactors and about 82% for the main sample.

2.4 Economic Lifetime

The economic lifetime plays a significant role in the determination of unit generation costs as well since it determines the lifetime power generation over which investment costs are to be recovered. Obviously, the shorter the lifetime the higher the unit generation cost and vice versa.

The OECD report on regulatory reform (OECD, 1997) has declared the typical economic lifetime of nuclear power plants as 40 years, which is also in accordance with commonly used assumption in recent modeling studies (e.g. Vaillancourt et al., 2008; Lenzen, 2008). In practice, however, an extension of plant lifetime is frequently observed as indicated below on the example of the United States.

The United States Nuclear Regulatory Commission NRC issues operating licenses for a maximum term of 40 years. However, in 1991 the NRC developed a set of procedures that features an extension of operating licenses by an additional 20 years. Since then the NRC has renewed licenses for 66 reactors (out of 104 operating reactors in the United States) and is considering 16 applications. The operating life of the nation's largest three-unit power plant has been renewed recently (Reuters, 21 April 2011).

2.5 Discount Rate

Naturally, interest rates and hence the discount rates investors use have a significant impact on the costs of investments in power generation. In computing levelized generation costs, investments costs are annualized using an assumed discount rate. The higher the discount rate, the higher the levelized generation costs. Typically, the real discount rate is assumed to be in the range of 5-10%. In the OECD-report (OECD; 2010), the values for investment, decommissioning and total levelized cost are reported for both 5% and 10% discount rates which makes explicit the significance of this assumption. The levelized cost of nuclear power generation for Belgium, for example, is computed as US$ 61.06/MWh at a 5% discount rate whereas it increases to US$ 109.14/MWh at a 10% discount rate.

2.6 O&M Cost

According to the OCED study (OECD, 2010), the O&M costs (2008 values) of nuclear power plants ranged from US$ 7.04/MWh for CPR-1000 type reactors in China through $29.8/MWh for PWR reactors in Hungary. The O&M cost of PWR reactors in Germany on the other hand is as low as $8.8/MWh. It should be noted that country-specific cost allocation schedules have a significant impact on the O&M costs item. The O&M cost of a Russian VVER-1150 type reactor is given as $16.8/MWh.

2.7 Construction Duration and Economic Impacts

Construction duration is defined as the time that elapses between the pouring of the first concrete and grid connection. Construction interest costs can be an important element of total capital costs, depending on the interest rate and construction duration. A study conducted at the University of Chicago (2004) shows that the interest payments during construction can amount to 30% of the overall expenditures under a five-year construction schedule, and to 40% under a seven-year schedule. A long construction period pushes up financing costs and therefore affects the economics.

The World Nuclear Association (WNA, 2011a) presents median construction duration of nuclear power plants as seven years. The median construction duration for US nuclear plants on the other hand is given by Koomey/Hultman (2007) as nine years. A review of various studies is done by Kennedy (2007) where the range of construction times is elaborated to be 60-120 months.

2.8 The Cost of a Nuclear Accident and Insurance Coverage

Operators of nuclear power plants are liable for any damage caused by them, regardless of fault. They therefore normally take out insurance for third-party liability, and in most countries they are required to do so.

The economic implications of a severe nuclear accident require valuation of death and illness (long-term and intergenerational) from radiation, compensation for lost work, radioactive contamination at sea and land, and massive evacuations for years. Estimates of the cost indicate a massive bill that may imply bankruptcy of a country; a bill which no insurance covers, and highlight as such one of the industry's key weaknesses.

The cost of a worst-case nuclear accident at a plant in Germany, for example, has been estimated to total as much as $11 trillion (Baetz, 2011). More conservative estimates given by governmental studies from the nineties amount to $7.2 trillion (Paulitz, 2008), which is way below the mandatory reactor insurance of $3.7 billion (beyond the insured amount, each reactor operator is liable with all its assets).

In Switzerland, the obligatory insurance is 1.8 billion Swiss francs ($2 billion), but a governmental agency estimates that a major nuclear disaster might cost about FS4.3 trillion which corresponds to nearly ten times- the country's gross domestic product (Guggenbühl, 2011).

In the United States (US), the liability of nuclear operators is capped at $375 million by federal law, with further claims funded by an industry liability pool up to a maximum of $12.6 billion. The bill of a major nuclear accident, however, is estimated to be about 55 times higher for property damage only: a 1982 study from Sandia National Laboratories (Strip, 1982), commissioned for the Nuclear Regulatory Commission (NRC), estimates the consequences of a nuclear meltdown as $314 billion (corresponding to $720 billion in year 2011 values) in property damage only. The 1982 study is –to our knowledge– the most recent cost estimate available for the US. Experts from the NRC, however, have declared that the agency is working on a new study which focuses on health impacts (Hargreaves, 2011).

Baetz (2011) reports that the nuclear industry is under-insured worldwide. It is emphasized that France requires an insurance of $134 million from plant operators, with the government guaranteeing liabilities up to $338 million only. Similar figures are in place for Britain, Russia and the Czech Republic.

3 The Cost of Nuclear Power Generation in Turkey

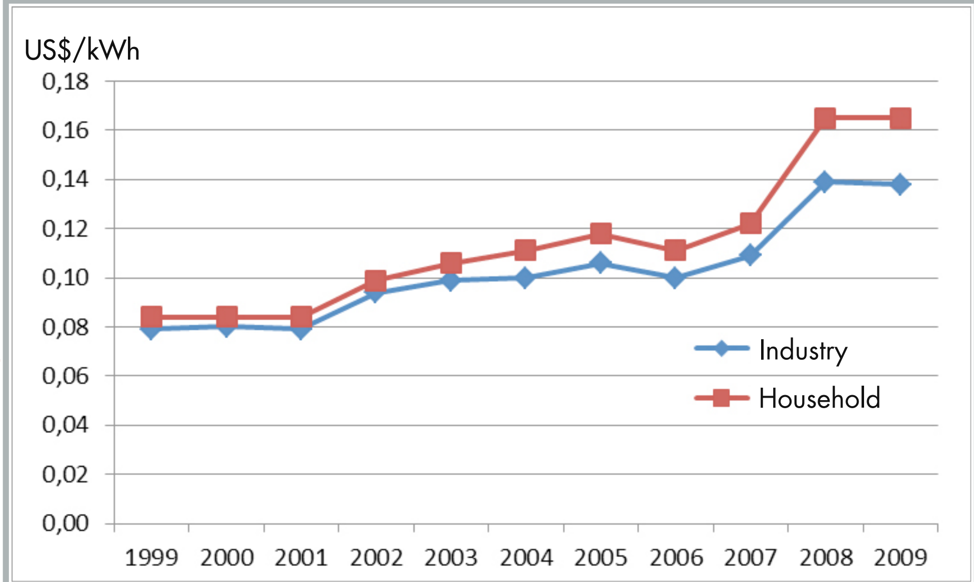
3.1 The Intergovernmental Agreement with Russia and İmplied Cost of Nuclear Power Generation

In May 2010, Russia and Turkey signed an agreement that a subsidiary of Russia's state-owned atomic power company Rosatom would build, own, and operate a power plant at the Akkuyu site, on Turkey's Mediterranean coast, comprising four VVER units of 1,200 MW installed capacity each. The first unit is expected to enter service in 2019 with the other three coming online subsequently.

The Turkish Electricity Trade and Contract Corporation (TETAS) has guaranteed the purchase of 70% power generated from the first two units and 30% from the third and fourth units over a 15-year power purchase agreement at an average price of 12.35 US cents per kWh excluding VAT. The quantity and price trajectories over the 15 years that make up this average price are not known/public. It should be noted, however, that this is a price quoted in *nominal* terms indicating the value of power averaged in the respective year of generation. A look at the historical evolution of *nominal* electricity prices in Turkey, depicted in Figure 1, helps to better interpret this number. During the period 1999-2009, the average annual growth rate has been 5.74% for industrial and 6.98% for residential prices including tax (which amounts to in aggregate an increase of 18.5% for industrial and 21.5% for residential end-use prices).

The power purchase agreement average price of US$ 0.1235/kWh corresponds to a value that is slightly above the end-use industrial price excluding tax (which corresponds to US$ 0.1125/kWh) and slightly below the household end-use price excluding tax (which corresponds to US$ 0.1295/kWh) for year 2009. Considering the fact that the agreement refers to a price that is the average of a price for the period 2020-2035 and therefore almost two decades ahead, it appears to be an economically advantageous deal for Turkey (in the sense that the agreed-upon average purchase price can be expected to be considerably lower than end-use electricity prices by that time) provided that safety measures and regulations related to the construction, operation and maintenance of the reactor as well as related to waste transport and management activities are all well defined and provide convincing confidence and reliability regarding the risk of an accident and nuclear leakage.

Figure 1: Evolution of End-Use Electricity in Turkey Prices (nominal values; inclusive tax)



Data source: International Energy Agency (2010)

It should be noted that, according to the intregovernmental agreement, after the power purchase agreement expiry dates, 20% of the Project Company's net profit shall be given to the Turkish party on an annual basis throughout the lifetime of the plant.

3.2 Technology-Specific Comparison of the Anticipated Generation (Levelized İnvestment, O&M) Costs in Turkey with Other Reactor-Level İnternational Data

Koomey/Hultman's (2007) reactor-level analysis evaluates busbar[1] costs during 1970-2005 for 99 nuclear reactors in the US. Assuming

- a 6% real discount rate
- a lifetime of 60 years for AP1000 type reactors and 40-years for all others

1- Busbar cost, also known as levelized costs, defines the cost of delivering electricity - beyond the generator but prior to the voltage transformation point in the plant switchyard.

in the calculation of a capital recovery factor for the levelization of investment expenditures, they find that all but one of 57 reactors finished in 1983 or before had busbar costs of 7 US cents (2004)/kWh or less, and that all but one of the reactors finished after 1983 had busbar costs greater than 5 US cents (2004)/kWh with the most expensive one generating at nearly 15 cents per kWh.

Kennedy's (2007) summary of cost estimates for nuclear generation reveals an average levelized cost of £32/MWh (2004 value) with a range of £12-60/MWh.

According to the OCED study (OECD, 2010), the levelized generation costs (2008 values) of nuclear power plants, under a discount rate of 10%, ranged from US$ 42.09/MWh for APR-1400 type reactors in Korea through $136.5/MWh for PWR reactors in Switzerland. The levelized generation cost of a Russian VVER-1150 type reactor is given as $68.15/MWh. It should be noted that a Russian nuclear reactor's levelized generation cost is much lower than European ones as indicated by the OÈCD report where only the Chinese and Korean reactors have lower cost figures.

When the levelized generation cost of Russian technology as reported by the OECD is compared with the agreed-upon average purchase price in the Akkuyu agreement, depending on the time value of money (i.e. discount rate used) there appears to be a very limited profit margin for the investors. The agreed-upon purchase price (average over 2020-2035) of 12.35 US cents per kWh in 2027 would be equal to 6.815 US cents per kWh in 2010 at a discount rate of 3.6%. In other words, in case the real discount rate over 2010-2027 turns out to be higher than 3.6%, the Russian party will make an economic loss from its nuclear investment in Turkey.

3.3 Technology-Specific Comparison of the Anticipated Generation Costs in Turkey with Assumptions Employed in Modeling Studies

Table 1 provides a summary of the technology-specific cost assumptions employed in modeling studies, including the implied unit generation cost. It can be seen that the cheapest nuclear power option is the AP1000 type of reactor with a levelized generation cost of US ¢ 4.09/kWh (2006 values). This is in accordance with the Chinese and Korean reactor data (using this type of technology) provided by the OECD as has been outlined in previous section. Assumptions for the PWR type reactor on the other hand remain below the figures indicated by the OECD.

Table 1: Technology Specific Nuclear Cost Assumptions Employed in Modelling Studies (2006 values)

Technology	Fixed O&M Cost [M£ / (GW x a)]	Variable O&M Cost [M£ / PJ]	Capacity Factor	Investment Cost [M£ / GW]	Economic Lifetime [a]	Generation Costs [US ¢ / kWh]
Advanced Gas-cooled Reactor (AGR)	42,8	0,045	%90	1913	35	5,33
AP1000 - 2010	0	0,77	%85	1625	50	4,09
EPWR – 2010	35	0,066	%85	1482,7	40	4,88
GTMH reactor - 2030	14,7	0,099	%90	1786,5	50	9,58
Pebble Bed Reactor (PBR) - 2030	0	0,385	%95	1786,5	50	6,93
PWR	42,8	0,045	%90	1913	40	5,18

Source: AEA Technologies

The levelized cost figures reported in Table 1 are comparable to the average purchase price of 12.35 US cents per kWh agreed upon in the agreement between Turkey and Russia - both are tax- and infrastructure (transmission & distribution) excluded values. It should be noted, however, that the agreement refers to a price in 2019 at the earliest whereas Table 1 provides year 2006 values. The time value of money needs to be taken into account when comparing these figures. Table 2 provides a comparison of the cost assumptions with the agreed upon purchase price of 12.35 US cents per kWh based on three real discount rate assumptions: 4.5% p.a. (“Low”), 7% p.a. (“Mid”), 10% p.a. (“High”). When the 2010 real values for both cases are considered, it can be seen that the “Mid” and “High” values for Akkuyu are lower than any cost assumption used in the modeling studies. Only the low discount rate case results in a value that is slightly higher than some modeling assumptions (the discrepancy in this case is limited: in comparison to the cheapest technology (AP1000) it is 33%). It should be noted that the lifetimes of Akkuyu and the modeling study assumptions are comparable as well: the economic lifetime of the plant to be build in Akkuyu is envisaged to be about 50 years as the Turkish Minister of Energy recently declared that the plant will be decommissioned in 2071 (NTVMSNBC, 2011).

Table 2: Comparison of Levelized Generation Cost Employed in Modeling Studies with the Turkey-specific Agreement Price

	Levelized Generation Cost Assumptions [US ¢ / kWh]		Akkuyu Agreement 2020-2035 Average Purchase Price [US ¢ / kWh]	
Technology	2006 nominal	2010 real[1]	2010 real	2027 nominal
AGR	5.33	5.71	Low (4.5% disc. rate): 5.84	12.35
AP1000	4.09	4.38		
EPWR	4.88	5.23	Mid (7% disc. rate): 3.91	
GTMH	9.58	10.27		
PBR	6.93	7.43	High (10% disc. rate): 2.44	
PWR	5.18	5.55		

1 The value of the deflator index used for 2006 is 103,257 and for 2010 it is 110,659. (1929-2010 US GDP Price deflator series, 2005=100, Bureau of Economic Analysis, US)

The Turkish Energy Market Regulatory Authority EMRA has announced the country's average wholesale electricity price for year 2010 as 14.07 Krş/kWh (EMRA Decision No: 2930; 16/12/2010). The average exchange rate for the same year has been announced as 1.5004 TL/US$ (Ministry of Development, 2011). Accordingly, the average wholesale electricity price 2010 is calculated as 9.38 US ¢/kWh. When compared with the Akkuyu agreement prices for 2010 in real terms shown in Table 2, it is seen that the wholesale price has been about 60% higher than the highest price estimate for the Akkuyu agreement (Low discount rate scenario – 5.84¢/kWh). The discrepancy is significantly higher (284%) for the low price scenario. Thus the agreed-upon average purchase price for Akkuyu appears to be an economically advantageous deal for Turkey.

3.4 Waste Management Costs: Turkey & International Comparative Analysis

According to the intergovernmental agreement between Turkey and Russia, the project company is being held liable for paying 0.15 US cents to the spent fuel fund for every kWh of electricity sold to the Turkish state owned electricity trading company TETAS. According to the same agreement, the project company is responsible for waste management and the spent waste can be shipped back to Russia for reprocessing. In that case, the spent fuel fund can be used to finance this operation to be carried out by the project company.

According to the World Nuclear Association (WNA, 2011a), the back-end of the fuel cycle, including used fuel storage or disposal in a waste repository, contributes up to 10% of the overall generation cost per kWh. It is noted that the US used fuel program is funded by a $1/MWh levy.

According to the OECD report, fuel cycle costs are in the range of $4-11.6/MWh with the mode being $9.33/MWh. These figures are reported to include both front-end costs as well as back-end costs associated with waste management. The World Nuclear Association (2011a) approximates the front-end cost of the fuel cycle to be $7.7/MWh. Adding a $1.5/MWh for the back-end, a total of $9.2/MWh is obtained, which indicates that the radioactive waste management accounting is in line with international experience.

3.5 Decommissioning Costs: Turkey & International Comparative Analysis

According to the intergovernmental agreement between Turkey and Russia, the project company is being held liable for paying 0.15 US cents to the decommissioning fund for every kWh of electricity sold to the Turkish state owned electricity trading company TETAS. According to the same agreement, the project company is responsible for the decommissioning of the Akkuyu nuclear power plant. In that case, the decommissioning fund can be used to finance this operation to be carried out by the project company.

According to the World Nuclear Association's report (2011a), decommissioning costs amount undiscounted to about 9-15% of the initial capital cost of a nuclear power plant. It is noted that they account for 0.1-0.2 cent/kWh in the United States.

Kennedy's (2007) summary of cost estimates for nuclear generation reveals a range of £195-500 million (2004 value) for decommissioning costs. In a conservative central case scenario, he assumes £0.7/MWh (2006 value).

3.6 Third Party Liability: Turkey & International Standards

There are two basic international regimes for nuclear third party liability in force:

i. the Vienna Convention on Civil Liability for Nuclear Damage (Vienna Convention), which was established in 1963 under the auspices of the International Atomic Energy Agency (IAEA) and entered into force in 1977.

ii. the Paris Convention on Third Party Liability in the Field of Nuclear Energy (Paris Convention), which was established in 1960 under the auspices of the OECD and entered into force in 1968.

Coverage under the Paris Convention is extended in 1963 by the Supplementary Convention on Third Party Liability in the Field of Nuclear Energy (Brussels Supplementary Convention). Furthermore, the Paris and Vienna Conventions have been linked in 1988 by the Joint Protocol Relating to the Application of the Vienna Convention and the Paris Convention (Joint Protocol) which entered into force in 1992. Parties to the Joint Protocol are treated as though they were Parties to both Conventions and a choice of law rule is provided to determine which of the two Conventions should apply to the exclusion of the other in respect of the same incident.

The Paris Convention and the Brussels Supplementary Convention have both been amended several times by additional protocols to provide for broader scope, increased amount of liability of the operator of a nuclear installation and enhanced means for securing adequate and equitable compensation (NEA, 2007). The recent amending protocol to the Paris Convention, signed in 2004, broadened the definition of "nuclear damage" to include environmental damage and economic costs, and set new limits of liability as follows: Operators (insured) €700 million, Installation State (public funds) €500 million, Collective state contribution (Brussels) €300 million implying a total of at least €1500 million (World Nuclear Association, 2011b). It should be noted that the 2004 amendment removed the requirement for a state to restrict the maximum liability of a nuclear operator, allowing states with a policy preference for unlimited liability to join the convention.

The international regimes prescribe some minimum liability requirements above which country-specific coverages may differ. However, in many countries the liability limits are still below the minimum requirements put forward by the 2004 amendment as can be seen in Table 3.

Turkey has ratified the Paris Convention in 1961 and the Joint Protocol in 2007.

Table 3: International liability and compensation coverage for various countries

Country	Operator Liability Limit	Financial Security Limit	Other Compensation: State+ Int. Fund
Argentina	$ 80 m	$ 80 m	-
Brazil	$ 160 m	$ 160 m	-
Austria	$ 106 m + 10% (I+L)*	$ 406 m + 10% (I+L)*	-
Belgium	$ 433.2 m	$ 433.2 m	0 + $ 197.6 m
Canada	$ 70.7 m	$ 70.7 m	-
China	$ 43.9 m	$ 43.9 m	$ 117.1 m + 0
Czech Republic	$ 445.7 m	$ 445.7 m	-
Finland	$ 276.6 m	$ 276.6	0 + $ 197.6 m
France	$133.3 m	$133.3 m	$ 144 m + $ 197.6 m
Germany	Unlimited	$ 2.5 b	$ 2.5 b + $ 197.6 m
Hungary	$ 158.1	$ 158.1	$ 316.2 + 0
Japan	Unlimited	$ 1.3 b	-
Korea	$ 474.2 m	$ 43.2 m	-
Morocco	$ 158.1 m		$ 7.9 m + 0
The Netherlands	$ 495.3 m	$ 495.3 m	$ 2.8 b + 197.6 m
Romania	$ 237.1 m	$ 237.1 m	$ 237.1 m + 0
Russian Federation	None specified	$ 350 m	-
South Africa	$ 322.4 m	$ 322.4 m	
Spain	$ 1 b + $1b (env. damage)	$ 1 b + $1b (env. damage)	0 + $ 197.6 m
Sweden	$ 474.2 m	$ 474.2 m	0 + $ 197.6 m
Switzerland	$ 960.7 m + 10% (I+L)*	$ 960.7 m + 10% (I+L)*	
UK	$ 227.6 m	$ 227.6 m	$ 49.6 m + $ 197.6 m
US	$ 11.6 b	$ 11.6 b	-

* I + L: Interest and legal charges

Source: IDSA (2010), based on OECD's Nuclear Energy Agency data from December 2009.

However, Turkey has neither ratified the Amendment Protocols to the Paris Convention, nor the Brussels Supplementary Convention yet.

Moreover, the intergovernmental agreement between Turkey and Russia did not introduce any thresholds regarding the çivil liability of the Project company in case of a nuclear accident. The Article 16 of the said agreement states that the third party civil liability will be determined according to the international agreements to which Turkey is or will be party to and to Turkey's domestic laws and regulations. At present according to the Code of Obligations, there is no limit to third party liability. Nonetheless negotiations have apparently been initiated with the Russian side to clarify this situation.

4 The Anticipated İmpact of Nuclear Power on Electricity Supply & Prices in Turkey

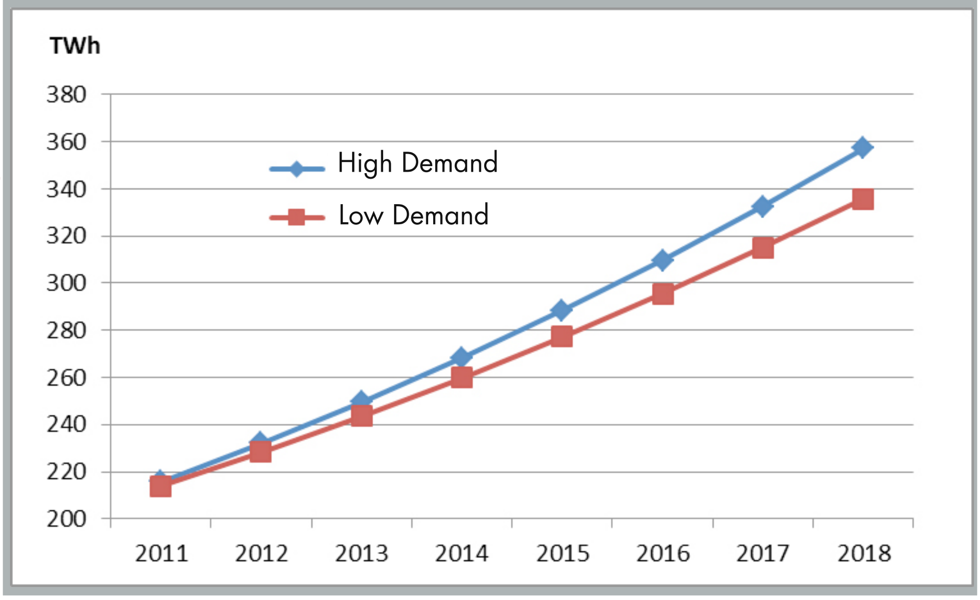
Electricity supply considerations in Turkey have been strongly driven by a rapid growth on the demand side and the historical dominance of hydropower and fossil fuel based thermal power generation on the supply side. Electricity demand has been growing at a remarkable average rate of 11.3% over the last 40 years, inducing annual investments in the generation, transmission, and distribution infrastructure in the order of US$ 4-5 billion. Installed generation capacity today is estimated to be around 48.6 GW as of December 2010 (EÜAS, 2011). Turkish electricity generation rests on hydropower and fossil-fueled thermal power generation. Of the total installed capacity, 31.8 GW is based on thermal power generation plants. In terms of generation shares the distribution is as follows: 45.9% of total electricity generation in 2010 has been produced using natural gas; 18.4% comes from domestic coal fired power plants, 6.9% from imported coal fired ones, 2.5% from liquid fuel fired ones, 1.35% comes from wind power, 0.47% from geothermal and 24.5% is generated by hydroelectric power plants. As a national policy priority it is aimed not to increase import dependence and therefore not to increase the share of imported coal and gas fired power plants. Only 2% of gas supply in Turkey has been coming from domestic sources in 2010, the rest being imported: 46% of the imported gas comes from Russia, 20% from Iran, 12% from Azerbaijan, 10% from Algeria, 3% from Nigeria and the rest is supplied from the spot market (EPDK, 2011). The use of coal, on the other hand, is accompanied by greenhouse gas and other pollutant emissions. It is therefore aimed to increase the share of nuclear and renewable power generation to meet the country's growing electricity demand. The expansion of nuclear capacity is planned well ahead as a result of long construction lead times and special purchase agreements.

The adoption and diffusion of new renewable energy technologies on the other hand is subject to subsidies and / or developments that bring down unit generation costs to a level where these technologies can actually compete with conventional technologies. Such developments can be conveniently represented by learning curves, which indicate the exponential reduction in the unit cost that can be expected as their cumulative production volume increases (e.g. IEA, 2000). Prospects for the diffusion of renewable energy technologies, however, are also affected by the high level of uncertainty that characterizes liberalized electricity markets (esp. regarding the price of and demand for electricity), and the way investors evaluate investment options under uncertainty.

4.1 Short-Term (Up To 2018) Impact on Supply Capacity and Electricity Prices

The latest capacity projection report from the Turkish Electricity Transmission Company (TEIAS, 2009) reports official supply / demand projections up to year 2018 which is a benchmark in terms of nuclear power as the first unit of the Akkuyu power plant is planned to feed electricity into the grid in year 2019.During 2011-2018, demand is projected to grow at an annual average rate of 6.7% reaching 336 TWh in 2018 in the low demand scenario, and at 7.5% reaching 357 TWh in the high demand scenario. The growth rate is assumed to be almost uniform as can be seen in Figure 1.

Figure 2 : Official Electricity Demand Projections until 2018

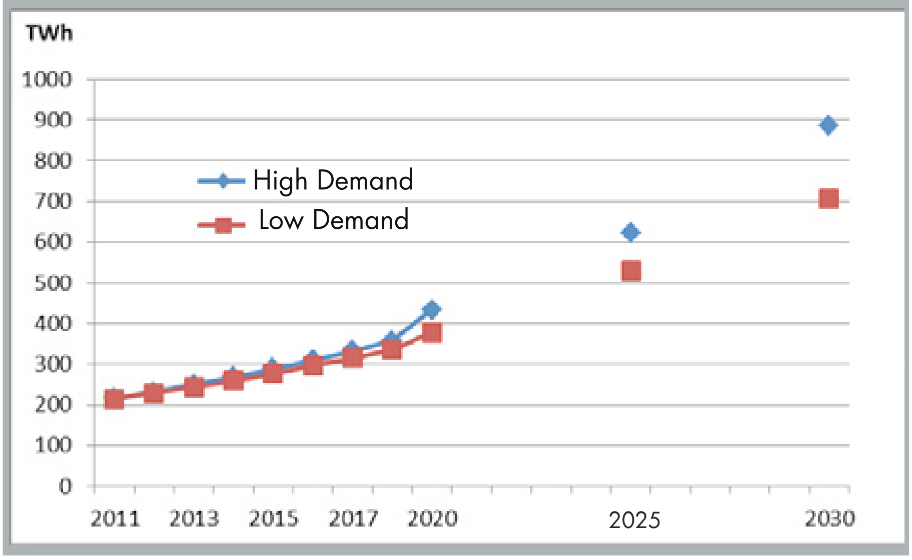


The projection of supply capacity, on the other hand, is based on applications for construction licenses and plants under construction. Two scenarios with differing assumptions on the construction durations are defined. Taking into account conservative estimates of hydroelectric power generation (i.e. based on reliable generation capacity factors in dry years) and the scenario assuming longer construction duration, it is found that there will be a shortage of capacity in 2014 if the high demand growth scenario materializes, and 2015 if the low demand growth scenario happens to be true. For the scenario with shorter construction durations, the shortage years are estimated to be 2015 and 2016 under high and low demand growth respectively. These figures are deferred by two years if non-conservative generation level estimates (based on project generation capacity factors) are used. In any case, additional capacity is needed before the nuclear power plant comes on-line. The fact that a significant amount of nuclear power generation capacity (with a power purchase agreement and relatively low marginal cost) will be added to the plant mix in subsequent years, however, may discourage private sector investors due to profitability concerns. Therefore, some measures need to be taken to avoid a possible supply shortage on the eve of the nuclear era.

4.2 Long-Term (2019-2030) Impact on Supply Capacity and Electricity Prices

Long-term projections of electricity supply and demand beyond 2018 are provided in 5-year intervals by the Energy Market Regulatory Authority of Turkey (EPDK) as shown in Figure 2. A slight reduction in growth is estimated in line with experience from other countries and expectations of structural changes in the economy. Accordingly, the average annual growth rate declines from 7.5% during 2020-2025 to 7.3% during 2025-2030 in the high growth scenario. In the low-growth scenario, on the other hand it declines from 6.9% during 2020-2025 to 5.9% during 2025-2030.

Figure 3: Official Electricity Demand Projections until 2030



On the supply side, two scenarios are considered: a fossil fuel oriented scenario with an additional 10,000 MW gas- and 5,000 MW oil-fired capacity; and a renewable oriented scenario with an additional 25,000 MW wind, 9,000 MW solar and 8,000 MW biomass capacity. In both scenarios, a nuclear capacity of 12,000 MW is considered, and all hydro and domestic coal potential is utilized. Accordingly, the share of nuclear capacity in 2030 is expected to amount to 7.4% in the fossil fuel oriented scenario, and 6.4% in the renewable oriented one. The impact of the nuclear capacity on electricity prices in the long term is thus limited to this share, and subject to the economics in power purchase agreements for new nuclear power plants to reach the 12,000 MW capacity level in excess of Akkuyu (which is envisaged to have a total capacity of 4,800 MW). For the Akkuyu plant, it is agreed upon that 30% of the generation of the first two units and 70% of the generation of the last two units shall be sold by the Project Company on the free electricity market via an energy retail supplier. The long-term design and structure of the Turkish electricity market will be decisive for a reasonable profit margin and controllable market power potential.

4.3 Impact on Private Sector İnvestment in Alternative Power Generation Technologies

Liberalization of electricity and other energy markets introduces much additional uncertainty, also and especially regarding the profitability of investments. With uncertainty, the risk profile of a particular technology influences the choice of the power generation mix, even when the technologies are commercially proven and have equal levelized costs. Table 4 presents a qualitative comparison of cost and risk characteristics for a set of selected generating technologies.

Table 4: Qualitative cost and risk assessment for different generating technologies

Technology	Unit size	Lead time	Capital cost per kW	Operating cost	Fuel cost	Regulatory risk
CCGT	Medium	Short	Low	Low	High	Low
Coal	Large	Long	High	Medium	Medium	High
Nuclear	Very large	Long	Very high	Medium	Low	High
Hydro	Very large	Long	Very high	Very low	Nil	High
Wind	Small	Short	High	Very low	Nil	Medium

Source: adapted from IEA (2003)

New renewable energy technologies for power generation (such as PV and wind power systems), on the one hand, have attractive low-risk characteristics, including short planning and construction lead times, no or low fuel cost and related greenhouse gas and pollutant emission, and low operating and maintenance costs. On the other hand, they are relatively capital-intensive - partly because the technologies are still fairly high up the learning curve, and partly because they have to concentrate a dispersed energy source. This is in contrast to, say, large hydro or nuclear power systems, which require large capital outlays, long lead times, long payback periods, and thus large investment risk. The flexibility characteristics and the risks that accrue from investment have a significant impact on private investors' technological choices, in addition to cost characteristics.

A purchase agreement that guarantees the purchase of produced power (as in Turkey's nuclear power agreement with Russia) features investment in capital-intensive high-risk technologies. This can be considered as a strategic subsidy to a new technology, without which its adoption could not be possible. The agreed upon addition of a considerable amount of nuclear capacity in Turkey may discourage investment into alternative technologies, especially renewables with high capital costs, unless their investment costs decline and/or subsidies assure a reasonable profit margin.

5 Conclusions

Regarding the economics of nuclear power in the Turkish context, the following conclusions can be drawn with respect to the agreement for the Akkuyu nuclear power plant.

- The average purchase price of 12.35 US cents per kWh in nominal terms, excluding VAT, appears to be economically advantageous for Turkey when international data on levelized generation costs, the historical evolution of end-use electricity prices, the long time horizon involved and the "Build-Operate-Own" investment model (according to which all financial risk is taken up by the project company) are considered
- More particularly the present value of the average purchase price has a range between 2.44¢/kWh and 5.84¢/kWh depending on the discount rate used. But even the higher price compares favorably with the average wholesale electricity price for 2010 of 9.38 ¢/kWh.
- With the price of 0.15 US cents per kWh to be paid on the account for spent fuel, radioactive waste management cost is in line with international estimates. The routes, means and security plans for the transportation of spent fuel are not detailed yet. This may be an item affecting economics due to a long international travel distance to Russia and possible public opposition along the way. The project company, however, is responsible for waste management and bears the financial risk.
- With the price of 0.15 US cents per kWh to be paid on the account for decommissioning, the cost is in line with international estimates. The project company is responsible for decommissioning and bears the financial risk.
- The cost of a severe nuclear accident (resulting in long-term/intergenerational health effects and deaths, radioactive contamination at sea and land and massive evacuations for years), besides the associated morale challenge, is estimated worldwide to be a multiple of national GDP figures and cannot be

covered by any insurance.[2] Typically, a liability limit is determined which is naturally a parameter that affects insurance dues and hence the economics of power generation – no such limit has been determined for the Akkuyu project. According to the agreement, third party liability for nuclear damage will be regulated in compliance with the international agreements and instruments that the Republic of Turkey is and will be a party and national laws and regulations of the Turkish party. Currently, there is no upper limit on liability according to the Turkish law on obligations. However, there might be a forthcoming agreement on this issue as it is being negotiated. If Turkey ratifies the Amending Protocol to the Paris Convention, operator liability will have to be regulated to cover at least €700 million.

- A long construction period pushes up financing costs and therefore affects the economics. It is planned that the first power unit in Akkuyu starts commercial operation in 2019, which implies a construction duration of seven years if construction starts in 2012. The responsibility to insure risks covering this period belongs to the project company. Furthermore, in case of failure, the Russian Party has the responsibility to designate a successor that possesses all necessary competencies and capabilities. Accordingly, there is no financial risk on the Turkish side related to possible construction delays, cost overruns or credit downgrades.
- Domestically produced material and equipment will be used in the construction of the plant (except the core) wherever economics and quality can be assured. This may boost the local economy during the construction phase to a limited extent (limited since Turkish companies may not have the know-how and production arrangement to produce economically at the required quality standards).
- The plant design is envisaged to be earthquake safe up to a magnitude of 9 on the Richter scale. However, earlier studies on the site's seismic properties are outdated and/or not reliable. Therefore, the Russian subsidiary company has outsourced independent measurements of seismic activity and other essential indicators like temperature, humidity and air salinity to evaluate the site-specific design safety. In case of increased seismic activity there could be a modification in design necessary, which would induce additional cost and affect the economics. The financial risk, however, is on the side of the project company.
- Electricity demand has been and is expected to continue to increase rapidly in Turkey in accordance with economic development. Supply shortage may be expected on the eve of the nuclear era unless new investment in excess of the existing construction license applications is initiated. The fact that a significant amount of nuclear capacity (with a power purchase agreement and relatively low marginal cost) will be added to the supply mix may discourage investment into alternative technologies, especially renewables with high capital costs, unless their investment costs decline and/or subsidies assure a reasonable profit margin.

2- The impossibility to put a value to human life, and the impossibility to correctly measure the loss from damage to environment and livelihoods should be noted.

In conclusion, as a final remark evaluating the findings of the study, it can be said that the agreement between Russia and Turkey appears to be an economically advantageous deal for Turkey. If the deal would have been possible without an intergovernmental agreement, as a stand-alone commercial treaty at the same terms, is rather questionable considering the economics and all the risks taken up by the Russian party. Other aspects such as the strong bilateral cooperation in the energy sector between Russia and Turkey and the promotion of Russian nuclear technology in new emerging markets might have been influential factors that contributed to this agreement. If Turkey is to have a nuclear future as envisaged in long-term official energy strategy, the agreement seems to be a good starting point economically as long as the possibility of leakage and a severe nuclear accident are excluded, waste management poses no concern, and the necessary regulatory and controlling mechanisms can be put in place successfully. The economics of a non-nuclear future, on the other hand, together with its feasibility and sustainability, is being discussed worldwide more extensively after the Fukushima accident.

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Section IV

Risks, Incentives and Financing Models of Nuclear Power Plants: International Experiences and the Akkuyu Model

IV

Assoc. Prof. İzak Atiyas

Executive Summary

Following the conclusion of an intergovernmental agreement between Turkey and Russia, a Russian company, namely Rosatom was entrusted with the construction and operation of a nuclear power plant in Mersin Akkuyu. When considered in terms of risk sharing, the Akkuyu model is akin to an extreme "commercial power plant" model, in such a way that a very significant part of the financial risks listed in the previous sections remain the responsibility of the project company. However, the electricity company undertaking these risks related to the construction and operation of the power plant is not a real private company; it is a public company owned by the Russian state. Therefore, in case the project revenues fail to cover the project cost and the need for additional financing emerges, mutual understanding calls for the coverage of this financing by the budget of the Russian state as a last resort. In a way, a very simple solution has been apparently found in the Akkuyu project for the question of sharing a very challenging risk which was tried to be settled with very difficult and complicated corporate mechanisms in other countries and environments: this solution calls for the shift of all risks to the company and thus to the Russian state.

In cases where a major part of the financial risks falls on the project company, the average cost is expected to be considerably high. Yet, the fixed price specified in the purchasing contract does not appear to be high. So, it must have been determined under the assumption that either the project price will be considerably higher than the wholesale prices in the liberalized electricity market or will be supported by the budget of the Russian government in one way or another. The general opinion is inclined towards the second option; which is to say that there is a wide belief that this project is in a way "political" in nature and has been directed and supported by the Russian government.

The assessment of the possible economic and societal consequences of the project, and more concretely of the behavioral motives of the project company throughout the implementation of the project, leads to the question whether this project is a "commercial" project or a project in which political characteristics mostly prevail; because, these two different assumptions imply different behavioral patterns.

The assumption that the project company will act on the basis of commercial motives depicts the following picture: a commercial company takes steps for establishing a nuclear power plant upon undertaking a substantial financial risk. Nearly half of the electricity produced will be sold to the public sector at a fixed price for a specified period of time (15 years for each unit). This price will not be affected by the costs incurred or the investments. The remaining part of the electricity will be utilized according to a competitive price mechanism. This is like a partial fixed price contract. The response to be provided to one of the key questions under this type of a contract in terms of public benefit is positive: the fixed price is a reasonable price and it is not too high. The key characteristic of the fixed price contract and the price mechanism is that they both encourage the reduction

of the company costs to the lowest level, because when the price is fixed every cost decrease will increase profits. Certainly, this has very positive aspects. For instance, the project company will strive to avoid delays in the construction phase. The project management will display every effort for the timely operation of the supply chain. However, there are highly negative aspects associated with a strong incentive for making profit. Many of the cost elements in nuclear power plant projects are related to safety and security measures. One of the strongest negative consequences of a strong incentive to reduce costs is the potential to place a low importance on safety and security issues.

The most important incentive mechanism in the market mechanism is when companies act on the basis of a incentive to make profit. When companies act on the basis of a motive to make profit in cases where the markets are operating effectively, this gives rise to desirable consequences for society; this prediction is one of the key elements rendering the market mechanism attractive. An important assumption underlies behind this prediction: that all the results of the activities of the companies are internalized, and, that, in other words, there is no externality. This is not the case for nuclear power plants. The damage to be caused by the power plant on the environment in case of any failure or accident will be much higher than the loss of the company itself especially when the financial responsibility of companies is restricted. Its own loss is composed of the investment costs and the profits waived. However, the damage on the society is much higher. Therefore, companies may not be expected to display a behavior which fully safeguards social welfare in the construction and operation stage. It is for this reason that there is an absolute need for a regulatory and supervisory authority for the adoption of safety and security measures.

So, the outcome of the Akkuyu model under the assumption that the project company will act on the basis of commercial incentives shall be closely linked to the effectiveness of the enforcement of safety regulations. In other words, the safety and security risk and the financial and related regulation very closely associated in Turkey. Yet, the regulatory and enforcement environment in Turkey displays significant weaknesses. First of all, the legal framework regarding regulations and enforcement is incomplete: The current internationally accepted institutional model calls for the oversight by an autonomous administrative authority that will operate independently from the government and the companies to be inspected and will not be influenced by them. There is no such authority yet in Turkey. Moreover, proper regulatory oversight and enforcement also requires significant human resources. There are severe deficits in Turkey also in this respect. The aggregation of risks on the project company reinforces incentives for cost reduction. But when coupled with the fact that Turkey's oversight and enforcement capacity is limited, this appears to be a combination giving rise to significant liabilities in terms of safety and security of nuclear power.

Another assumption to be made regarding the project company may be that its behavior is shaped also according to (or mainly due to) the political priorities of the Russian state, in addition the commercial motives. The fact that political motives play a role may have shaped the project to Turkey's advantage at least in the short term. Consequently, Turkey plans to make a substantial addition to its electricity production capacity while assuming relatively low risks and committing a partial purchasing guarantee which is not expensive in light of the risks assumed by the project company. However, the presence of political motives should be regarded as a significant additional risk in the medium and long term.

When evaluated only on the basis of financial parameters, the Akkuyu project appears to be an advantageous project for Turkey. However, considering the behavioral patterns incentivized by these parameters and the inadequacy of the oversight and enforcement capacity in Turkey, it should be stated that a nuclear project, where all risks are undertaken by the project company, will in all likelihood have safety and security deficits. The main issue here is not financial, but the absence of a legal and human infrastructure required for the proper oversight and enforcement in the short term and the absence of nuclear energy policy in Turkey based on social consensus in the medium and long term.

1 Introduction

In the last fifty years, interest in nuclear power plants fluctuated significantly. In the US, nuclear plants were first constructed in the 1960's and the first half of the 1970's, whereas the construction of new nuclear power plants stopped almost completely in the 1980's. More generally, a significant number of developed countries have stopped investing in new nuclear power plants since nearly three decades. Almost all of the nuclear power plants constructed in the last decade are located in Japan, South Korea, China and India (Joskow and Parsons, 2009).

There are many reasons for nuclear power plants to lose favor in the 1980's. In order for nuclear power plants, which are heavily capital intensive, to be economically viable, they need to produce electricity during a significant part (for instance, in nearly 85-90 percent) of the year. Yet, the capacity factor in 1985 was 58 percent in the US (Joskow and Parsons, p. 46). The construction time and the costs of power plants proved to be higher than expected. One of the most important reasons for this rise in cost was the increase in security concerns over time. Especially the accidents at Three Mile Island in the US in 1979 and later on at Chernobyl in Ukraine in 1986 led to delays in the approvals of governments or regulatory authorities and gave rise to changes in the designs of power plants.

While costs of nuclear power plants turned out to be much higher than expected, coal and natural gas prices have either decreased or increased slowly particularly in the 1980's and 1990's and therefore thermal power plants based on coal or natural gas have become more attractive. Meanwhile, developments in the natural gas turbine technology in particular and the reduction of the cost of such power plants have led nuclear plants to lose much of their commercial appeal in the 2000's.

In addition to these economic developments, political and social opposition emerged against nuclear technology with the development of social awareness against nuclear arms and environmental issues particularly in the US and Europe.

Finally, electricity producing industries underwent a restructuring process in the 1990's and 2000's; the vertically integrated monopolistic production model began to be replaced with the competition based market model, which increased the risk of production activities and nuclear power plants were particularly negatively affected by these developments. As a result, while the annual additions made to the global nuclear power production capacity was approximately 30 gigawatts in mid 1980's, this figure dropped to nearly 4 gigawatts on average in the 2000's (Kessides, 2009: 348).

Nuclear power has made a revival in recent years. One of the reasons is the increase in the efficiency of the existing nuclear plants. For instance, significant improvements began to take place in the performance of nuclear power plants in the US in the 2000's. According to Joskow (2006), the operational and maintenance costs of nuclear power plants dropped from a level of nearly US$ 2.7 cents/kWh US$ 1.7 cents/kWh between 1997 and 2005. Power plant capacity factors rose from 60 percent to around 90 percent. An increase was observed in the capacity factors also at a global level, but not at such a dramatic degree (Joskow and Parsons, 2009, p. 47).

The fact that natural gas prices have entered a rising trend (at least until the 2008 global economic downturn) enhanced the commercial feasibility of the existing nuclear power plants and also led to a change in the perception of economic life of these power plants; for instance, many power plants in the US applied for the extension of their license and these applications were approved. The increase in the price of fossil fuels made new nuclear power plant investments economically more attractive.

Another important factor is global warming and climate change policies. While nuclear power plants do not produce carbon emissions, believed to cause global warming, coal and natural gas plants produce carbon dioxide. Producing power through nuclear energy seems cleaner within the scope of a policy trying to restrict carbon emissions.

Another reason for the increase in the trend towards nuclear energy is related to the concept of "energy security" or "energy independence". In European countries and Turkey, this concept is generally used in the context of reducing dependence on Russian natural gas. Concerns about dependence on natural gas imports have increased particularly in 2009, when Russia stopped supplying natural gas to Ukraine. Not only Europe, but countries such as Japan, India and China have also considered nuclear plants as an alternative to producing power from natural gas and thus envisaged a decrease in natural gas imports.

Another reason for the rise in interest in nuclear power plants specifically in the US is the modification and simplification of the licensing processes. For instance, the Nuclear Regulatory Commission (NRC) chose to approve power plant types. Hence, once the type (or design) of a power plant is approved, the same design may also be utilized in the construction of another power plant, thus eliminating the obligation to undergo a design review every single time.

As a result of these developments, in the 2000's, at least until the Fukushima power plant accident in Japan, many countries had stated that they would consider again the construction of nuclear power plants or revise their decisions to stop the construction of nuclear power plants. The US has taken one step further and provided some fiscal and financial assistance for the construction of nuclear power plants through a law adopted in 2005. The document entitled *An Energy Policy for Europe* published in 2007 in the European Union highlighted that nuclear energy is one of the cheapest sources of low carbon energy (European Commission, 2007, p. 16). In the document entitled *Energy 2020* published in 2010 (European Commission, 2010), it was underlined that the contribution of nuclear energy must be "assessed openly and objectively"[1]. In a UK government report in 2008

1- "..the contribution of nuclear energy …. must be assessed openly and objectively" (p. 5).

in, it was stated that nuclear energy is low-carbon, affordable, reliable and safe and it was highlighted that in case carbon prices reach levels expected by the government, nuclear power stations would become the cheapest mode to produce electricity (BERR 2008).

It is probable for a new change to occur in the approach towards nuclear power stations in the wake of Fukushima. In fact, it was declared that every single one of the 143 nuclear power plants located in the European Union would be subjected to a stress test as of June 1 2011, after Fukushima.[2] Thus, nuclear power stations will be assessed in 3 steps. First, nuclear power plant operators will reply to the questionnaires relating to the stress test and submit the relevant documents. In the second step, regulatory authorities will prepare a national report and assess whether these responses are convincing. A "peer review" will be carried out in the third step and national reports will be assessed by an international team consisting of a representative of the European Commission and six representatives of national regulatory authorities.[3] In the meantime, Germany declared on May 30, 2011 that it will close down all of its nuclear power plants.[4] On June 8, the Swiss parliament decided to phase out nuclear energy by the year 2034. In a referendum held on June 13, Italians voted against the construction of new nuclear power plants.

Electricity markets are undergoing a restructuring process at a global scale. The goal of this restructuring process is to open up the electricity industry to competition. The electricity industry in Turkey is undergoing a similar restructuring process. This study aims to analyze the economic characteristics and financial risks of nuclear power plants, investigate the position of these power plants in electricity markets and the ongoing restructuring processes, discuss the financing models and regulatory policies relating to nuclear power stations and thus evaluate the nuclear energy policies in Turkey and the Akkuyu project, specifically.

2- Press Release IP/11/640: "After Fukushima: EU Stress tests start on 1 June".

3- In a press statement issued on June 23, 2011, the representatives of the ministries of energy and national authorities responsible for nuclear energy of 7 neighboring countries of the European Union, including Turkey, declared that they would voluntarily participate in this stress test process. Therefore, Turkey also committed her participation in the stress tests. http://ec.europa.eu/energy/nuclear/safety/doc/20110623_stress_test_joint_declaration_eu_neighbouring_countries.pdf

4- Just one year ago, the German government had suspended a 110-year decision aiming to phase out nuclear power plants by 2022. "Nuclear? Nein Danke", the Economist, June 2, 2011.

2 Characteristics of Nuclear Electricity Production

The main economic characteristics of nuclear power plants and the risks they are facing will be taken up in this section. Some of these risks (such as the price risk) are also relevant for other power plants; however, the capital-intensive characteristic of nuclear power plants increases the sensitivity of power plants towards the price risk. While, some risks (such as changes to nuclear waste policies) are specific to nuclear power plants.

2.1 High Fixed Costs, Low Variable Costs

One of the most important characteristics of nuclear power plants is the fact that their fixed costs are very high, while their variable costs are relatively low. The following table prepared by Joskow and Parsons (2009) may be presented as an example:

Table 1: Cost Structure of Electricity Production

	Overnight Cost $/kW	Fuel Cost $/MMBtu
Nuclear	4,000	0.67
Coal (low)	2,300	1.60
Coal (medium)	2,300	2.60
Coal (high)	2,300	3.60
Gas (low)	850	4.00
Gas (medium)	850	7.00
Gas (high)	850	10.00

Source: Joskow and Parsons (2009)

This table demonstrates the construction cost of nuclear, coal and gas based electricity production as well as the fuel cost, which is one of the most important elements of variable costs.[5] As shown, the "overnight" construction cost of a nuclear power plant is nearly 2 times higher than that of coal and almost 4.5-5 times higher than that of a gas plant. The table compares the fuel cost with various coal and gas price scenarios. Even at lowest fuel price scenarios, the fuel

5- The data on the table have been obtained under certain assumptions. For instance, the cost of the capital will vary according to the financing model. The cost of capital of a power plant established under public property will be lower than that of a power plant constructed under a "commercial model" where the main risks are undertaken by the private sector. The figures on the table have been given on the assumption that the nuclear power plant based on a commercial model (Joskow and Parsons, 2009, p.53). The objective here is not to evaluate the figures as absolute but to draw attention on how fixed costs and variables costs differ in different fuel types Kumbaroğlu (2011) discusses comparatively in detail the costs of nuclear power plants.

cost of nuclear power plants amounts to almost 40 percent of coal and 15 percent of gas. According to another comparison (Finon and Roques, 2006), the share of construction cost within nuclear energy based electricity production is 65-80 percent, the share of the operational cost is 10-20 percent, while the share of the fuel cost is between 5-10 percent. These shares are respectively 20-30 percent, 5-10 percent and 60-80 percent in the production with combined cycle gas turbine.

Another characteristic of nuclear power plants is the fact that the minimum efficient scale is very high compared to gas plants in particular. While the efficient scale is considered to be at least 1,000 MW in nuclear power plants, this may be a few hundred MW in natural gas plants. This is a factor which increases the amount of minimum investment.

2.2 Uncertainty in the Construction Time and Costs

One of the major risks encountered in the construction of nuclear power plants is the uncertainty concerning construction costs. As shown in Table 2, the construction time of nuclear power plants constantly increased in 2000's. As a result of a very high share of fixed costs within the cost structure of nuclear power plants, the increase in the construction time also led to a significant rise in the construction costs.

Table 2: Construction Time of Nuclear Power Plants in Worldwide

Period of referace	Number of Reactors	Average construction time(months)
1965 - 70	48	60
1971 - 76	112	66
1977 - 82	109	80
1983 - 88	151	98
1995 - 2000	28	116
2001 - 05	18	82

Cited by: Kessides (2009)

Cost indicators relating to previous constructions may provide a major input in predicting the future. However, the fact that the number of new power plants constructed in the last 20-30 years is low renders forward-looking predictions severely uncertain. Likewise, predictions on the construction costs related to new power plant designs are also marred by significant uncertainties.

Under these circumstances, recent construction experiences in various countries may provide important hints regarding the costs. The overnight costs[6] of the power plants constructed in Korea and Japan between 2004 and 2006 are indicated to be relatively low (US$ 3,100 per kW on average).[7] Although recently there have been

6- The concept of overnight cost is based on the cost of capital to arise under the assumption that the power plant is constructed overnight and thus does not comprise the financial costs and the other costs arising during construction.

7- Cited by Davis (2011) from Du and Parsons (2009).

more efforts to construct nuclear power plants in Europe, experiences relating to these plants actually demonstrate the high degree of the uncertainty regarding construction costs. Davis (2011) gives the example of two nuclear power plants being constructed in France and Finland. The construction of the Olkiluoto nuclear power plant in Finland had been initiated in 2005; the plant was expected to be completed in 2009 at a cost of US$ 2,800 per kW. However, due to the emergence of issues and the delays which occurred, the completion date of the power plant was extended to 2013. The cost of this power plant is estimated to be twice higher than the initial prediction. One of the issues arising in this plant was the fact that the concrete foundation of the reactor building was regarded to be too permeable. The construction of the Flamanville power plant in France began in 2007 and it was planned to be completed in 2011 at a cost of US$ 2,900 per kW. The completion date of this power plant has been postponed to 2014 while the cost is expected to be 50 percent higher than the planned amount. Cracks were identified in the concrete foundation and it was concluded that steel supports were misplaced. In other words, the main reasons for the delays in both power plants were the issues arising in the safety inspections during the construction period. According to Davis, the project managers in both power plants were accused of using inexperienced contractors.

Another major issue mentioned in relation with construction costs (Davis, 2011 p. 11) is the significant decrease in the number of manufacturing companies producing the components of power plants compared to the 1970's. This leads to problems in the supply chain which may give rise to delays. Likewise, Joskow and Parsons (2009, p. 57) stated that the human equipment and manufacturing infrastructure required for the construction of new power plants decreased significantly in recent years and that an increase to occur in the request for nuclear power plants would face difficulties due to such type of infrastructural deficiencies.

The high level of fixed costs and minimum scale and the long construction periods render the cost of nuclear power plant investments very sensitive to the cost of capital and the discount rate. As the construction time extends and the cost of capital rises, financing costs constitute a very significant share of the overall construction cost. As shown in Table 3, if the cost of the capital is taken as 10 percent, the financing costs of a power plant to be completed in 5 years constitute 22 percent of the total construction costs, while this rate reaches 40 percent when the construction period increases to 10 years.

Table 3: Financing Costs as a Fraction of Total Construction Costs

	Construction Period		
	One Year	Five Years	Ten Years
5% Cost of Capital	2%	12%	22%
10% Cost of Capital	4%	22%	40%
15% Cost of Capital	6%	30%	54%

Source: Davis (2011)

The construction risk is traditionally undertaken by the electricity operators owning the project (Finon and Roques, 2008, p. 6). This solution does not appear to be very problematic in vertical integrated environments where there is no competition. There are recent debates on how this risk may be distributed more effectively between the actors. For instance, the construction of the power plant as a turn-key project will shift the risk considerably to the supplier.

2.3 Energy Policy and the Risks Generated by Regulatory Policies

The economic feasibility of nuclear power plants will be closely associated with the policies of governments. The fact that political or regulatory decisions may change over time increases risks associated with nuclear energy investments. Although such types of risks apply also for other electricity production technologies, they are higher in the field of nuclear energy characterized by extremely complicated processes and requiring a much closer monitoring and intervention of regulatory authorities especially in terms of security. For instance, each one of the areas of licensing, nuclear waste policy and financial responsibility in the event of accidents shall be subjected to regulatory interventions and decisions. Governments and regulatory authorities carry important functions regarding these issues in terms of reducing regulatory risks.

The taxation of carbon emissions will also affect the value of nuclear power plant investments. In case a carbon tax is introduced, the unit costs of the electricity produced by coal and gas plants will increase, in which case the electricity produced by nuclear power plants will become more competitive. For instance, Joskow and Parsons (2009, p.53) claim that in case a tax of US$ 50 is applied per ton on carbon dioxide gas, the average unit cost of the electricity produced by nuclear power plants will be lower than the cost of the electricity produced by coal plants and that it will be even cheaper than gas based electricity under some gas price scenarios.

Expectations regarding future policies have already begun to influence the behavior of investors. For instance, according to Davis (2011), one of the most important reasons for the re-emergence of the interest for nuclear energy in the US in 2007 and 2008 was the expectation that a ceiling limit would be applied on carbon emissions.[8] The fact that the envisaged law consequently got stuck at the Congress in 2009 was regarded as a major setback in terms of the future of nuclear power plants.

The safest way to minimize policy or regulatory risk is therefore to ensure policy predictability and apply available policy options in a consistent manner over time. Certainly, this requires a high management capacity.

8- Sixteen license applications were submitted for 24 power plants between 2007-2008 to the US Nuclear Regulatory Commission for the first time after an interval of nearly 30 years.

2.4 Operational Risks

Once the nuclear power plant is constructed, another risk factor is whether it will operate in a flawless manner at a high capacity. This risk will become even more important in new power plant designs lacking previous construction and operational experience. One way to reduce this risk in practice for the investor is to identify the capacity rates specified on the contract signed with the vendor as target or performance criteria. This option was selected in the abovementioned Olkiluata power plant and the nominal capacity factor was determined as 91 percent.

2.5 Market Risks

One major risk faced by nuclear power plants relates to the prices of fossil fuels. For instance, the marginal costs of electricity in many countries are determined by natural gas prices. A decrease in natural gas prices has a negative impact on the profitability of the nuclear power plants planning to sell electricity in wholesale markets. More generally, fluctuations in the wholesale electricity prices are among the major factors increasing the risk of nuclear power plants.

Certainly, the price risk affects all electricity production units, but more so for nuclear energy based electricity production due to its larger fixed investment requirements (Finon and Roques, 2008, p. 6).

There are a few ways to reduce the market risk. Among these are long-term sales contracts with large buyers. Large buyers and producers may be willing to protect each other against the price risk up to a certain degree. Certainly, in case wholesale prices are markedly reduced , buyers may have the tendency to waive these contracts, but long-term contracts may play a key role in sharing the risk. Making the buyers partners in the nuclear power plant and the sales of the electricity from the power plant to this consortium as a type of cost plus a reasonable profit formula, as in the example in Finland, may be another solution (this option will be discussed below in further detail). Another way to reduce the price risk is to achieve vertical integration especially between production and retail sales. Vertical integration leads to the internalization of the extreme fluctuations in wholesale prices within a vertical integrated structure.

2.6 Technological Risks

The fact that the economic life of nuclear power plants is long (forty years or longer) renders these power plants more vulnerable to technological risks. Sun or wind based electricity production may become more widespread within forty years as a result of technological developments. Technologies which effectively reduce carbon emission may emerge in electricity production.

2.7 Disposal of Nuclear Fuel and Decommissioning of Nuclear Power Plants[9]

One of the cost items specific to nuclear power plants is the issue of disposing of nuclear wastes. A final solution has not yet been found for these wastes and geological disposal (storing underground) is currently regarded to be the safest solution. Decommissioning the power plant is a long term activity and the decommissioning phase is believed to reach 10-20 percent of the total overnight cost. One of the most important issues in decommissioning is the availability of sufficient financial funds in the period when decommissioning is initiated. One of the methods pursued is the collection of the required financing in a fund during the period when the power plant is operational. According to the agreements made with governments or regulatory authorities, the collection of this fund may be under the responsibility of the relevant company or it may comprise a public contribution.

2.8 Nuclear Liabilities and Insurance

Nuclear power plants are subjected to a special international legal framework concerning the liabilities associated with the damage to arise in the event of an accident. Most of the countries availing of a nuclear program have signed the Paris or Vienna Convention concerning this topic. These Conventions call for the compensation of a part of the damages by the governments and the insurance of the remaining damages by the relevant company. The prices of such type of insurances are observed to be increased in recent years (OECD 2009). The need to insure has become one of the factors rendering nuclear power plant investments more difficult.

9- See Or, Saygın and Ülgen (2011) for details.

3 Alternative Models in Financing Nuclear Power Plants

There are very significant differences between the electricity markets in the 60's and 70's when nuclear power plants first emerged and the current market. Electricity markets were mostly dominated by public ownerships in the 60's and 70's, while vertical integrated monopolies of the private sector dominated in the US. In this model, the retail price of electricity was either directly determined by governments or regulated by regulatory authorities; consumers had no right or opportunity to select their own suppliers. The risks faced by nuclear power plants were either financed directly by the budget of the central government or reflected on the consumers via tariffs as in the "service cost regulation" (or the "rate of return regulation") model which prevailed at that time.

Yet, liberalization policies were introduced in the electricity industry in many countries in the 2000's, efforts were undertaken to establish competition in the phases of manufacturing and retail sales and the vertical integrated structure was fully abandoned in some countries. Vertical unbundling became one of the main goals in the electricity industry in the European Union and it became either limited or forbidden for companies operating in the transmission and distribution segments, where natural monopolistic characteristics prevailed, to be present in the production and retail sales segments that may be opened to competition. More importantly, wholesale prices of electricity were completely liberalized and efforts were made to terminate regulatory intervention in the retail sales tariffs concerning the development of competition. This meant that a major portion of the risks undertaken by the state or consumers in the old model would now be undertaken by various actors present in the market. Therefore, one of the topics mostly discussed in the 2000's when nuclear power plants regained popularity was how these risks would be distributed between different actors and states and whether nuclear power plants would be able to survive without financial support in the liberalized electricity markets.

In this section, the responses provided by various agencies and contract types to this question will be discussed. It would be appropriate to regard the models discussed below as different aspects of managing the risks and features of nuclear power plants and not as mutually exclusive models.

3.1 Traditional Model: Vertical Integrated Public Enterprises

The liberalization and privatization of the electricity industry was undertaken in many countries in the last 20-30 years. These reforms had a number of different objectives. The first objective was to open the industry to competition as much as possible so as to benefit from the expected efficiency increase. Secondly, they aimed to put an end to the inefficiencies believed to be caused by public ownership. Privatization was expected to terminate politicization on one hand while tightening budgetary restrictions[10] so as to enhance efficiency. Another goal of the reforms in the electricity industry was to reduce the role of the public sector in electricity investments, mobilize private sector resources for the investments and thus to relieve public budgets. Especially in emerging countries like Turkey, this "public finance" goal is believed to play a major role in the reforms.

On the other hand, it is also acknowledged that the vertical integrated model provides some benefits in financing nuclear investments. Such types of companies usually avail of their own customer pool. The presence of customers who do not have other procurement opportunities at the retail level facilitates the financing of investments requiring a large capital.

A recent prominent example within this framework is the Flamanville 3 nuclear power plant project in France. It is observed that the said project is part of a long term "relearning" strategy (Finon and Roques, 2008, p. 18). The overall objective of the project is to renew the power plants constructed in the 1970's and 1980's. This reactor was provided by AREVA in this project, but the owner of the project is the French electricity company EDF (*Electricite de France)*[11] and the engineering and construction services will be fulfilled by this company. Thus, the construction risk will also be undertaken by EDF. According to Finon and Roques, the fact that the service fee for the engineering and construction will be paid as "cost plus" reduces the conflict of interests between the company and the regulatory authority responsible for safety and security issues; as the cost will be covered anyhow, the company will not refrain from additional spending for eliminating safety and security related concerns of the authority.[12]

Clearly, the main issue in this model is that it is contrary to the competitive model that many countries have tried to adopt in the last 20-30 years. Many countries aim to liberalize retail sales. Legally, the rate of opening to the market is 100 percent even in France. However, France is one of the countries where the supplier replacement rate of customers is very low; in other words, competition is not very effective at the retail level. France is also one of the countries where the

10- It is accepted in literature that one of the major issues arising from public property is the "soft budget constraints". This refers to non-rigid budget constraints, where the losses of companies operating inefficiently and for instance companies which are incurring a loss are covered by the public sector and where, in a way, bad performance is not penalized and/or is awarded.

11- The share of the state in EDF is 85 percent since 2008.

12- As discussed below, a very different approach has been adopted for the Akkuyu power plant.

concentration level is very high in the wholesale markets (European Commission 2010).

The distinguishing feature of this model in terms of risk distribution is its competitive dimension. The relation between a vertical integrated private company subjected to a cost plus regulation and the government or the regulatory authority may demonstrate similar characteristic in terms of risk distribution.

3.2 Purchase Guarantees

The potential role of purchase agreements with consumers or intermediaries (wholesalers, retailers) has been mentioned above. Another method frequently brought up not only within the context of nuclear power plants, but also in energy investments in general is the purchase guarantee provided by the state. This method was partially applied specifically in the Akkuyu power plant.

As discussed above, it is clear that purchase guarantees reduce the price risk of producers. Turkey's experience in this area provides an idea about the issues that may arise. Build & Operate (BO) and Build, Operate and Transfer (BOT) models were implemented in the energy industry in 1990's. A guarantee for purchasing electricity with a pre-determined tariff, which is generally fixed or varies according to a predetermined formula, is provided for in such type of contracts. This model proved to be problematic for two main reasons. First, the guarantees conflict with the logic of the competition based electricity market. Usually, in cases where there is a low possibility of decrease in demand, the possibility for BO and BOT power plants to sell electricity without having to compete may result in the exclusion of more efficient power plants. It should be underlined that such type of a risk of ex-post efficiency loss is present in any type of long term contract; an ex-ante reasonable contract may not be ex-post efficient due to environmental risks. Therefore, this would not be a very justified criticism by itself. However, the issue here was that as a major part of the demand in a young and developing market was foreclosed in this manner, raising the risk for the investments of independent private sector entrepreneurs getting ready to enter the market.

Another problem related to the almost total lack of transparency in awarding these contracts. There was no public tendering. It has also been claimed that these contracts were not well monitored and irregularities emerged during practice. Some of these claims have found their way in the reports of the Court of Accounts (Atiyas, 2006, pp. 80-81).

3.3 Commercial Financing and Debt Guarantees

Some supports were provided to nuclear energy investments with the new energy law adopted in the US in 2005. One of these supports targeted the electricity companies ordering the first 6GWe investment (prior to the determined dates) and comprised a debt guarantee to be offered up to 80 percent of the investments. In case the electricity company could not pay its debts, the creditors would receive their payment from the state through this guarantee. The aim of the guarantee is to reduce the learning costs and risks related to the first 6 GWe investment. The law also includes a production tax credit of US$18/KWh for 8 years.

One of the projects using this model is the Southern Texas Project. Purchasing contracts have also been signed with municipalities in this project so as to minimize the price risk (Roques and Finon, 2008).

3.4 Large Consortium of Buyers

This model was brought to the agenda especially with the Olkiluoto III nuclear power plant, whose construction is ongoing in Finland.[12] Sixty percent of the electricity company TVO, which is the operator of this power plant, is owned by PVO, a cooperative of pulp and paper manufacturer. The rest of the company belongs to the main electricity company Fortum (25%), the distribution company EPVO (6.6%) and the city of Helsinki (8.1%). The project has been based on two contract bundles. The first bundle is composed of the long term (60-year) fixed price purchasing contracts signed with paper and pulp manufacturers. Thus, the power plant will sell the electricity produced at the production cost to its paper manufacturing partners. Hence, the buyer and the seller will be completely isolated from the market prices. Certainly, this does not imply that the collective integrity is totally cleared from the price risk, because in case market prices drop below the contract price, this means that paper manufacturers are incurring a loss in terms of ex-post and opportunity cost. The second contract bundle is composed of the turn-key contract signed with the reactor seller AREVA. Hence, the construction risk is shifted to the supplier AREVA. The operational risk is transferred to AREVA with a capacity factor commitment of 91 percent. The project could obtain a loan at a very low interest rate through these contracts. The average weighted cost of capital of the project was indicated as 5 percent, which is a considerably low rate.

Is it possible for this model to be imitated in other countries and environments? Certainly, the key point of the model is the presence of buyers who are willing to sign a long term electricity contract. Furthermore, these buyers have become partners in the property of the power plant. Maybe, it is not impossible to find such buyers in other liberalized markets, but it is more probable that most of the consumers will not prefer to commit themselves for a long term. Still, it may be stated that the consortium or cooperative model is applicable under certain conditions.

On the other hand, the fact that a suitable financing model is found does not imply that the project will be successful. In fact, as indicated above, serious obstacles were encountered in the construction of the Olkiluoto power plant. These issues have demonstrated that the project management capacity or skills are equally important in the construction of a nuclear power plant.

13- See Finon and Roques (2008) and Roques v.d. (2006) for details.

4 Nuclear energy in Turkey

4.1 Brief History

Efforts for building nuclear power plants have a history of 30-40 years in Turkey, but the current legal framework was established upon the adoption of Law No. 5710 on Construction and Operation of Nuclear Power Plants and Energy Sale in 2007. This law is based on the principle of tenders in the construction of power plants. Arrangements regarding tender procedures and incentives were issued in 2008 (Şirin 2010). According to the referred law, the company winning the tender will sign an energy purchasing contract with TETAŞ (Electricity Trading and Contracting Co. Inc.). The term of the contract will be 15 years and it will comprise power plants that will be activated latest by 2020. A National Radioactive Waste Fund and a Decommissioning Fund (DF) will be established for waste management and decommissioning of the power plant and the company will provide a contribution of US$ 0.15 cents/kWh to each of these funds. The cost of decommissioning is expected to be covered by the DF. In case DF sources are insufficient for these procedures, up to 25 percent of the sources collected at the DF will be covered by the Treasury and by the company in case this also proves to be insufficient.

The tender for the power plant was launched in September 2008. Only one group participated in the tender. The offer made by the bidding group proved to be high with US$ 21.16 cents/kWh. The bidding company then lowered this price to 15 cents/kWh. However, while the offer was evaluated, the Council of State decided to suspend the execution of some articles in the relevant regulation and the tender was consequently annulled.

As no result was obtained from the tender process, negotiations were initiated with Russia as a result of which an intergovernmental agreement was signed. A Russian company, namely Rosatom was entrusted with the construction and operation of a nuclear power plant in Mersin Akkuyu.

4.2 The Akkuyu Model

The intergovernmental agreement on the construction and operation of the Akkuyu Power Plant was published in the Official Gazette dated October 6, 2010. The agreement signed between the Turkish Government and the Government of the Russian Federation envisages the cooperation between the two parties in areas such as the design of the power plant, its construction, operation, the purchase and sale of the electricity produced by the power plant, nuclear fuel supply, dismantling of the power plant and the nuclear fuel cycle. The main provisions of the agreement are as follows:

- The power plant will be operated by a project company to be established by the Russian party. The referred project company, namely Akkuyu Nükleer Güç Santrali Elektrik Üretim A.Ş. has been established in 2011. According to the agreement, the share of the Russian party in the project company will not be less than 51 percent. The distribution of the remaining shares of the company and the "topics relating to company management" will be subjected to the consent of the Turkish party. In case the project company fails, the Russian party will assume all relevant responsibilities for appointing its successor that will fulfill its liabilities to arise from the agreement.

- The Akkuyu power plant is planned to be composed of 4 units with equal capacity. According to the agreement, the first unit is to be activated within 7 years following all approvals and permits required for the construction. The remaining units will be activated with an interval of one year between each unit. The responsibilities of the parties to arise in case the units are activated earlier or later have not been specified in the agreement; it is only stated in the agreement that these liabilities will be determined in the Electricity Purchasing Agreement. Therefore, the settlement of the risk relating to the construction time, which occupies a key place financially among abovementioned risks, has been specified in the relevant law. The general contractor has been identified as the company Atomstroyexport.
- An Electricity Sales Agreement (ESA) will be signed between the project company and TETAŞ. With this agreement, TETAŞ guarantees to purchase 70 percent of the electricity planned to be produced in Units 1 and 2, and 30 percent of the electricity planned to be produced in Units 3 and 4 for 15 years once each unit becomes operational. The project company will sell the remaining electricity to the electricity market directly itself or via the retail energy suppliers. The average weighted price of the purchase to be made by TETAŞ will be US$ 12.35 cents/kWh, excluding VAT. The annual differences will make it possible for the project to be reimbursed and shall be calculated in a manner so as to not surpass the upper limit of US$ 15.33 cents/kWh.
- In the agreement the unit price was indicated to be calculated on the basis of the following principles: All capital expenditures required for four units to be operating commercially will be reimbursed within 15 years after the date the units become operational. In contrast, all operational costs will be financed "on the basis of realization" once the units are activated. With regard to the activation of the units, the investments made directly or indirectly by investors into the project company will be paid back within 15 years on the basis of equal amortization method. No change will be requested in the unit price throughout the ESA period. Changes in the cost to arise as a result of the amendments in the Turkish legislation will be reflected to TETAŞ at the rate corresponding to the amount of electricity purchased by TETAŞ. Besides for legislative amendments, the agreement is not very clear on the conditions at which the unit price may be changed.

Currently, the responsibility of the company is not limited in the event of an accident. The responsibility of insuring the risks comprising the investment and operation periods of the project belongs to the Project Company according to the agreement. However, the amount and details of this insurance have not been specified in the agreement.

According to the agreement, the project company is responsible for nuclear waste management and the decommissioning of the power station. As envisaged in the relevant law, the company will contribute with US$ 0.15 cents/kWh to the two separate funds established for financing each of these activities.

4.3 Evaluation of the Akkuyu Model

When considered in terms of risk sharing, the Akkuyu model is akin to an extreme "commercial power plant" model, in such a way that a very significant part of the financial risks listed in the previous sections remain the responsibility of the project company. However, the electricity company undertaking these risks related to the construction and operation of the power plant is not a real private company; it is a public company owned by the Russian state. Therefore, in case the project revenues fail to cover the project cost and the need for additional financing emerges, mutual understanding calls for the coverage of this financing by the budget of the Russian state as a last resort.[14] In a way, a very simple solution has been apparently found in the Akkuyu project for the question of sharing a very challenging risk which was tried to be settled with very difficult and complicated corporate mechanisms in other countries and environments: this solution calls for the shift of all risks to the company and thus to the Russian state.[15]

Certainly, there are some risks undertaken by the Turkish state. According to the relevant law, if the decommissioning costs result to be higher than the savings in the Decommissioning Fund, the Treasury commits to contribute up to 25 percent of the amount accumulated in the fund. In case the market price of electricity falls below US$ 12.35 cents/kWh throughout 15 years when the purchasing contract will be applicable, TETAŞ will be purchasing electricity at an expensive price, which constitutes a cost element in terms of opportunity cost. However, as discussed below, the purchasing price determined in the agreement appears to be reasonable in general. In case of delays in the activation of the units, this may also give rise to a cost in terms of lack of a sufficient capacity in the market. As the prices will probably increase in this case, the burden of the delay in the activation of a unit will probably fall on the consumers. More importantly, in case of an accident, its cost will mostly fall on the public and the state.

In cases where a major part of the financial risks falls on the project company, the average cost[16] is expected to be considerably high. When we consider the fact that nearly half of the electricity will be purchased by TETAŞ within the first 15 years, we may draw the conclusion that the purchasing contract will have a significant share in the project revenues; therefore, the purchasing price in the purchasing contract may be expected to be high so as to cover these risks. Yet, the fixed price specified in the purchasing contract does not appear to be extremely high.[17] So, it must have been determined under the assumption that either the project price will be considerably higher than the wholesale prices in the liberalized electricity market or will be supported by the budget of the Russian government in one way or another. The general opinion is inclined towards the second option; which is to say that there is a wide belief that this project is in a way "political" in nature and has been directed and supported by the Russian government.

14- In the meeting held with the authorities of the Project Company this association between the financial risks of the company and the Russian budget was emphasized.

15- As highlighted by Or, Saygın and Ülgen in this compilation, the fact that the reactor model selected for Akkuyu was not constructed before gives rise to the consequence that both financial and safety and security risks will be higher.

16- The concept of average cost is used in the sense of "levelized cost", which is the unit price required to be achieved by the electricity to be sold throughout the duration of the project so as to be at par.

17- See Kumbaroğlu in this compilation for further analysis.

The assessment of the possible economic and societal consequences of the project, and more concretely of the behavioral motives of the project company throughout the implementation of the project, leads to the question whether this project is a "commercial" project or a project in which political characteristics mostly prevail; because, these two different assumptions imply different behavioral patterns.

The assumption that the project company will act on the basis of commercial motives depicts the following picture: a commercial company takes steps for establishing a nuclear power plant upon undertaking a substantial financial risk. Nearly half of the electricity produced will be sold to the public sector at a fixed price for a specified period of time (15 years for each unit). This price will not be affected by the costs incurred or the investments. The remaining part of the electricity will be utilized according to a competitive price mechanism. This is like a partial fixed price contract. The response to be provided to one of the key questions under this type of a contract in terms of public benefit is positive: the fixed price is a reasonable price and it is not too high. The key characteristic of the fixed price contract and the price mechanism is that they both encourage the reduction of the company costs to the lowest level, because when the price is fixed every cost decrease will increase profits. Certainly, this has very positive aspects. For instance, the project company will strive to avoid delays in the construction phase. The project management will display every effort for the timely operation of the supply chain. However, there are highly negative aspects associated with a strong incentive for making profit. Many of the cost elements in nuclear power plant projects are related to safety and security measures. One of the strongest negative consequences of a strong incentive to reduce costs is the potential to place a low importance on safety and security issues.[18]

The most important incentive mechanism in the market mechanism is when companies act on the basis of a incentive to make profit. When companies act on the basis of a motive to make profit in cases where the markets are operating effectively, this gives rise to desirable consequences for society; this prediction is one of the key elements rendering the market mechanism attractive. An important assumption underlies behind this prediction: that all the results of the activities of the companies are internalized, and, that, in other words, there is no externality. This is not the case for nuclear power plants. The damage to be caused by the power plant on the environment in case of any failure or accident will be much higher than the loss of the company itself especially when the financial responsibility of companies is restricted. Its own loss is composed of the investment costs and the profits waived. However, the damage on the society is much higher. Therefore, companies may not be expected to display a behavior which fully safeguards social welfare in the construction and operation stage. It is for this reason that there is an absolute need for a regulatory and supervisory authority for the adoption of safety and security measures.

So, in this case, isn't there any other factor which reduces the potential tension between the interests of companies and social welfare and which is also inherent in the market mechanism? A potential element is underlined in theory: the importance placed in future contracts by the company and the motive to enhance its market value.[19] Consequently, one of the long term goals of Rosatom is to sell

18- The argument that a strong incentive to reduce costs may not always lead to positive results in terms of public welfare has been a matter of debate in literature. See Hart et al. (1997).

19- This is referred to as "reputation effect" in literature.

such type of power plants to other countries in the future; this is required by the long term profit maximization of the company. It may also be claimed that this incentive will push the company to place due importance to safety issues. However, it is unclear whether this rationale will be sufficient to fully internalize abovementioned externalities. Although the economic life of nuclear power plants is very long, it would not be realistic to expect the current management of the company to last for such a long term.[20]

So, the outcome of the Akkuyu model under the assumption that the project company will act on the basis of commercial incentives shall be closely linked to the effectiveness of the enforcement of safety regulations. In other words, the safety and security risk and the financial and related regulation very closely associated in Turkey. Yet, the regulatory and enforcement environment in Turkey displays significant weaknesses (Or, Saygın, Ülgen 2011). First of all, the legal framework regarding regulations and enforcement is incomplete: The current internationally accepted institutional model calls for the oversight by an autonomous administrative authority that will operate independently from the government and the companies to be inspected and will not be influenced by them. There is no such authority yet in Turkey. Moreover, proper regulatory oversight and enforcement also requires significant human resources. There are severe deficits in Turkey also in this respect (*ibid*). The aggregation of risks on the project company reinforces incentives for cost reduction. But when coupled with the fact that Turkey's oversight and enforcement capacity is limited, this appears to be a combination giving rise to significant liabilities in terms of safety and security of nuclear power.

Another assumption to be made regarding the project company may be that its behavior is shaped also according to (or mainly due to) the political priorities of the Russian state, in addition the commercial motives.[21] The fact that political motives play a role may have shaped the project to Turkey's advantage at least in the short term. Consequently, Turkey plans to make a substantial addition to its electricity production capacity while assuming relatively low risks and committing a partial purchasing guarantee which is not expensive in light of the risks assumed by the project company. However, the presence of political motives should be regarded as a significant additional risk in the medium and long term. It is at least conceptually possible to estimate the type of choices to be made by a player acting based on commercial incentives in different environments and to adopt suitable regulatory measures in cases where these choices are not aligned with the maximization of social welfare. In cases where political motives are present or prevail, it may not be possible to be similarly in command of the dynamics of the game. No problems will arise where political developments are "normal". However, in cases where political tensions arise, even if the chances are low, the dynamics of this game and its consequences will comprise severe uncertainties that may not be coped with

20- In fact, the recent global financial crisis has shown that his type of reputation effects do not generate a strong discipline effect in the long term.

21- It is frequently discussed in the literature that Russia steers commercial agreements on the basis of political priorities. For instance, see Pirani et al. (2010) at political content of the agreement signed between Ukraine and Russia in 2010, comprising a significant discount in the procurement of gas from Gazprom Pirani et al. (2010).

ordinary regulatory measures. We cannot claim that there is any established know-how on the types of measures to be adopted against these uncertainties.[22]

In that case, will the fact that political motives are important help to restrain the extreme incentive to reduce costs? Such a conclusion may be drawn at first glance: political motives reduce the incentive for profit maximization and therefore the incentive to reduce costs to a minimum level which may bridle the tendency to save on security measures. However, whether this effect will arise or not or to what degree it will arise depends on the relationship of interests between the government and the company and the nature of the conflict therein. Usually, this relation is expected to comprise a significant information asymmetry. For instance, will the loss of the project company be covered by the budget as expected, when the costs increase? Will the company's statements about costs be regarded as realistic by the government? The answers to these questions are not known, but if they are not positive, at least part of what has been mentioned above with regard to the motive of the company to reduce costs will apply also in case political motives prevail.

4.4 The Electricity Market model and Nuclear Power Plants in Turkey

The Turkish electricity market is undergoing a restructuring process. The goal of this restructuring process is a rather decentralized market model where the intervention of the state is limited and the state does not assume a large role especially with regard to investments and risks. What may be the place of nuclear power plants in this model?

Although the discussion on whether purely commercial[23] nuclear power plants may survive in competitive markets is not yet fully finalized, academic research reveals that these power plants are not competitive when current carbon and alternative fuel prices are taken as basis.[24] The type of policies that may be effective in order to make these power plants economically viable is another matter of debate.

Within this framework, the potential impact of the type of partial electricity purchase guarantees foreseen also for the Akkuyu power plant should be

22- The situation may be even more complicated than what is described above for Akkuyu. Rosatom may have undertaken such a project which is political in nature because of the obligation of the government and not through its own will. So, in this case, there is a potential conflict of interests between Rosatom and the Russian government. The implication of this conflict of interests on the application of the project is another question where the answer is not very clear. In the meantime, it is highlighted in the literature that the financial relations between Rosatom and the government are not very clear and transparent also within the context of the nuclear investments within Russia itself. See Andreev (2011).

23- Here, the term "purely commercial" refers to not availing of any financial support, "being on its feet financially", "trying to distribute the risk carried within different financial models in the market mechanism".

24- For instance, Roques et al. (2006), Joskow and Parsons (2009), Thomas (2010).

addressed. Certainly, the presence of purchasing guarantees excludes the generation activities of nuclear power plants from the full competition framework. Nuclear power generation is expected to reach 5 percent of the total established power generation capacity by the year 2023 (Energy Market Regulatory Authority EPDK, 2010, p. 17). With such a share, it is unlikely for purchasing contracts to have a disruptive effect on the competition in the market. Moreover it is possible to conceive a well-designed support mechanism for nuclear power without hindering market based competition.

The real issue regarding nuclear energy is the absence of a long term policy in Turkey, debated among stakeholders and on which a consensus is reached. As indicated by Şirin (2010), who addresses this severe deficiency, there are serious deficits within the legal framework with regard to insurance, fuel cycle and decommissioning. The shortcomings related to the legal and human infrastructure for ensuring the safety and security oversight constitutes even a larger problem. Finally, the choice of nuclear energy has not become a policy path approved by the public or owned by the public. Currently, nuclear energy policy is managed with 2-3 public agencies, without public participation. The fact that the Energy Ministry has not made available a policy paper on nuclear energy is one the best indicators showing how unprepared Turkey is.[25] As stated above, this overall lack of preparedness and the significant deficiencies in the oversight and enforcement capacity, as well as the presence of a financing model mechanism where almost all of the risks are transferred onto the project company does not appear to constitute an optimum regulatory mechanism. Various models are discussed worldwide on how a more optimum risk distribution may be achieved; however such a discussion has not yet been started in Turkey.

5 Conclusion

When evaluated only on the basis of financial parameters, the Akkuyu project appears to be an advantageous project for Turkey. However, considering the behavioral patterns incentivized by these parameters and the inadequacy of the oversight and enforcement capacity in Turkey, it should be stated that a nuclear project, where all risks are undertaken by the project company, will in all likelihood have safety and security deficits. The main issue here is not financial, but the absence of a legal and human infrastructure required for the proper oversight and enforcement in the short term and the absence of nuclear energy policy in Turkey based on social consensus in the medium and long term.

25- For comparison, see: "A White Paper on Nuclear Power" (BERR 2008) issued by the UK government, the pages related to energy on the web site of the Finnish Ministry for Employment and Economy (http://www.tem.fi/index.phtml?l=en&s=183) or the web site of the Office of Nuclear Energy of the US Department of Energy (http://www.ne.doe.gov/).

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Section V

The Security Dimension of Turkey's Nuclear Program: Nuclear Diplomacy and Non Proliferation Policies

V

Sinan Ülgen

Executive Summary

History has shown that many Middle Eastern states have, at one point or another, attempted to acquire missile and other technologies associated with weapons of mass destruction (WMD). Added to these threats are the ones posed by non-state actors like al Qaeda and the Kurdistan Workers Party (PKK). Having faced the threat of terrorism for much of its history, Turkey is no stranger to the dangers posed by non-state actors and has worked diligently with its international partners to combat terrorism, as well as prevent the spread of WMD technologies to non-state actors and rogue regimes. In recent years, these efforts have coincided with Turkey's renewed efforts to acquire nuclear energy as a means to reduce its dependence on foreign energy suppliers and contribute to the global movement to decrease carbon emissions. Since then, officials in Ankara have worked hard to strike a balance between stringent nonproliferation policy with the indigenous right of all non-nuclear states to access peaceful nuclear technology.

Warming relations with Iran and the subsequent no vote at the United Nations Security Council (UNSC) has intensified global scrutiny of Turkish nonproliferation and nuclear policies. Despite the increased attention Turkey's policy positions vis-à-vis the Iranian nuclear program, tactical nuclear weapons, and missile defenses are still not widely understood by the global community, prompting pundits and analysts to misinterpret Turkish nonproliferation policy. This has even led some to openly speculate about Turkey's own nuclear intentions and whether or not Ankara may be tempted to pursue its own nuclear weapons program.

Turkey has a long history of supporting international policies designed to stop proliferation. During the Cold War, these efforts were part of a larger NATO effort to maintain strategic stability and military parity with its Warsaw Pact adversaries. Since the advent of the nonproliferation regime, Ankara has adopted strong nonproliferation policies due in large part to its NATO membership, location at the apex of the Middle East and its front-line state status during the Cold War. Turkey is firmly against the proliferation of WMD, favors the establishment of regional nuclear weapons free zone, and advocates for the eventual disarmament by nuclear weapons states. Turkey is a signatory of the NPT, the Chemical Weapons Convention (CWC), and the Biological Weapons Convention (BWC) – the three most comprehensive Treaties governing the spread of WMD.

Turkey's nuclear diplomacy is influenced strongly by the fact that it is a non-nuclear weapons state seeking to develop an indigenous nuclear energy program. Ankara has positioned itself as a champion of nonproliferation, while maintaining a strict interpretation of Article IV of the NPT. Article IV grants every signatory the right to pursue peaceful nuclear activities and obligates the nuclear supplier countries to facilitate in the exchange of nuclear technology and material. In recent years, the Turkish interpretation of Article IV has been the source of friction between Turkey and some of its Western allies, especially when it comes to

international efforts to limit nuclear aspirant countries from accessing enrichment and reprocessing technologies. Officials view these efforts as a threat to its own nuclear ambitions, and have challenged proposals designed to make it harder for a state to access nuclear technologies.

As part of its NATO commitment Turkey has hosted American nuclear weapons for nearly six decades. The weapons are deployed as part of NATO's collective security posture and, during the Cold War, were meant to deter a Warsaw Pact invasion. After the collapse of the Soviet Union, the weapons' strategic value waned, raising questions about their military value and whether or not the forward deployment of tactical nuclear weapons (TNW) enhances NATO security or not. While planning for the 2010 NATO summit in Lisbon, the Allies fiercely debated the status and practicality of the American TNWs in Belgium, Germany, Italy, the Netherlands, and Turkey. Many within the alliance advocated for their removal, while others opposed, saying they should remain until the nuclear threat to NATO is removed. Turkey quietly supports maintaining the weapons on its territory and expects other NATO countries to continue their TNW stewardship as part of the Alliance's burden sharing principle.

The Turkish position on TNWs is also shaped by the non-politicization of this issue. Despite being at the forefront of the Cuban missile crisis in 1962 as host to the Jupiter missiles, the question of nuclear weapons has not exactly been the subject of an internal debate in Turkey. Much unlike the Western European countries, there is no visible anti nuclear political force in the country. The Green movement is politically weak, almost to the extent of being non-existent. Remaining political parties have clearly prioritized the national security angle of the debate and have not developed an anti nuclear platform. Also from an economic standpoint, unlike the UK and Germany, Turkey does not face an imminent decision on the future of its Dual Capable Aircraft (DCA). The F-16s that are at the disposal of the Turkish Air Force do not have to be renewed until the mid 2030s. There is therefore no economic pressure that forces a decision on the Turkish policy makers.

During the 2010 NATO summit in Lisbon, the twenty-eight allies fiercely debated whether to adopt BMD as an alliance wide mission. The Obama administration was seeking to integrate the United States BMD system with that of its European allies to better defend against Iranian ballistic missiles. The Turkish position was the source of great consternation and misunderstanding during the debate. Turkey maintained that BMD should not worsen it relationship with neighboring countries, that the system should cover all Turkish territory, and that BMD components on Turkish territory should be operated by the Turkish military.

An agreement was reached only after the allies agreed not to name Iran and Syria as specific threats, and to put off any decisions about who will operate the system, in accordance with Turkish demands. Turkey also agreed to host the early warning radar in its territory.

Turkey's reluctance to name Iran and Syria as specific threats was grossly misunderstood by the international press and the other NATO allies. Ankara worried that specifically naming Iran, as a threat to the Alliance, would prompt hardliners in Tehran to accelerate their missile and nuclear programs to defeat the system. In general, BMD as a concept is controversial because a robust system, if it were technically effective, has the potential to upset strategic stability. Opponents of the system argue that it may encourage the BMD target state to develop systems to overwhelm and defeat even the most advanced BMD system. iv

In light of these facts, the Turkish delegation chose to tread carefully and limit any bellicose rhetoric that could encourage the Iranians to accelerate their missile and WMD programs. Turkey adopted a capabilities approach and called on its NATO partners to consider all states with ballistic missile capabilities when deploying the system. In addition, officials believe the system should be defensive and not single out any country as a target. Turkey believes naming threats would only hasten the desire to develop the counter measures to defeat BMD.

History has shown that states willing to commit resources and time can overcome the technical obstacles and successfully develop first generation nuclear weapons. However, most nuclear-capable states have chosen to remain non-nuclear. The decision to pursue nuclear weapons is rooted in technical capability combined with decision maker intent. At the moment, policy makers worry that an Iranian nuclear weapon will force its neighbors to explore the nuclear option. The oft-repeated argument claims that an Iranian nuclear weapon will lead to a regional arms race. Turkey, along with Egypt and Saudi Arabia, are the countries most often cited as the countries most likely to develop indigenous nuclear capabilities to counter Iran.

A Turkish decision to proliferate would seriously complicate its international standing, undermine its economic resurgence and seriously damage relations with the United States and its other NATO allies. Moreover, any Turkish move towards weaponization would draw a harsh rebuke from the United States and would likely be met by an American proposal to strengthen security guarantees, as well as the threat of sanctions if Turkey were to continue its weapons efforts. Given Turkey's non-nuclear history and its long-standing reliance on the NATO security guarantee, it is hard to imagine a scenario where Turkey would simply cast aside its long-standing non-nuclear policy in favor of an independent weapons capability.

As a whole, Turkish actions and statement suggest that Ankara will remain committed to the NATO security guarantee, while developing indigenous capabilities to increase its intelligence, surveillance and information management capabilities. The presence of NATO nuclear weapons in Turkey, as well as Turkey's membership in the Alliance underpins its long-term defense strategy. Abandoning the Alliance or undertaking an illicit nuclear program would seriously derail defense planning and undermine Turkish security. A far more likely response to an Iranian nuclear weapon would be a re-evaluation of the battle readiness of the B-61s at Incirlik air base, as well as the acquisition and training of nuclear capable front line fighters. Together, these two moves would reinforce the underlying principle of deterrence, which stipulates that a credible deterrent rests on the willingness and ability to use nuclear weapons. Turkey would also be likely to speed up the deployment and development of BMD. More broadly, Ankara will be pushed closer to the United States and would likely join American efforts to contain Iran.

Turkey's non alignment with its traditional partners in the West on a number of issues related to nuclear and non proliferation policy should not however be taken as an indication that the Turkish policy elites harbor designs of developing a nuclear weapons program. The level of democratic maturity reached in Turkey and the long standing anchoring of Ankara within the Western precludes such an outcome. Turkish policy makers take offense in such unfounded and simplistic allegations. From the foreign policy as well, the development of concealed nuclear weapons program is devoid of a rational. Turkey's goal is to enhance its position as a pivotal and central state based on an extension of its soft and smart power. This vision is surely incompatible with becoming the next rogue state of the region, which would be a sure recipe for losing elections in democratic societies. Even in a scenario where Iran would end up acquiring nuclear weapons despite all the efforts of the international community, the Turkish reaction would be to fully take part in the emerging strategy for containing Tehran.

1 Introduction: Changing Threat Perceptions

Since the end of the Cold War states have begun dedicating more resources to combating asymmetric threats like terrorism and the proliferation of weapons of mass destruction. The intense focus on terrorism naturally gave way to discussions about potential scenarios involving non-states actors using weapons of weapons of mass destruction, especially after the devastating attacks on 11 September. These heightened fears overlapped with the discoveries about Iraq's clandestine nuclear program in the late 1980s and early 1990s, the arrest and subsequent revelations about A.Q. Khan's extensive illicit proliferation network and the current controversy surrounding North Korea and Iran's nuclear programs. The latter two issues have pushed the Middle East, a region with a long history proliferation, to the forefront of the global nonproliferation agenda.

History has shown that many Middle Eastern states have, at one point or another, attempted to acquire missile and other technologies associated with weapons of mass destruction (WMD). Added to these threats are the ones posed by non-state actors like al Qaeda and the Kurdistan Workers Party (PKK). Having faced the threat of terrorism for much of its history, Turkey is no stranger to the dangers posed by non-state actors and has worked diligently with its international partners to combat terrorism, as well as prevent the spread of WMD technologies to non-state actors and rogue regimes. In recent years, these efforts have coincided with Turkey's renewed efforts to acquire nuclear energy as a means to reduce its dependence on foreign energy suppliers and contribute to the global movement to decrease carbon emissions. Since then, officials in Ankara have worked hard to strike a balance between stringent nonproliferation policy with the indigenous right of all non-nuclear states to access peaceful nuclear technology.

Domestically, the global focus on non-state actors and the spread of WMD has largely coincided with the election of the Adalet Kalkinma Partisi (AK Party) and the introduction of its new "zero problems with neighbors" foreign policy. Warming relations with Iran and the subsequent no vote at the United Nations Security Council (UNSC) has intensified global scrutiny of Turkish nonproliferation and nuclear policies. Despite the increased attention Turkey's policy positions vis-à-vis the Iranian nuclear program, tactical nuclear weapons, and missile defenses are still not widely understood by the global community, prompting pundits and analysts to misinterpret Turkish nonproliferation policy. This has even led some to openly speculate about Turkey's own nuclear intentions and whether or not Ankara may be tempted to pursue its own nuclear weapons program.

This paper is intended to alleviate many of these understandings by examining Turkey's nonproliferation policies, Turkey's stance on the Iranian nuclear issue, NATO tactical nuclear weapons, and the nuclear deterrence in general. The paper will conclude with a discussion about Turkey's nuclear future and whether or not Ankara is prone to pursue nuclear policies independent of its traditional Western allies.

2 Nuclear Governance

2.1 The Evolution of the Nonproliferation Regime

Efforts to control the spread of nuclear weapons and technology began in the mid-1950s and gained steam after the Cuban Missile Crisis and American President John F. Kennedy's warning in 1963 that twenty-one states might develop nuclear weapons within ten years. In the early days of the Cold War, arms control was one of the few areas where the interests of the United States and USSR converged. Beginning in the 1950s, the two rival superpowers began negotiating a number of agreements to combat proliferation. From the outset, the negotiations were driven by the desire to maintain strategic stability by preventing the proliferation of nuclear weapons to other states.

Instruments governing the spread of WMD can be broken down into three different categories:

1) Arms Control,

2) Nonproliferation,

3) Counter proliferation.

- **Arms Control –** Treaties designed to limit the numbers of deployed nuclear weapons and their launch vehicles. At its core, these treaties are tied to maintaining the US – Russia nuclear balance. The agreements are underpinned by the belief in deterrence and the inescapability of mutually assured destruction in the nuclear relationship between the U.S. and Russia.
- **Nonproliferation -** Agreements meant to limit the spread of nuclear technology through the enforcement of export controls, Treaties and ad-hoc coalitions.
- **Counterproliferation –** A set of policy options when nonproliferation diplomacy fails and the use of force is necessary to neutralize hostile states seeking WMD.

The most prominent and extensive Treaty governing the spread of nuclear weapons is the Treaty on the Nonproliferation of Nuclear Weapons (NPT). The NPT is a worldwide treaty banning all signatories except the United Kingdom, China, France, Russia, and the United States from possessing or receiving nuclear weapons.[1] In exchange, the nuclear powers agreed to provide technical assistance to the non-nuclear weapons states in their pursuit of peaceful applications of nuclear technology and negotiate the end the nuclear arms race, reduce the number of nuclear weapons, and eventually disarm. At its core, the NPT is a bargain between the nuclear and the non-nuclear weapon states, which essentially saw the non-nuclear states give up their rights to nuclear weapons in exchange for access to nuclear technology and the commitment that eventually no state will possess nuclear weapons. If a non-nuclear state chooses to pursue nuclear energy it must allow for the inspection of its nuclear facilities by the IAEA to ensure that the nuclear material is not being diverted for weapons use. The nuclear weapon states also agree not to transfer nuclear weapons to non-nuclear states and the non-nuclear states agree not to accept nuclear weapons if offered. The treaty is considered to rest on three fundamental pillars: nonproliferation, disarmament, and the right to use peaceful nuclear technology. Turkey signed the NPT in 1979 and is an ardent supporter of the regime's mandate, believing strongly in maintaining the three pillars.

Talk of an international organization to monitor the spread of peaceful nuclear technology emerged shortly after the Second World War. International oversight to control nuclear technology was first outlined in the Acheson-Lilienthal Report, which proposed international inspections to monitor nuclear energy use worldwide. It also contained a provision for the internationalization of stockpiles of fissile material, which is an issue the nuclear and non-nuclear states are still debating to this day. These proposals were included in the Baruch Plan, before being incorporated into American President Dwight D. Eisenhower's "Atoms for Peace Speech" to the United Nations General Assembly (UNGA) in 1953. The speech laid out a proposal to share peaceful nuclear technology under the auspices of an international agency, which after further negotiations became of the International Atomic Energy Agency (IAEA).

The IAEA's two primary functions are to assist member states in the development of nuclear technology and to ensure the non-diversion of fissile material for military use. The IAEA's safeguards system is intended to provide a "credible assurance to the international community that nuclear material and other specified items are not diverted from peaceful nuclear uses." Before any state can receive nuclear technology, it must first conclude a safeguards agreement with the Agency. Afterwards, the IAEA relies on a number of interrelated protocols to independently verify the nuclear declarations made by the recipient state. Using basic accountancy, inspectors are able to ensure that fissile material is not being diverted for weapons use.

1- The nuclear weapons states are defined by the Treaty on the Nonproliferation of Nuclear Weapons (NPT) as those that tested a nuclear weapon before 1 January 1967. The five official nuclear weapons states are the United States, Russia, the United Kingdom, France, and China. India and Pakistan are known to have nuclear weapons, and Israel is strongly suspected of possessing nuclear weapons, but none of these countries have signed the NPT.

The safeguard system is designed to provide credible assurances that a country's nuclear facilities are not being misused and that the declared material is not being diverted for weapons use. However, the discovery about the scope of Iraq's clandestine nuclear program in 1991 prompted officials to devise ways to strengthen the safeguards system. According to the UN Inspectors, Iraq had acquired 39.3 kilograms of weapons grade uranium (a Hiroshima type nuclear weapon uses 25 kilograms of weapons grade uranium) and a fully working, but untested and un-built bomb design. Iraq had fully concealed its program and its activities were not detected by the IAEA until after first Gulf War. Negotiations commenced in 1993 and culminated in 1997 with IAEA Board of Governors approving the Model Additional Protocol (AP).

The goal of the AP was to give IAEA inspectors more investigative powers, by transforming them from nuclear accountants to nuclear detectives. The protocol greatly expanded the tools at the disposal of the inspectors to the ensure non-diversion of fissile material. Once a state ratifies the AP they are obligated to declare all aspects of the uranium fuel cycle, allow inspectors short notice inspections of all buildings at a nuclear site within 24 hours, allow the IAEA to use satellite imagery for inspections purposes and obligates signatories to report the manufacture and export of critical nuclear weapons related technologies. Turkey first signed the AP in July 2000 and the agreement entered into force one year later after it was ratified by the Parliament.

In addition to the NPT and its safeguards framework, states seeking to limit the spread and development of nuclear weapons have advocated for a comprehensive ban on nuclear testing. While the ban may not prevent the development of simple fission devices like the one used at Hiroshima, proponents argue that a comprehensive test ban would prevent the development of more powerful nuclear weapons and warheads small enough to be mounted on a missile. In 1954 Indian Prime Minister Jawaharlal Nehru first proposed the idea of a comprehensive nuclear test ban treaty (CTBT), but Cold War politics prevented states from making much progress.

Freed from the politics of the Cold War, member states at the 1995 NPT Review Conference (Revcon), agreed to indefinitely extend the NPT's mandate, and included a provision in the Final Document calling for negotiations to begin on a CTBT by 1996.[2] During the negotiations, its was agreed that the Treaty's entry into force would require the signature and ratification of the 44 States included in the most recent IAEA list of countries with an operating nuclear reactor. Turkey was included in the IAEA list because it is home to two small research reactors at Istanbul Technical University and the Cekmece Nuclear Research and Training Centre (CNRTC). Turkey signed the CTBT on 24 September 1996; the same day it was opened for signature and the Turkish Parliament ratified it on 16 February 2000. Despite Turkey's signature, the Treaty has not yet entered into force because some of the 44 required States have not signed or ratified the CTBT.

2- For more information please refer to United Nations Office of Disarmament Website: http://www.un.org/disarmament/WMD/Nuclear/1995-NPT/1995NPT_OfficialDocs.shtml.

In parallel, other states have been pushing the international community to adopt a fissile material cut off treaty (FMCT). The Treaty would ban the production of fissile material for military purposes. Provisions for an FMCT were first proposed in the Acheson-Lillenthal report and after in the Baruch Plan, before American President Dwight D. Eisenhower officially proposed a Treaty in 1956. The Soviet Union objected until 1989 over fears that a FMCT would hinder its ability to maintain nuclear parity with the United States. After the Soviet Union lifted its objection, former President George H.W. Bush rejected the proposal over fears that it would undermine the U.S. nuclear deterrent.

Since the end of the Cold War, the United Nations General Assembly (UNGA), at the suggestion of President Bill Clinton, proposed and adopted Resolution 48/75L, which called for a non-discriminatory, multi-lateral and internationally and effectively verifiable treaty banning the production of fissile material for nuclear weapons or other nuclear explosive devices. Two years later in 1995, the Conference on Disarmament established a committee to discuss the FMCT. At the 2000 NPT Review and Extension Conference, member states agreed to begin negotiations to complete the FMCT within five years. Despite the commitment, states have not been able to agree upon the language for an FMCT due to a number of objections of states like Pakistan, Israel, North Korea and China.

More broadly, the unofficial and official nuclear weapons states have serious reservations about the FMCT. They worry that it would only ban the production of fissile material and not prevent potential proliferators from acquiring the technical capability to produce a nuclear weapon. The non-nuclear weapon states (NNWS) believe that the FMCT is part of the larger disarmament process that should include overall cuts of nuclear forces by the official and unofficial NWS.

In addition to these efforts, states have come together to form a number of ad hoc coalitions to govern the spread of critical nuclear technologies. The most prominent of these coalitions is the Nuclear Suppliers Group (NSG). The NSG was first conceived after India's "peaceful nuclear explosion" (PNE) in 1974. It was later discovered that the plutonium used was derived from a Canadian supplied nuclear reactor. After India's PNE, the nuclear supplier nations came together and drafted a "trigger list" of sensitive dual use technologies in order to control nuclear exports and prevent other states from following in India's footsteps. If an exported item sets off a "trigger" than the receiving state must have in place a full scope safeguards agreement and legally binding commitment not to produce nuclear weapons. Turkey is also member of the 46-member coalition. Although it is not a nuclear power state, Turkey's membership was requested due to its manufacturing capacity for materials of potential use in the nuclear industry.

Turkey was also a founding member of the of the Wassenar agreement in 1996, which regulates the export of dual use technologies and conventional weapons by encouraging states to adopt stringent export control regimes to ensure that conventional weapons export do not undermine security and stability. Shortly thereafter, Turkey joined the Missile Technology Control Regime (MTCR) in 1997. The MTCR is an informal group of states that have come together to coordinate national export licensing efforts to help prevent the export of technologies that may aid in the development of WMD delivery systems. In addition, Turkey became a member of the Zangger Committee, the Australia Group in 2000, which is an agreement designed to harmonize and strengthen export control laws and technology control lists to prevent proliferation.

In another effort to limit the spread of sensitive nuclear technologies, the United States first proposed the Global Nuclear Energy Partnership (GNEP) in 2006. The program's original intention was to manage the expected increase of the use of nuclear energy worldwide as a means to combat energy dependence and climate change. Since its proposal, GNEP's name has changed to the International Framework for Nuclear Energy (IFNEC) but the mission has remained the same. [Sinan, I'm not an expert on GNEP or its successor, but think that the original intention was more ambitious, and that the subsequent changes are more significant. Ideally, I would know exactly what to say, but I don't. I also don't think the paper would suffer by omitting this para, as IFNEC is going nowhere]. The underlying goal is to develop proliferation resistant fuel cycle technologies, while ensuring the supply of nuclear fuel, and continuing research and development of fast reactors. Turkey has not agreed to participate in GNEP because it has historically shunned attempts to limit a state's right to pursue enrichment and reprocessing technology. Turkey has oft repeated its desire to balance its NPT obligations and strong nonproliferation policies with its own desire to pursue a peaceful nuclear energy program.

When it comes to interdicting the illegal transfer of controlled technologies, Turkey has been a staunch supporter of international efforts to stymie illicit nuclear procurement. Launched in 2003 by the former Bush Administration, the Proliferation Security Initiative (PSI) is an effort by the United States to form relationships with other countries and develop legal, diplomatic, economic and military tools to thwart proliferation. Member countries train to interdict shipments at sea, in the air, or on land. The effort is designed to make proliferation decisions more costly and make decisions to pursue an illicit program clandestinely more difficult because the cost of doing so is too great.

In 2006, Turkey hosted 37 member States for land / sea / air interdiction training. Under the aegis of PSI, Turkish authorities, suspecting the illegal shipment of WMD technology, forced an Iranian airplane bound for Syria to land in Turkey in March 2011. Turkish officials removed explosive materials and rocket propelled grenades bound for Syria. In addition to increasing the potential costs of proliferation, PSI is an effort to increase the tools available to interdict illicit shipment of WMD technologies to prevent would be proliferators from acquiring the materials needed for a non-conventional weapon.

As a catch all measure designed to help thwart illicit trafficking, the United Nations Security Council (UNSC) adopted Resolution 1540, a legally binding Chapter VII resolution requiring all states to implement measures to prevent non-state actors from acquiring nuclear, chemical, or biological weapons or material and the means the deliver them. Turkey was quick to support the resolution and welcomed UNSC resolution 1810, which extended 1540's mandate indefinitely.

Despite these numerous organizations, coalitions and Treaties, states like Iran, pre-1991 Iraq, Pakistan and North Korea were able to successfully circumvent international regulations and clandestinely acquire nuclear technologies. In the face of the threats posed by illicit proliferation networks, greater international cooperation is necessary to stem the flow of these dangerous items. However, the effort to significantly curtail the access of additional states to nuclear technology that has peaceful (and dual-use) applications has been met with stiff resistance by the nuclear aspirant states. Turkey, which has extensive plans to develop nuclear energy, has broken with its Western allies over this issue and has maintained its belief that international efforts should balance nonproliferation commitments with every NPT signatories right to access nuclear technology. This range in outlook puts a premium on understanding individual country nuclear diplomacy in order to develop strategies to combat proliferation affectively.

2.2 Turkey's Nonproliferation Policies

Turkey has a long history of supporting international policies designed to stop proliferation. During the Cold War, these efforts were part of a larger NATO effort to maintain strategic stability and military parity with its Warsaw Pact adversaries. Since the advent of the nonproliferation regime, Ankara has adopted strong nonproliferation policies due in large part to its NATO membership, location at the apex of the Middle East and its front-line state status during the Cold War. Turkey is firmly against the proliferation of WMD, favors the establishment of regional nuclear weapons free zone, and advocates for the eventual disarmament by nuclear weapons states. Turkey is a signatory of the NPT, the Chemical Weapons Convention (CWC), and the Biological Weapons Convention (BWC) – the three most comprehensive Treaties governing the spread of WMD.

In general, Ankara promotes nuclear disarmament, but believes that this process will take decades to achieve. In the interim, it remains committed to NATO's nuclear deterrent force, believing that American tactical nuclear weapons in Europe contribute to the Alliance's burden sharing principles and enhance Turkish security. Ankara welcomed American President Barack Obama's Prague Speech on nuclear weapons, in which he committed the United States to nuclear disarmament, while warning that the process "may not happen during [his] lifetime."[3] The tone of the American President's speech fit nicely with Turkey's nuclear outlook and reinforced Turkish thinking about the subject.

During and after the Cold War, Turkey's nonproliferation policies have been closely tied to that of its NATO allies and with those of the United States. However, in recent years, Ankara has been advocating the implementation of a regional nuclear weapons free zone, which officials see as part of an overall strategy to decrease tensions in the region. Promoting disarmament, in addition to its staunch commitment to the nonproliferation agenda gives Ankara the image of being a reliable and committed international partner and helps decrease tensions in the volatile Middle East.[3] Efforts to promote stability have become the centerpiece

3- For full text of President Obama's speech please refer to: http://prague.usembassy.gov/obama.html of Turkish security and foreign policies with the advent and promotion of the "strategic depth" foreign policy.

Regional upheaval and the fact that other states in the region have failed to follow Turkey's example continue to shape its nonproliferation outlook. For example, Israel, India and Pakistan are nuclear weapons states outside of the NPT framework and have elected not to sign the Treaty. Algeria, Sudan, and Israel have not signed the BWC and Egypt and Syria have thus far refused to sign the CWC. Iran is pushing ahead with its nuclear and missile program. No state in the region is a formal member of the MTCR and many states in the region are known to have pursued non-conventional weapons in the past. Turkey hopes that international efforts to establish a regional nuclear weapons free zone will help ease tensions and eventually lead to global disarmament. Ankara has always maintained that this process will take decades, but it sees the lessening of regional tensions as the first step towards achieving this goal.

Export Controls: The First Line of Defense

At the heart of proliferation strategy is the assumption that limiting a country's access to the technologies critical for WMD production can help prevent proliferation. At the forefront of this strategy is a state's export control system. Export controls are national legislation, and corresponding implementation agencies and practices, intended to control the spread of sensitive technologies, material, or information. Much of the controlled trade is dual use technologies – meaning nuclear, chemical, or biological technologies or materials that have military and civilian applications. It is the export control official's job to make a determination about whether or not dual use items will be used for civilian purposes or be diverted for military applications within the framework of a state's export control laws.

As a testament to Ankara's nonproliferation commitment, Turkey has announced a zero proliferation policy and has joined all relevant instruments and the government has taken a number of steps to tighten domestic legislation to prevent proliferation. On 26 September 2004 the Turkish National Assembly adopted a new criminal code that includes a series of articles pertaining to export control and WMD - articles 6, 172, 173, and 174.

Articles 6 defines weapons as "nuclear, radioactive, chemical, and biological materials that can burn, abrade, perforate, injure, suffocate, poison, or cause permanent disease or injury." Article 172 assigns specific penalties for the intentional release of radiological material, in reference to a "dirty bomb" scenario. Article 173 deals with the act of "Causing Explosion with Atomic Energy" and mandates that a person shall spend no less than five years in jail if it is determined that the explosion was deliberate.

Article 174 criminalizes the export, import, transporting, and transshipping of dual use materials without the express written consent of the Turkish authorities. The "Law on the Control of the Private Industrial Enterprises Producing War Weapons, Equipment, Vehicles, Ammunition, Explosives" (Law no. 5201) was adopted on 4 July 2004 and renewed the mandate of the Ministry of National Defense (MND) as the licensing body for the export of weapons and ammunition. Nuclear and biological weapons also fall under the purview of this law and under the jurisdiction of the MND.

Dual use items are included in a "catch all" provision encapsulated in Turkey's broader export control regime and restricts the export of sensitive technologies even if they are not specifically enumerated in any international export control list. If it is suspected that the end user will divert materials for nefarious purposes the exporting company must secure the permission of the Undersecretariat for Foreign Trade (UFT). In cases where the exported item is on a restricted export list the process is overseen by both the MND and the UFT. In these cases, the MND will first issue the export license and then the UFT is tasked with overseeing the implementation of Turkey's export policy. Membership in the Istanbul Metals and Minerals' Exporters Union (IMMIB) is required to export dual use items and sensitive goods and the union is responsible for determining whether or not an item is subjected to export controls.

Authorities have created a centralized monitoring mechanism and an effective inter-agency collaboration to help prevent the proliferation of sensitive dual use items without proper authorization and user end agreements (a certification from the importing entity ensuring that they are the final destination for the exported item and that they will not divert the item for military purposes.) The aforementioned export control system coincides with the EU, as well as, the United Nations (UN) and the Organization for Security and Cooperation in Europe (OSCE) export control lists.

Despite these efforts, Turkey is a target for illicit procurement networks intent on circumventing international nonproliferation controls. The fact that Turkey sits where Europe and Asia meet makes it an ideal place for the transshipment of dual use items. Transshipment refers to a clandestine effort by some states to illegally import banned material. States will usually set up a front company in a third country and use it to import banned items from Western suppliers. The companies falsify the end user certificates for the controlled goods and then, after receiving them, will re-label the shipment and send items and send them along to their home country. Turkey's close relationship with the West, as well as its participation in NATO, the MTCR, and the NSG make it even more attractive for these illicit networks because Turkish companies do not face the same kind of restrictions as those in Iran.

For example, a shipment of dual use missile components was intercepted by a joint operation involving the Central Intelligence Agency (CIA) and the Turkish National Intelligence Organization (MIT) trying to cross from Turkey into Iran in 2006. STEP-SA, the Iranian owned and operated firm, was using Istanbul as a major transshipment hub for Iran's nuclear and missile program. This case followed closely news that two Turkish firms, Elektronik Kontrol Aletleri and ETI Elektronik supplied centrifuge technology to the A.Q. Khan network. A centrifuge is the critical technology used to separate uranium for use in nuclear weapons or nuclear power plants. The Khan network was a black market nuclear supplier of Pakistani nuclear weapons technology to a number of countries in the Middle East and elsewhere. Khan was able to evade export controls and clandestinely transport hordes of nuclear weapons technology all over the world. They were then exported to Dubai where members of the Khan network would take advantage of Dubai's lax export controls to transship them to Iran, Libya, and North Korea.

Efforts to crack down on these illicit procurement networks led to the signing of an agreement known as Export Control and Related Border Security Assistance (EXBS) on 14 June 2005. EXBS provides for equipment and training to help prevent the proliferation of WMD and delivery vehicles. The Turkish Grand National Assembly passed a bill related to the *Approval of the Agreement between Turkey and the United States on Enhancing Cooperation for the Facilitation of Assistance for Preventing the Spread of Weapons of Mass Destruction,* a technical assistance agreement meant to enhance border security and prevent WMD proliferation in 2005.

Despite these setbacks it is clear that Ankara is dedicated to preventing the proliferation of WMD. Turkey has proven that it is willing to change its export control strategies to meet new and emerging proliferation challenges. The growing ranks of new potential nuclear suppliers, combined with growing global trade have made the control of dual use items more difficult. Moreover, the conflagration of these factors has made Turkish diplomacy surrounding the NPT and other nonproliferation issues even more important, especially given its desire to develop a nuclear energy program.

2.3 Turkey's Nuclear Diplomacy

Beginning in 2006, Turkey was among the thirteen countries in the Middle East that announced intentions to begin developing a new or long dormant nuclear energy program.. For more than four decades, the Turkish government has proposed developing an indigenous nuclear energy program to lessen dependence on external energy suppliers. Turkey is part of a growing movement of developing and developed states that are pursuing nuclear energy as a way to decrease carbon emissions, while also decreasing reliance on unstable foreign energy suppliers.

Turkey's nuclear diplomacy is influenced strongly by the fact that it is a non-nuclear weapons state seeking to develop an indigenous nuclear energy program. Ankara has positioned itself as a champion of nonproliferation, while maintaining a strict interpretation of Article IV of the NPT. Article IV grants every signatory the right to pursue peaceful nuclear activities and obligates the nuclear supplier countries to facilitate in the exchange of nuclear technology and material. In recent years, the Turkish interpretation of Article IV has been the source of friction between Turkey and some of its Western allies, especially when it comes to international efforts to limit nuclear aspirant countries from accessing enrichment and reprocessing technologies. Officials view these efforts as a threat to its own nuclear ambitions, and have challenged proposals designed to make it harder for a state to access nuclear technologies.

This has come at a time when Turkey's surging economy and growing population is straining the country's current electrical infrastructure. Electricity demand has on average grown at more than 8 percent per year in the last decade, prompting Turkey to import almost 75 percent of its primary fuel sources just to meet internal demand. According to the estimates of Turkey's energy regulator, the growth in electricity demand will average 6.5 percent per year to 2030. Natural gas makes up 48 percent of all energy imports, making Turkey extremely susceptible to price fluctuations and market disruptions. To combat these vulnerabilities, the Turkish government has moved aggressively to increase the capacity of its existing power plants while also planning for the eventual introduction of a whole slew of alternative energy projects. The government plans for renewable energy, fossil fuels, natural gas, and nuclear energy to each provide 25 percent of Turkish electricity by 2040. The goal is ambitious and many analysts have argued that the timeline is unrealistic, especially with regards to Turkey's nuclear ambitions.

These ambitious plans have made Turkey one of the most potentially lucrative and active nuclear markets in the world. In 2008, the government announced a tender for the country's first nuclear power plant. In 2009, Russia and Turkey signed a nuclear tender that stipulates Russia will build and operate four 1,200 megawatt (MW) reactors in Akkuyu, a town near the Mediterranean coastal city of Mersin. Construction is expected to begin in 2012 and finish in 2019. The government is planning for nuclear energy to account for 5 percent of Turkish electricity production by 2023. Russia has agreed to supply the fuel for the reactor and remove the spent fuel, setting off debates about Turkish dependence on Russia for an even larger portion of its electricity production.

Turkey has not announced its official fuel cycle plans, but has taken steps to ensure that its right to these technologies will not be infringed upon. Enrichment and spent fuel reprocessing technologies are useful for large-scale nuclear programs, but are also necessary for the production of fissile material for nuclear weapons. Acquiring fissile material, as well as these technologies is the most difficult and most expensive part of the nuclear fuel cycle. For this reason, limiting the spread of these technologies has been the focus of international efforts to prevent proliferation. However, for Turkey, protecting its right to these nuclear technologies has become a centerpiece of its nuclear diplomacy.

2.3.1 Turkey Objects to Efforts to Black Box Critical Nuclear Technologies

The desire to maintain the balance between the three pillars of the NPT has heightened Turkish sensitivity to any perceived infringements on the right to access peaceful nuclear technology. Prompted by the current crisis surrounding Iran's nuclear program and the recent push by some Middle Eastern states to acquire critical technologies, nuclear suppliers have proposed a series of measures to tighten export controls. The most restrictive proposal was put forward by the United States in 2004. The proposal sought to restrict the export sensitive enrichment and reprocessing technologies to states without existing facilities. The Bush Administration argued that these restrictive measures were necessary to curb the spread of enrichment and reprocessing technologies, especially after the revelations about A.Q. Khan's illicit proliferation network and Iran's nuclear program. In its place, nuclear aspirant states would be able to receive nuclear fuel from an internationally controlled consortium or fuel bank. The proposal bounced around the NSG for four years without winning the necessary consensus for adoption. Eventually, the United States joined the NSG's other 44 members in supporting a criteria based system for the enrichment of enrichment and reprocessing technologies. The approach, which was first put forward by Canada, establishes a set of objective and subjective criteria a recipient state must meet before being allowed access to sensitive nuclear technologies.

The United States agreed to the Canadian proposal in principle but attached a series of riders to strengthen the restrictions. The U.S. proposal would "black box" and only supply complete "turn key" facilities to the important country. These facilities would be operated by non-native personal with the recipient country's consent and be built so that recipient country would not be able to replicate the facility, including the sensitive components."

A number of countries, including Turkey, strongly objected to these stringent export control guidelines, arguing that they violate the spirit of Article IV of the NPT. Opponents argue that NSG guidelines already say that suppliers should exercise restraint in transferring enrichment and reprocessing technologies and that the regulatory framework already exists to reassure supplier countries that the technology will not be diverted for weapons use. Moreover, strong objections were levied against the imposition of subjective guidelines, which many felt were deliberately vague and designed to prevent the sale of critical technologies to a whole host of states. According to NSG guidelines:

2.3.1.1 Special Controls on Sensitive Exports

Suppliers should exercise restraint in the transfer of sensitive facilities, technology and material usable for nuclear weapons or other nuclear explosive devices. If enrichment or reprocessing facilities, equipment or technology are to be transferred, suppliers should encourage recipients to accept, as an alternative to national plants, supplier involvement and/or other appropriate multinational participation in resulting facilities. Suppliers should also promote international (including IAEA) activities concerned with multinational regional fuel cycle centers.

2.3.1.2 Special Controls on Export of Enrichment Facilities, Equipment and Technology

For a transfer of an enrichment facility, or technology therefore, the recipient nation should agree that neither the transferred facility, nor any facility based on such technology, will be designed or operated for the production of greater than 20 percent enriched uranium without the consent of the supplier nation, of which the IAEA should be advised.

The guidelines are voluntary, but they have thus far prevented the sale or transfer of enrichment of reprocessing technologies to any new states.

After years of negotiations, the NSG agreed on more stringent restrictions designed to prevent the spread of enrichment and reprocessing technologies in June 2011. The new rules prevent the sale of these critical technologies to countries that haven't signed the NPT and that don't allow tougher IAEA inspections under the Additional Protocol. The NSG agreement is seen as a reaction to a decision that granted India an exception to NSG guidelines. Under the old agreement, India would have been able to purchase sensitive enrichment and reprocessing technologies, despite not signing the NPT.

The new rules mirror Ankara's policy, which always supported placing these tangible conditions on enrichment and reprocessing technology sales. However, the debate about imposing these criteria wasn't easy and many states had been pushing for tougher restrictions. Moreover, it is likely that further efforts to control the transfer of enrichment and reprocessing technologies will continue at the NSG.

Turkey is steadfastly opposed to calls for supplier states to take into account whether or not the actions by the importing state may compel its neighbors to seek similar technologies, or whether the recipient state is in an unstable region. Officials worry that Turkey could be penalized for its proximity to Iran and the Middle East and that it could be classified as being in an unstable region. Turkey put forward its own argument, saying that only those states engaged in "bad" behavior should not be able to enrich and reprocess, without elaborating who those "bad" states were.

The NSG's June 2011 agreement ended debates about the proposals put forward by France in 2008, which called for the strengthening of the criteria for technology transfer by adding the following requirements:

- A member of the NPT in full compliance;
- A comprehensive Safeguards Agreement and Additional Protocol in force;
- No breach of safeguards obligations, no IAEA Board of Governors decisions taken to address lack of confidence over peaceful intentions;
- Adherence to NSG guidelines;
- Bilateral agreement with the suppliers that includes assurance on non-explosive uses, effective safeguards in perpetuity, and retransfer controls;
- Commitment to apply international standards of physical protection; and
- Commitment to IAEA safety standards.

Ankara had said that it was willing to accept the proposal outlined above, but it was not prepared to support further subjective criteria.

Turkey also stridently objects to the introduction of the "black-box" and turnkey concepts over concerns that they may hamper the civilian cooperation between countries in good standing with the NPT. Ankara believes that specific criteria must be established by the NSG and that the criteria should take into account any justifiable concern about proliferation because non-specific subjective criteria may prove to be impossible to streamline and will undermine nuclear cooperation between states.

Moreover, Ankara is concerned that restrictions on enrichment technology to members states in good standing with the NPT also infringe on Article IV rights. With regards to the United States' "black box" proposals Turkey has argued that it limits the recipients ability to cooperate with supplier states. Ankara believes that Middle Eastern states will bear the brunt of these restrictions, even if they meet the criteria put forward by the NSG. With an eye towards its own nuclear program, officials worry that these conditions will hamper Turkish efforts to develop its own nascent nuclear industry. In addition, there is a fear that these restrictions will make recipient states dependent on the nuclear suppliers for energy, thus negating the off-stated desire to achieve energy independence. Despite these objections, Turkey welcomes the inclusion of the Additional Protocol as one of the criteria for nuclear export, believing that the AP is enough to halt proliferation without the use of "black box" and "turn key facilities."

Turkey maintains that nuclear supplier states should take steps to ensure that they don't practice discriminatory policies that prevent nuclear cooperation. At the very heart of Turkish objections, is the country's desire to maintain balance between the three pillars of the NPT so that Turkey can better carry on with its own nuclear program and that these stringent measures belie the spirit of the NPT.

2.3.2 Turkey's Nuclear Power Plans: Safeguarding NPT Rights

Recent trends in supply side controls are driving many aspects of Turkey's current nuclear diplomacy. Since the early 2000s, nuclear supplier countries like the United States, France, Japan, and Korea have made a more strident effort to control the transfer of nuclear technology to recipient states. From a proliferation standpoint enrichment and reprocessing technologies are inherently dual use. The process to enrich uranium for reactors is virtually the same as producing fuel for a nuclear weapon. The difference lies in the percentage of Uranium-235 in the fuel. Light water reactors use 3-5 percent enriched uranium fuel, while the core of nuclear weapon uses 90 percent enriched uranium. Reactor fuel is referred to as low enriched uranium (LEU) and uranium enriched to 90 percent is called highly enriched uranium (HEU). In both cases, uranium gas is fed through a series of centrifuges – rapidly spinning tubes that separate uranium-235 from uranium-238. The heavier U-238 naturally moves to the wall of the centrifuge and the lighter U-235 collects in the center. The lighter, more fissile U-235 is collected in a scoop and fed to another centrifuge. The process is repeated over and over again until the desired purity is reached.

On the back end, states are also seeking to limit a recipient country's access to reprocessing technology. Reprocessing is the process that separates plutonium from spent reactor fuel. Like 90 percent enriched uranium, plutonium can be used in a nuclear explosive device. Many arms control advocates believe that placing controls on the spread of centrifuge, enrichment, and reprocessing technologies is vitally important to decreasing the threat of proliferation. The recently signed nuclear cooperation agreement between the United States and the United Arab Emirates is the most striking example of these new efforts. The agreement explicitly precludes the UAE from enrichment and reprocessing.

Ankara has become increasingly sensitive to global efforts to limit the transfer of nuclear technology. They view these efforts as an infringement on their NPT Article IV right that specifically enumerates a state's right to peaceful nuclear technology. The government's ambitious nuclear power plans, as well as its of stated desire to wean its dependence on foreign energy sources, raises a number of questions about Turkey's future fuel cycle ambitions. As of now, Turkey has not announced any plans to pursue enrichment or reprocessing, but has hedged about its future plans, leaving open the possibility that Ankara may decide to pursue these technologies at a later date. Indeed 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.

Proposals to limit enrichment and reprocessing have been around since shortly after the Second World War, but have recently gained momentum over concerns about Iran and North Korea's nuclear programs. One of the ideas gaining the most traction is for the establishment of a multilateral enrichment center to provide nuclear fuel to NPT member states that are deemed to be in good standing with the IAEA. The IAEA has recently approved two international fuel banks proposed by Russia and the Nuclear Threat Initiative (NTI). The NTI model gives the IAEA the responsibility for maintaining reserve stocks of low enriched uranium (LEU) that could be released under certain circumstances or enrichment centers would be internationally controlled and operated. The idea is that states developing nuclear energy would not need enrichment or reprocessing technologies or centers, drastically reducing the likelihood of clandestine proliferation.

When the multilateral fuel bank initiative was discussed by the IAEA Board of Governors in September 2009, Turkey did not voice its support for the initiative. Turkish policy makers are still keenly aware of the Bush era initiative prohibiting the transfer of sensitive technologies including enrichment to countries that did not already possess such an infrastructure. At the time, this initiative was resisted as a violation of the rights granted to signatory states of the NPT. The multilateral fuel bank proposal initially rekindled the fears of countries like Turkey that interpreted it as a measure that will help to substantiate demands to prohibit the transfer of sensitive technologies to aspirant countries. Similarly it stoked fears that the establishment of multilateral fuel banks could be used to usurp the sovereign rights related to uranium enrichment.

The bottom line is that Turkey wants to protect its enrichment rights and views these international efforts to limit these rights as part of larger issue relating to the

NPT rights of the non-nuclear states to nuclear technology. Turkey's vocal support for Article IV rights has greatly influenced its public position on Iran's nuclear program. With an eye towards its own nuclear future, Turkey has unequivocally supported Iran's right to enrichment, despite Western efforts to pressure Iran to give up this right.

From the Turkish perspective, the controversy surrounding the Iranian issue is not related to a state's right to enrich uranium, but rather Tehran's refusal to answer a number of IAEA questions about its previous nuclear activities and its failure to declare its nuclear facilities to the IAEA. Since efforts to sanction Iran began to heat up in 2003, Turkey has tried to walk a fine line between its strong support for Article IV, and by extension Iran's right to enrichment, with the international efforts to pressure Iran to answer the IAEA's questions about possible undisclosed nuclear activities involving the military.

2.4 Iran and Turkey: A Delicate Balancing Act

Turkish – Iranian relations have long been dominated by their history of rivalry, stemming from rival imperial and religious ambitions. The Ottomans were the historic protector of the Sunni faith and the protectors of Mecca and Medina. The Ottoman Sultan was deemed Caliph, which put the empire at odds with the Shi'i Saffavid Empire in modern day Iran. The empires have a history of war and rivalry for control of major portions of the Middle East. However, the relations between the two empires, and their successor states, have been relatively stable since the signing of Kasr-ı-Şırın Treaty in 1639, which delineated Iran's and Turkey's current border and granted control of the Iraqi territories to the Ottomans.

From 1979 until the late 1990s, Turkish officials viewed Iran with contempt because of the regime's alleged support for Islamic extremists seeking the overthrow of Turkey's secular Republic and Iran's alleged support for Kurdish separatists in Northern Iraq and Southern Turkey. Relations began to thaw after the two countries agreed to work together to combat Kurdish terrorism. The agreement coincided with the rise of the Free Life Party of Kurdistan (PJAK) – the Iranian branch of the Kurdish Worker's Party (PKK).

The latest Western efforts to sanction Iran began in 2003, which roughly coincided with the election of Erdogan's AK Party and the introduction of its new "zero problems" foreign policy. In contrast to Turkey's previous Iran policy, AK Party has publicly embraced the Islamic Republic and has sought ways to increase diplomatic and economic cooperation. While insisting on the need for Iran to cooperate with the IAEA and to ensure the transparency of its nuclear activities, Prime Minister Erdogan has supported Iran's controversial enrichment and nuclear program, drawing the ire of the United States and its Western allies who have been working hard to financially and diplomatically isolate the Islamic Republic for its failure to answer a number of outstanding questions regarding its previous nuclear activities.

Iranian and Turkish diplomatic relations have flourished in recent years due to a growing economic relationship and security cooperation against common threats. Between 1991 and 2008, Turkey's exports to Iran increased from $87 million to $ 2 billion and imports from Iran increased from $91 million to $8 billion during the same time period on account of Turkey's growing demand for Iranian natural gas. Trade volume between the two countries recently surpassed $10 billion albeit with a $6 billion Turkish trade deficit. The bulk of trade is tied to natural gas, but Iran has shown some interest in opening its economy to Turkish investment. TAV was at first contracted to build the new Khomeini airport in Iran. However, the Iranian Revolutionary Guard Corp. interfered and did not allow TAV to finish construction for a number of political and economic reasons. Similarly, Turkcell came close to acquiring Iran's second GSM license, but the deal fell through after the Iranian government insisted that it maintain a majority ownership stake in the project. Interference by the Iranian government in both of these projects have prompted many skeptics of the Iranian-Turkish rapprochement to point out the relationship, thus far, has been far more economically beneficial for Iran.

Turkish investors have had far more success investing in Iran's energy sector, having signed a number of agreements with their Iranian counterparts giving Turkish energy companies concessions in developing Iran's massive South Pars gas field. The agreements have irked the United States, which has passed a number of unilateral sanctions meant to limit investment in Iran's oil and gas sector. The other important industry is tourism. Every year 1 million Iranians visit Turkey. Iran is also an important conduit for Turkish trucks taking products to central Asia. In 2007, 92,000 Turkish trucks traveled from Iran through Iran to other countries.

According to the Turkish foreign ministry, the Turkish-Iranian relationship is defined by the shared belief in non-interference, amicable neighborly relations, and economic and security cooperation. These principles have led the Turkish government to publicly proclaim its preference for dialogue and intense diplomacy to resolve the Iranian nuclear crisis, meaning that Ankara has not been an enthusiastic supporter of the United States' and European sanctions policy.

The Turkish policy regarding sanctions is a microcosm for Turkish nuclear diplomacy in general. Turkey is willing to accept the multi-lateral UN sanctions because they deride Iran for not abiding by the binding demands of the UNSC and because they are backed by the legitimacy of the United Nations. However, Turkey has thus far refused to support American and European sanctions because they believe that would only strengthen the Iranian hardliners and disproportionately affect the Turkish economy. Moreover, the government views the West's demand that Iran halt enrichment as a clear violation of Iran's right under the NPT. Officials in Ankara are wary of setting a precedent that limits the right's of states to pursue nuclear technology.

However, it is incorrect to conclude that Turkey is comfortable with the idea of a nuclear-armed Iran. Ankara is very concerned about the possibility that Tehran may develop nuclear weapons. A nuclear-armed Iran would undermine regional stability, a bedrock principle of Turkey's foreign and security policy. At the heart of the "zero problems" foreign policy is the belief that regional stability is pivotal for Turkish economic development. Moreover, AKP believes that "soft power" – the diplomatic ability to get what you want via co-option rather than coercion – is the most effective ways to deal with problems in the volatile Middle East. Turkey, with its democratic institutions and its majority Muslim population, can serve as a model for the rest of the region.

Without a doubt, a nuclear-armed Iran would pose problems for Turkish foreign policy and regional ambitions. While Turkey, does not feel directly threatened by Iran, a nuclear-armed Iran would certainly alter the balance of power and upset strategic stability. There is also the possibility that an Iranian nuclear weapon could prompt other states in the Gulf to take a series of steps to ensure their own security. The possibility of a regional arms race would seriously alter the region's landscape. Finally the Iranian nuclear program may lead to a military strike by Israel targeting a range of nuclear facilities on Iranian soil.

From the outset, Turkey and its Western allies agreed that Iran should not have nuclear weapons. However, Turkey's approach to convince Iran to be more cooperative differs from many of its traditional Western allies. Since 1979, the United States has generally pursued a coercive sanctions-based policy that seeks to isolate the Islamic republic. Though President Barack Obama has sought to invite Iran into direct dialogue, Iran has not accepted the offer of direct diplomacy. As a result, Washington reverted to its strategy of forcing behavioral change through the threat and finally the reality of sanctions. Turkey has taken the opposite approach, and believes that the levying of sanctions only serves to strengthen Iranian hardliners and has thus engaged directly with Iran on a number of diplomatic issues. Ankara has consistently argued that coercive sanctions are counterproductive because they encourage rash behavior. Moreover, there is a belief that sanctions are simply the prelude to military intervention by either the United States or Israel. The potential fallout from a military strike, the threat of the Middle East being sucked into a regional war, and the possibility that Turkey could be targeted by Iranian missiles in a counterstrike has strengthened Ankara's resolve to negotiate a settlement.

Given the stakes, it is clear that Turkey would never have sat idly on the sidelines while Western powers negotiated with Iran. Prime Minister Erdogan has defended Iran's right to enrichment, while staunchly re-affirming his country's belief that Iran should not acquire nuclear weapons. Diplomatically, Foreign Minister Davutoglu has acted as an important intermediary between Tehran and the West. In times of diplomatic deadlock Davutoglu has worked to overcome the political obstacles to resolve the impasse. One such instance took place in May 2010, when Iran, Brazil, and Turkey brokered a deal that would have had Iran send 1,200 kg of LEU to Turkey before being sent to Russia and France for further enrichment and fuel fabrication. The Brazil, Iran, Turkey joint declaration stipulated that Iran would receive 120 kg of uranium fuel for the Tehran research reactor in exchange. The Joint Statement varied little from an earlier proposal put forward by the United States and its European allies that would have also had Iran send 1,200 kg of LEU to Turkey and then onto Russia and France. It was widely reported that Iran had initially agreed to the Western led and backed October fuel swap proposal, before internal domestic political pressure led to Iran walking back from its earlier agreement.

The Iran-Brazil-Turkey Joint Declaration was announced just days before the UN Security Council passed resolution 1929, which ratcheted up the sanctions against Iran for not answering IAEA questions about its previous nuclear activities. Turkey and Brazil ultimately voted no to the sanctions, believing that they countered the spirit of the Joint Declaration and undermined the trust earned by the agreement. On the other side, Western nonproliferation analysts were critical of the deal because, at the time, the amount of LEU Iran would have shipped to Turkey would not have seriously hampered Iran's ability to quickly develop a nuclear weapon because Tehran would have still retained enough LEU for one nuclear weapon had Iran decided to further enrich its LEU to 90 percent. In addition the deal did not address the 20 percent enriched uranium at Tehran's disposal and whether Iran would continue to enrich to this level even if it received foreign fuel, and whether Iran would commit not to enrich beyond this level. The crux of the United States' and European strategy was to carve out a two-year window for negotiations by removing enough LEU to prevent Iran from being able to quickly develop a nuclear weapon. Turkey, on the other hand, argued that the deal was an important confidence building measure and believed that it had succeeded where the major powers had not.

Turkey's no vote seriously strained relations with the United States, who was counting on Ankara to support Washington's efforts to punish Iran for its nuclear intransigence. Since the signing of the Joint Declaration and the very public rebuke by many members on the UNSC, Turkey has changed tactics and has once again assumed the role of facilitator, often acting as a conduit for messages from the West to Tehran and vice versa. In January 2011 diplomats from the United States, the United Kingdom, France, China, Russia, and Germany met their Iranian counterparts in Istanbul for discussions about the Iranian nuclear program. Turkey did not take part in the negotiations and only served as the host of the event. The next meeting between this group of the five permanent members of the UNSC plus Germany (P5+ 1) and Iran is also scheduled to take place in Turkey.

Given the stakes, Ankara will likely remain an active diplomatic partner in the West's quest to resolve the Iranian nuclear crisis. However, Turkey has said over and over again that it believes Iran has the right to enrichment and nuclear technology. Ankara's position is very clear, it will support the UNSC sanctions but will leave the enforcement of unilateral American and European sanctions up to private Turkish businesses, despite the intense pressure to comply with these unilateral sanctions. Moreover, Ankara will remain staunchly opposed to any military action and will maintain that all avenues of diplomacy must be exhausted. However, the controversy surrounding the conclusion of the Joint Declaration has prompted Ankara to change tactics and work behind the scenes to ensure that its interests are being maximized.

Clearly, the desire to be a regional power and exert greater influence over regional affairs has contributed to Ankara's Iran position. Domestically, Turkey's own nascent nuclear program and its desire to develop its own indigenous nuclear program have greatly influenced its policy position. Moving forward, Turkey will continue to be an active player on the Iran front and push its inclusive and non-coercive policy solutions to this very difficult problem.

2.5 The NATO Debate and the Future of Tactical Nuclear Weapons

As part of its NATO commitment Turkey has hosted American nuclear weapons for nearly six decades. The weapons are deployed as part of NATO's collective security posture and, during the Cold War, were meant to deter a Warsaw Pact invasion. After the collapse of the Soviet Union, the weapons' strategic value waned, raising questions about their military value and whether or not the forward deployment of tactical nuclear weapons (TNW) enhances NATO security or not. While planning for the 2010 NATO summit in Lisbon, the Allies fiercely debated the status and practicality of the American TNWs in Belgium, Germany, Italy, the Netherlands, and Turkey. Many within the alliance advocated for their removal, while others opposed, saying they should remain until the nuclear threat to NATO is removed.

Turkey quietly supports maintaining the weapons on its territory and expects other NATO countries to continue their TNW stewardship as part of the Alliance's burden sharing principle. Turkey hosts an estimated 90 B-61 gravity bombs at Incirlik air force base near Adana. 50 bombs are slated for use by the American air force, with the other 40 to be delivered by the Turkish air force. The scenario raises a number of questions about these weapons' operational readiness because the United States does not permanently maintain a nuclear fighter wing at Incirlik and the Turkish air force is the only one in NATO not certified for nuclear missions. Should these weapons have to be used, the United States would have to fly in a nuclear fighter wing from another European country.

For Turkey, the forward deployment of American nuclear weapons strengthens the trans-Atlantic security partnership, and contributes to deterrence. Ankara has gone out of its way to emphasize its support for a nuclear weapons free world, but has acknowledged that these efforts will likely take many years, prompting the need to maintain a credible minimum deterrent until disarmament is achieved. Turkish security elites also view nuclear weapons as a status symbol, believing that their presence firmly solidifies the U.S. - Turkish defense partnership. There is an assumption that if the weapons were removed, Turkey's status in NATO would be negatively affected. In short, the weapons are not only for deterrence, but have a number of political implications and have come to symbolize the United States' commitment to Turkey's defense.

The Turkish position on TNWs is also shaped by the non-politicization of this issue. Despite being at the forefront of the Cuban missile crisis in 1962 as host to the Jupiter missiles, the question of nuclear weapons has not exactly been the subject of an internal debate in Turkey. Much unlike the Western European countries, there is no visible anti nuclear political force in the country. The Green movement is politically weak, almost to the extent of being non-existent. Remaining political parties have clearly prioritized the national security angle of the debate and have not developed an anti nuclear platform. Also from an economic standpoint, unlike the UK and Germany, Turkey does not face an imminent decision on the future of its Dual Capable Aircraft (DCA). The F-16s that are at the disposal of the Turkish Air Force do not have to be renewed until the mid 2030s. There is therefore no economic pressure that forces a decision on the Turkish policy makers.

American proponents of TNWs in Europe have long argued that their presence has dissuaded nuclear latent countries from pursuing an indigenous nuclear weapons program and that their removal would galvanize states to develop their own weapons to deter emerging threats. Some argue that Iran's controversial nuclear program could catalyze a Turkish nuclear weapons effort if the United States were to prematurely remove its nuclear weapons from Turkey. Susi Snyder and Wilbert van der Zeijden countered these claims in a report for IKV Pax Christi, writing that Turkish officials were "slightly offended by the suggestion, and pointed out that Turkish governments have consistently denied that they would even consider reneging on their NPT commitment and developing their own arsenal." In fact, Turkey indicated that it would support the withdrawal of American TNWs if it is consulted beforehand and NATO is operating in consensus. Premature removal by the Americans could hurt the alliance, but an alliance wide agreement would not be opposed by Ankara if a consensus could be reached. In its place, Ankara believes that NATO could rely on its conventional forces, or other strategic and non-strategic American nuclear forces for deterrence.

Discussions about the removal of TNWs have gained traction in recent years, prompting a number of discussions about the future of the NATO's nuclear mission. Thus far, Turkish officials haven't directly addressed the issue, suggesting a certain amount of reticence about throwing their full support behind TNW withdrawal. Despite this, the growing debate within NATO will likely force the alliance to address this topic in the not so distant future, prompting the need for a serious reevaluation of NATO's burden sharing principle. For Turkey, the forward deployment of American TNW speaks to the larger issue of nuclear of Turkey's stance on nuclear deterrence and how Ankara envisions reconciling its commitment to disarmament with its immediate security concerns.

2.6 Turkey's Viewpoint on Nuclear Deterrence

The theory of deterrence was first surmised shortly after the Soviet Union's first nuclear detonation in 1949. Frightened by Russian nuclear and rocket advances and the prospect of nuclear war, American nuclear planners worked hard to redefine war in the atomic age. American strategists such as Bernard Brodie, William Kaufmann, Albert Wohlstetter and Herman Kahn, among others, eventually agreed that the threat of massive nuclear retaliation would prevent either the Soviet Union or the United States from ever using nuclear weapons against one another. The theory of deterrence was predicated on each side maintaining a number of redundant early warning systems and a large number of delivery vehicles and nuclear warheads to ensure that an arsenal could not be destroyed in an initial first strike. As such, both sides built up a number of different launch platforms and built a robust command and control system to make sure that neither side would ever believe they could destroy the adversary's entire nuclear arsenal in the initial attack. The threat of mutually assured destruction held each side hostage for the duration of the Cold War and influenced the formulation of nuclear strategy.

With the Cold War raging, the United States entered into agreements with its NATO allies to extend the threat of retaliation against an adversary with nuclear weapons. Known as extended deterrence, the agreement obligates the United States to retaliate against a nuclear state with its own nuclear forces in the event that any NATO ally is attacked. In order to maintain credibility, reassure allies and decrease the likelihood of some European powers building its own nuclear weapons, the United States forward deployed nuclear weapons in Europe. The former Soviet Union made similar arrangement with the Warsaw pact countries.

In the past, Turkey's main reason for hosting American nuclear weapons was to deter its historic regional rival, the former Soviet Union. Turkey takes NATO's burden sharing principle very seriously, believing that this aspect of the agreement is the most critical for the maintenance of Turkish security. Events in the past, like the unilateral American decision to remove its medium range ballistic missiles (MRBMs) from Turkey, in exchange for the former Soviet Union to do the same in Cuba convinced many in the Turkish security establishment that the United States would sell out its allies if it were directly threatened with annihilation by the USSR. These feelings were exacerbated after the United States imposed an arms embargo on Turkey for its invasion of Cyprus in 1974. These suspicions can be traced back to hesitancy by many NATO member states to include Turkey in the Alliance over fears that its proximity to the unstable Middle East could embroil NATO in a Middle East war. The continued presence of American TNWs has come to symbolize NATO's commitment to Turkey's defense and is an important confidence building mechanism.

The direct link that the forward deployed nuclear weapons establishes between Turkey and the U.S. is also of relevance to those Turkish policy makers that are increasingly uncertain about NATO's willingness and ability to honor its Article 5 collective defense commitments. The episode during the first Iraq war in 1991 when the Turkish request to invoke Article 5 so as to obtain a NATO sponsored missile defense system was blocked for several weeks at the NATO Council is still fresh in the memory of the Turkish security establishment. This inability of the Alliance to act decisively at a time when Ankara believed to be under the threat of Saddam's WMD arsenal convinced Turkish policy makers to maintain their privileged security relationship with the US.

Since the end of the Cold War Turkish officials believe that the weapons deter its proliferation prone neighbors like Iran, Syria, and pre-2003 Iraq. Turkey was actively involved in the drafting of NATO's most recent "Strategic Concept", which stated:

> Deterrence, based on an appropriate mix of nuclear and conventional capabilities, remains a core element of our [NATO] overall strategy. The circumstances in which any use of nuclear weapons might have to be contemplated are extremely remote. As long as nuclear weapons exist, NATO will remain a nuclear alliance.

The debate about NATO's nuclear posture have taken place against the backdrop of growing international concern about Iran's advancing nuclear program. However, the debate about stationing these weapons in Europe is increasing and the calls to remove these weapons have grown louder in recent years.

During the run-up to the 2010 NATO Summit meeting in Lisbon, NATO members Belgium, Germany and the Netherlands openly opined for the reassessment of nuclear weapons in Europe and encouraged NATO to take steps to being about a nuclear free world. This is significant because these three countries are home to American TNW. Notably, Turkey and Italy, the only other two countries still home to TNW, remained silent and did not openly support the countries' removal efforts. While the swift withdrawal of American nuclear forces remains unlikely, the growing rhetoric surrounding their removal suggests that this issue will be intensely debated in the foreseeable future, potentially creating problems for Turkish defense policy in the medium term.

In short, Turkey believes that the stationing of nuclear weapons on its territory is the physical representation of NATO's burden sharing commitment and believes that their removal could undermine this. However Turkey would be willing to part with these weapons if the decision is made in consensus and not carried out or catalyzed by individual states. In the place of TNWs, some have suggested that an alliance wide ballistic missile defense (BMD) system could come to symbolize the Alliance's burden sharing principles.

2.7 The Missile Defense Debate: Turkey's Position Misunderstood by the West

After the fall of the Soviet Union, Turkish security planners became acutely aware of the threats posed by its Middle Eastern neighbors growing arsenal of ballistic missiles. This reevaluation of Turkey's main security threats coincided with the renewed emphasis in the United States and Israel on the development of ballistic missile defense (BMD) to defend against the growing missile threat in the Middle East. Turkish security planners, who have long harbored suspicions about the intention of regional leaders, concluded that they should explore BMD, or run the risk of being vulnerable to retaliatory missile strikes should hostilities break out in the Middle East.

Given the technical constraints in Turkey's domestic defense industry, officials turned to a number of foreign suppliers for BMD. They concluded that the joint U.S. - Israel Arrow system would best serve Turkey's immediate security needs because the system has been engineered to counter the missiles deployed by Turkey's Middle Eastern neighbors. Between 1996 and the mid-2000s, Turkish and Israeli officials held dozens of meetings about the sale of Israel's powerful Green Pine Radar and its Arrow II interceptor. The United States was initially opposed to the system's export, but eventually acquiesced and encouraged Israel to deepen discussions with their Turkish counterparts. The United States provides most of the funds for the Arrow program, making the formal approval of the U.S. and Israeli government necessary for export.

Despite the lengthy discussions, diplomatic, financial, and logistical problems prevented Ankara from acquiring BMD. Ankara has continued to pursue BMD, but has expanded the list of potential suppliers to include potential systems like the USA's Patriot, Russia's S-400, China's FD-2000 and the Eurosam Samp-T produced by a French-Italian partnership in spite of its previous procurement difficulties. The project is reportedly meant to be separate from the larger missile defense shield that NATO wants to deploy through out Europe to protect the alliance from Iranian missiles.

During the 2010 NATO summit in Lisbon, the twenty-eight allies fiercely debated whether to adopt BMD as an alliance wide mission. The Obama administration was seeking to integrate the United States BMD system with that of its European allies to better defend against Iranian ballistic missiles. The Turkish position was the source of great consternation and misunderstanding during the debate. Turkey maintained that BMD should not worsen it relationship with neighboring countries, that the system should cover all Turkish territory, and that BMD components on Turkish territory should be operated by the Turkish military.

An agreement was reached only after the allies agreed not to name Iran and Syria as specific threats, and to put off any decisions about who will operate the system, in accordance with Turkish demands. Turkey also agreed to host the early warning radar in its territory.

Turkey's reluctance to name Iran and Syria as specific threats was grossly misunderstood by the international press and the other NATO allies. Ankara worried that specifically naming Iran, as a threat to the Alliance, would prompt hardliners in Tehran to accelerate their missile and nuclear programs to defeat the system. In general, BMD as a concept is controversial because a robust system, if it were technically effective, has the potential to upset strategic stability. Opponents of the system argue that it may encourage the BMD target state to develop systems to overwhelm and defeat even the most advanced BMD system.

In light of these facts, the Turkish delegation chose to tread carefully and limit any bellicose rhetoric that could encourage the Iranians to accelerate their missile and WMD programs. Turkey adopted a capabilities approach and called on its NATO partners to consider all states with ballistic missile capabilities when deploying the system. In addition, officials believe the system should be defensive and not single out any country as a target. Turkey believes naming threats would only hasten the desire to develop the counter measures to defeat BMD.

2.8 The 2012 Conference on a Nuclear Free Middle East

In the past, Turkey quietly supported efforts to establish a Middle East Nuclear Weapons Free Zone (MENWFZ), but never considered becoming part of any agreement because it hosts American TNWs. Fears of a Soviet led invasion strongly influenced security planning and reinforced the military utility of TNWs. However, changing threat perceptions since the end of the Cold War combined with growing threats posed by illicit procurement networks, non-state actors and the proliferation of WMD have led to a change in Turkish rhetoric.

Article VII of the NPT maintains the "right of any group of States to conclude regional treaties in order to assure the total absence of nuclear weapons in their respective territories." A nuclear weapons free zone (NWFZ) is a specific region where countries agree not to manufacture, possess, acquire, or test nuclear weapons. Currently, NWFZs cover 116 countries, including the entire Southern Hemisphere. Besides barring the development of nuclear weapons, NWFZs "provide signatories with negative security assurances – a pledge from the five NPT nuclear weapon states not to use or threaten to use nuclear weapons against zone member states."

Beginning in 1974, Egypt and Iran first proposed the establishment of Middle East Nuclear Weapons Free Zone (MENWFZ). The UN General Assembly has adopted a number of Resolutions supporting the idea since then, and a UN study laid out the steps for implementing a MENWFZ in 1991. These efforts were bolstered shortly after the first Gulf War, when the UNSC passed Resolution 687, which endorsed the establishment of a MENWFZ. Delegates at the 1995, 2000 and 2010 Review Conferences (Revcon) also adopted Resolutions calling for the implementation of a MENWFZ.

Efforts to establish a MENWFZ have been stymied by strong opposition from Israel, the region's only nuclear power. As a precondition for negotiations, Egypt and other Arab nations insisted on Israel accession to the NPT as a non-nuclear state as a prerequisite for negotiations, while Israel has said it would support a MENWFZ if a comprehensive peace agreement with all of its neighbors could be reached. Efforts to address this impasse dominated negotiations at Subsidiary Group 2 – the sub-committee tasked with finding a way to implement the 1995 Revcon Action Plan. Eventually, negotiators were able to address concerns expressed by the United States, which was negotiating on Israel's behalf, and the Arab states on a draft calling for "an initial" conference on establishing a MENWFZ in 2012.

Components from the draft were eventually included in the 2010 Revcon Final Document. The final document commits the United States, Russia and the United Kingdom (the three co-sponsors of the 1995 Middle East Resolution at the Revcon) to convene a conference to be attended by all regional states, "on the establishment of a Middle East zone free of nuclear weapons and all other weapons of mass destruction, on the basis of arrangements freely arrived at by the States of the region, and with the full support and engagement of the nuclear-weapon states."[4]

Before and after the 2010 Revcon, Turkey strongly advocated for the global community to take concrete steps to hasten the implementation of MENWFZ. In April 2011, Foreign Minister Davutoglu joined his counterparts from Australia, Canada, Chile, Japan, Germany, Mexico, the Netherlands, Poland and the United Arab Emirates in Berlin to discuss ways to expedite the implementation of the Action Plan. Following the meeting the Group of 10 (G10) released a statement calling on the international community "to work towards achieving nuclear disarmament and a strengthening of the international non-proliferation regime." Amongst their proposals is call for "a Middle East free of nuclear weapons and all other weapons of mass destruction." As a member of the G-10, the Turkish Foreign Minister took the primary responsibility among his peers to advance the agenda of 2012 conference on the MENWFZ. Turkey is also interested in being the host for this conference, though Finland and the Netherlands are the most likely candidates.

Turkey's vocal push to hasten the implementation of a MENWFZ has coincided with the rapid deterioration of Turkish-Israel relations following the killing of 9 Turkish citizens aboard the Mavi Marmara. It has also come at a time when Washington and Brussels have increased their efforts to isolate Iran for its controversial nuclear program. The Turkish position has angered some in Washington who believe that Erdogan's very public calls for the establishment of MENWFZ are an overt rebuke of Israel's nuclear program and distract from global efforts to limit Iran's nuclear program. Washington has made it abundantly clear that they wish to de-couple these two issues and pursue each issue independently. Thus far, Turkey has shown little interest in de-coupling the issues of the Israeli nuclear program, Iran's nuclear program and nuclear proliferation in the Middle East. Turkey sees all of these issues as interconnected, believing that the establishment of a MENWFZ would go a long way to stabilize the region and decrease tensions.

4- "Final Document," 2010 Review Conference of the Parties to the Treaty on the Non-Proliferation of Nuclear Weapons, http://www.un.org/ga/search/view_doc.asp?symbol=NPT/CONF.2010/50%20 (VOL.I).

3 Would Turkey Build the Bomb?

3.1 A Theoretical Debate

Despite Turkey's technological limitations, history has shown that states willing to commit resources and time can overcome the technical obstacles and successfully develop first generation nuclear weapons. However, most nuclear-capable states have chosen to remain non-nuclear. The decision to pursue nuclear weapons is rooted in technical capability combined with decision maker intent. At the moment, policy makers worry that an Iranian nuclear weapon will force its neighbors to explore the nuclear option. The oft-repeated argument claims that an Iranian nuclear weapon will lead to a regional arms race. Turkey, along with Egypt and Saudi Arabia, are the countries most often cited as the countries most likely to develop indigenous nuclear capabilities to counter Iran.

In 2009, Brent Scrowcroft, the former National Security Advisor to both Presidents Gerald Ford and George H.W. Bush, told the Senate Foreign Relations committee, "If Iran is allowed to go forward, in self-defense or for a variety of reasons we could have half-a-dozen countries in the region and 20 or 30 more around the world, doing the same thing, just in case." U.S. Secretary of State Hillary Clinton told a Senate Appropriations subcommittee, "A nuclear-armed Iran with a deliverable weapons system is going to spark an arms race in the Middle East and the greater region." The most anti-Iranian hawk in the United States, former Bush Administration official John Bolton told the United States House of Representatives' Committee on Foreign Affairs, "If Iran obtains nuclear weapons, then almost certainly Saudi Arabia will do the same, as will Egypt, Turkey and perhaps others in the region, and we risk this widespread proliferation even if it is a democratic Iran that possesses nuclear weapons."

These warnings about a Middle Eastern regional arms race are eerily similar to the dire Cold War era warnings about the likelihood of a global nuclear arms race. In 1957, a secret CIA National Intelligence Estimate (NIE) concluded, "within the next 10 years countries could, by exploiting the potential of their nuclear research and power programs, produce at least a few nominal (20-40kt) nuclear weapons using only native resources." Believing that only France, Canada, Sweden and West Germany had the financial wherewithal to pursue an indigenous capability, the United States worried that a European weapons efforts would spark a cascade of proliferation beginning in East Germany and ending in Japan. These worries contributed to the American decision to forward deploy nuclear weapons at military bases through out Europe.

In both cases, policy makers assumed that in an anarchical self help world, individual states will logically seek out nuclear weapons to defend themselves from annihilation. While useful, the neo-realist/realist security paradigm fails to explain the relatively small number of states with nuclear weapons, compared to the large number of states capable of building those weapons. In reality, states are subjected to a series of proliferation constraints and the decision to proliferate is rarely easy.

A Turkish decision to proliferate would seriously complicate its international standing, undermine its economic resurgence and seriously damage relations with the United States and its other NATO allies. Moreover, any Turkish move towards weaponization would draw a harsh rebuke from the United States and would likely be met by an American proposal to strengthen security guarantees, as well as the threat of sanctions if Turkey were to continue its weapons efforts. Given Turkey's non-nuclear history and its long-standing reliance on the NATO security guarantee, it is hard to imagine a scenario where Turkey would simply cast aside its long-standing non-nuclear policy in favor of an independent weapons capability.

Turkish policy makers have, in fact, been quietly dealing with the pressures of Iran's nuclear program since the mid-1990s. Ankara has actively sought an independent missile shield to counter the growing threats posed by the proliferation of ballistic missiles. In tandem, it has adopted a conciliatory foreign policy favoring robust diplomacy and economic cooperation. The policy is aimed at decreasing regional tension, which officials believe will lessen Iran's incentive to go nuclear, while developing technologies to protect Turkey from Iranian missiles.

Instead of developing its own nuclear weapons capability, Turkey seems more interested in pursuing robust conventional capabilities that could, in theory, replace some of the missions previously reserved for nuclear weapons. To do so, Turkey has turned to foreign suppliers, but has also committed to begin designing and manufacturing hi-tech weapons domestically. Turkey's changing military posture is aimed at countering the threats posed by non-state actors and bolstering Turkey's conventional war fighting capabilities. Interoperability with NATO forces remains the key component of Turkey's defense policy and it is unlikely that Turkey would threaten its membership with its most important allies.

As a whole, Turkish actions and statement suggest that Ankara will remain committed to the NATO security guarantee, while developing indigenous capabilities to increase its intelligence, surveillance and information management capabilities. The presence of NATO nuclear weapons in Turkey, as well as Turkey's membership in the Alliance underpins its long-term defense strategy. Abandoning the Alliance or undertaking an illicit nuclear program would seriously derail defense planning and undermine Turkish security. A far more likely response to an Iranian nuclear weapon would be a re-evaluation of the battle readiness of the B-61s at Incirlik air base, as well as the acquisition and training of nuclear capable front line fighters. Together, these two moves would reinforce the underlying principle of deterrence, which stipulates that a credible deterrent rests on the willingness and ability to use nuclear weapons. Turkey would also be likely to speed up the deployment and development of BMD. More broadly, Ankara will be pushed closer to the United States and would likely join American efforts to contain Iran.

In the absence of a NATO security guarantee Ankara's security situation would change dramatically and could pressure the government to explore developing nuclear weapons capability. It is an open secret that Turkey has not been very comfortable with the robustness of the Alliance's commitment to come to Turkey's defense. Turks vividly remember NATO hesitance to deploy missile interceptors in 1991 during the first Gulf War. As outlined before, the maintenance of the American TNWs on Turkish soil has a deep political meaning and represents the American commitment to Turkish defense.

If a nuclear decision were to be made, Turkey would first have to acquire the necessary infrastructure to produce fissile material. The initial nuclear weapons effort would probably come in the form of a government directed feasibility study, followed by a sustained government led push for nuclear weapons and, if successful, the eventual acquisition of a nuclear device.

3.2 Turkey's Nuclear Infrastructure: Could Turkey Build the Bomb?

Turkey doesn't have the necessary infrastructure to produce fissile material for a nuclear weapon, nor does it have the relevant infrastructure to mine uranium, enrich uranium or reprocess spent nuclear fuel. Without this vital infrastructure, Turkey could not indigenously manufacture the fissile core for a nuclear weapon. However, the designs for first generation nuclear weapons are widely understood and it is likely that that Turkish physicists are technically capably of fashioning first generation nuclear weapons, if the leadership were to give the go ahead. If the Turkish leadership were to decide to build a nuclear weapon, it would almost certainly start by designing a simple "gun type" or first generation implosion type device.

The "gun-type" bomb is by far the easiest weapon to build. The basic bomb design contains a gun barrel, pointed at a sub-critical highly enriched uranium (HEU) target. To start the chain reaction, another sub-critical HEU projectile is fired at the HEU target. Once combined, the two components start the nuclear chain reaction, resulting in a nuclear explosion. 90 percent HEU is the most effective material for this style of weapon, but a bomb could be made to work with 80 percent HEU.

An implosion bomb, works by precisely squeezing the weapon's plutonium core with conventional explosives, which detonate precisely and squeeze the sub-critical fissile core to achieve criticality. The explosive shock wave also compresses the nuclear initiator, releasing a burst of neutrons, which augment the chain reaction. It was this style weapon, that American Manhattan Project scientists tested on 9 August 1945 in the New Mexico desert. The plutonium core came from plutonium production reactors in Hanford, Washington. For weapons use, bomb designers need about 6 kgs of 90 percent plutonium-239 (Pu-239).

Typically, a proliferating state attempts to develop the complete nuclear fuel cycle because the technologies allow would-be proliferators to indigenously produce the necessary fissile material for weapons use under the guise of a civilian power program. The nuclear fuel cycle is the preparation of uranium for use in a nuclear reactor or nuclear weapon. The process involves the mining and milling, conversion, enrichment and fuel fabrication. These steps make up the front end of the nuclear fuel cycle. After spending time in a nuclear reactor, the spent fuel may undergo a further series of steps including temporary storage, reprocessing, and recycling before eventual disposal as waste.

The process to create and recycle nuclear fuel for civilian reactors is nearly identical to the processes for the production of weapons usable fissile material. In the past, suspicions have been raised when developing countries have sought to acquire the complete fuel cycle. To date, Turkey has not announced any plans to develop or acquire fuel cycle technology, despite its robust commitment to pursue nuclear energy. However, it has not ruled out developing or acquiring enrichment or reprocessing technologies in the future.

3.2.1 Turkey's Front End Capacity

Mining: This refers to the process of extracting uranium, or other fissile materials like Thorium, from the ground. Despite having deposits of uranium and thorium scattered through out Anatolia, Turkey does not have the infrastructure to mine uranium commercially.

Milling: Once extracted, the mined uranium is taken to a mill, where it is crushed and turned into uranium "yellowcake". Beginning in 2009, the MTA Laboratory in Ankara began producing uranium hexafluoride on a small scale. Small-scale uranium purification is also done at the Nuclear Fuel Facility Unit.

Conversion: Conversion refers to the process of converting the milled uranium into uranium hexafluoride gas (UF6). Turkey has no facilities designed and dedicated to the conversion of uranium, although it converts natural uranium to uranium oxide (UO2) on a limited scale. The UO2 can be used in heavy water reactors, which don't require enriched uranium.

Enrichment: When mined, natural uranium is 99.3 percent Uranium-238 (U-238) and .7 percent Uranium-235 (U-235). The fuel for a majority of the world's nuclear reactor requires a 3 - 5 percent concentration of U-235. Enrichment is achieved using gaseous diffusion, gas centrifuge or laser isotopic separation. Turkey does not possess any commercial scale enrichment centers, nor have plans been announced to acquire or construct one. However, it has refused to rule out acquiring the technology in the future.

The process to enrich weapons grade uranium is very similar to the civilian enrichment process. If a country were to choose to develop a nuclear weapon, it would simply repeat the process until the desired purity is achieved. A nuclear weapon needs between 80 and 90 percent enriched uranium. For example, the uranium bomb used by the United States in Hiroshima used 64 kg of 80 percent uranium. The resulting yield is estimated to be between 13 and 18 kilotons. The enriched uranium was produced using a gaseous diffusion plant in Oak Ridge, Tennessee.

Fuel Fabrication: After enrichment, the UF6 is converted back into UO2 and pressed into pellets for use in a nuclear fuel rod. Since 1986, the CRNC Fuel Pilot Plant has, on a small scale, been producing UO2 pellets suitable for use in a nuclear reactor.

3.2.2 Turkey's Back End Capacity

- **Reprocessing:**

Plutonium containing 90-95 percent of Plutonium-239 (PU-239) is weapons grade. To produce weapons grade PU-239 the uranium fuel rod should only spend a few weeks in the reactor core to prevent the build up of the isotope plutonium-240 (PU-240).

Civil power reactors are operated at a higher burn-up, in order to maximize the energy output from the fissile material. In the nuclear weapons context, heavy water reactors are better suited for plutonium production. The vast majority of reactors in the world are light water reactors, which are not ideally suited for weapons grade plutonium production.

After being irradiated in the reactor core, the plutonium is separated from the irradiated fuel rods. In contrast, most spent fuel from civilian power programs is reprocessed and held in store. The PUREX process separates plutonium, uranium, and the transuranics by dissolving spent reactor fuel in nitric acid. The fuel rods cladding is removed to expose the irradiated fuel. The contents of the fuel rod are then dissolved in nitric acid solution and the cladding is removed and discarded as nuclear waste. The solution is exposed to tributyl phosphate mixed with kerosene, where the transuranics are separated from the plutonium and uranium. After the plutonium and uranium have been separated plutonium nitrate and uranium nitrate remain in the solution. Plutonium is generally converted into an oxide for transport and storage, or machined for use in the core of a nuclear weapon.

It is unlikely that Turkey could quickly or easily acquire a reprocessing capability because the supplier states have tightened export restrictions and have only transferred a small number of equipment in recent years. Turkey also does not have any nuclear reactors.

Turkey's agreement with Russia is for the construction of 4 Standardized VVER-

1000s (known in Europe as the MIR-1200 or Modernized International Reactor). While not impossible, these light water reactors are not ideally suited for the production of weapons grade plutonium. Moreover, Russia plans to deliver a "turnkey" reactor and repatriate all of the spent nuclear fuel. Russia will provide the fuel rods, oversee and operate the plant, and then remove the spent fuel. Turkey will not have access to the fuel rods, nor will it have access to accumulated spent fuel.

Turkey has invested in a number of technologies needed to form the basis of a civilian nuclear energy program. However, its lack of commercial scale enrichment and reprocessing technologies make it unlikely that Turkey could quickly develop a nuclear weapon. Given the nascent state of its nuclear industry, as well as the difficulties involved with the development of commercial scale enrichment and reprocessing, Turkey would likely have to rely on foreign suppliers for fuel cycle technology. As outlined in the export control section above, the international community closely controls these technologies. However, the rise of illicit procurement networks, as well as the spread of technological know how does not preclude states from developing enrichment technologies by themselves.

Turkey has a stellar history of nonproliferation and has signed on to every relevant IAEA and international instrument governing the spread of nuclear technology. Moreover, it is a member of NATO and a EU candidate country. It is unlikely, absent a rupture in relations with its NATO allies or a significant change in its security environment or drastic re-evaluation of Ankara's immediate interests by the civilian leadership, that Turkey would consider developing nuclear weapons illicitly.

For much of the Cold War, Turkey faced a nuclear-armed adversary. Instead of developing a small nuclear arsenal, Turkey chose to ally itself with the United States. Iranian nuclear weapon would alter the balance of power and significantly constrain Turkish freedom of action in the region. If this were to occur, it is far more likely that Turkey will continue with its decades' old policy of relying on NATO's nuclear policy for deterrence.

Turkey is desperate to prevent this scenario. Turkish policy makers constantly remind their Western counterparts that they have no desire to become a "front line" state again. Ankara's return to the Middle East is in part driven by a belief that economic integration, interdependence and friendly relations are more effective than sanctions and threatening language. The Turkish policy has thus far revealed a state more interested in pursuing soft power solutions to foreign policy problems. If faced with a nuclear trigger, Ankara would likely continue its neo-liberal approach by strengthening ties with the traditional guarantors of its security.

4 Conclusion: To What Extent is Turkey Prone to Pursue an "Independent" Policy from the West in the Nuclear Sphere?

One of the core tenants of the "zero problems" foreign policy is the desire to balance relations between Turkey's traditional Western allies with neighbors in the region. In a departure from its previous policy, Turkey has been more willing to shrug off Western political pressure, in favor of establishing closer ties with its neighboring countries. The most obvious example is Ankara's unwillingness to go as far as it Western allies in condemning Iran for defying the IAEA and for its refusal to answer a number of outstanding questions about its previous nuclear activities. This reluctance has sparked some in the West to openly question whether or not Turkey can still be counted on as a steadfast Western ally.

Turkey's change in rhetoric coincided with the shift away from Cold War thinking towards a more inclusive regional strategy, which at its core is an effort to promote regional stability and economic development. As a centerpiece of its domestic political agenda, the Turkish government has invested heavily in large-scale infrastructure improvement projects. In some cases, these projects have affected Turkish foreign policy. For example, the decision to pursue nuclear energy is a domestic decision with broader foreign policy implications. The government has clearly identified nuclear energy as a useful alternative to imported fossil fuels and has made it a national priority to develop nuclear power. However, given the country's technical restraints, Turkey will have to rely on foreign suppliers for nuclear technology for the foreseeable future, which naturally leads to an overwhelming interest in ensuring that the three pillars of the NPT are not eroded by the efforts of some of the Western nuclear suppliers nations. Concerns about Western overreach in this area have fueled Turkey's very public pronouncements of Iran's right to enrich.

Turkey and its Western allies share a common interest in ensuring that Iran does not develop a nuclear weapon. Turkish security and government officials worry that an Iranian nuclear weapon will disrupt the balance of power in the region and undermine Turkish security interests, a concern shared by officials in Washington and Brussels. However, differences lie in how Turkey and the West are seeking to resolve the Iranian nuclear crisis. The West has adopted a coercive sanctions based policy, while Turkey has shunned this policy in favor of a "soft power" approach. The disagreement is spurred on by divergent opinions about the practicality of isolating the Iranian regime, domestic politics and simple economics. Turkey believes that sanctions strengthen the nuclear hardliners in Iran and the West believes sanctions limit Iran's incentives to push forward with its nuclear program. This divergence in opinion culminated in the West's annoyance over the Turkey-Iran-Brazil Joint Statement and Turkey's subsequent refusal to support UNSC 1929.

Turkey's willingness to defy the United States at the UNSC speaks volumes about Ankara's new security outlook and willingness to pursue a more independent policy to achieve regional security objectives. In this respect, it is fair to say that if the policies being pursued by the Western powers clash with Turkish national security interests then Ankara will be hesitant to support it. Another example of Ankara's willingness to shun Western pressure is its recent efforts to expedite the implementation of a MENWFZ. Turkey has always supported a MENWFZ but remained largely silent about its implementation before adopting a much more proactive policy stance in recent years.

However, with regards to Turkey's TNW policy, the opposite is true. Turkey has maintained its Cold War era policy of support because it sees these weapons as a representation of NATO's collective security agreement, which is the centerpiece of the country's defense strategy. Ankara is hesitant to fully back other NATO member state calls to have discussions about the removal of TNWs, joining Italy in its quiet support for the maintenance of their deployment. In this respect, Ankara remains anchored to its NATO allies and the collective security guarantee.

Perhaps, the most strident example of Ankara's foreign policy balancing efforts was its BMD position during the NATO negotiation in 2010. On the one hand, Turkey's historical pursuit of BMD shows that it recognizes the threat posed by the proliferation of ballistic missiles. However, like Ankara's stance on how best to solve the Iranian nuclear issue, Turkey is wary of signaling out Iran as the reason for the system's deployment over fears that threatening the Islamic Republic will only make some in Tehran more likely to choose to rapidly build up its arsenal of ballistic missiles. During this debate, Ankara supported the concept of BMD, but made sure that Iran or Syria were not mentioned as a threat to NATO in the final document. Turkey successfully balanced Western demands with those of Iran and other States in the region.

Moving forward, Turkey will likely continue to pursue an interest-based foreign policy, which may at times, clash with the goals of the West. The re-election of the AKP in the June 2011 elections will ensure some level of political continuity in the short to medium term in the Turkish foreign policy. The strong popular mandate given to the ruling party will also be interpreted by the AKP leadership as a vindication of the more assertive and ambitious foreign policy that now underpins Ankara's approach to international relations. The election results demonstrate that the AKP's foreign policy narrative has become the overriding paradigm for a significant part of Turkish public opinion. Having received a renewed, strong popular mandate, the government in Ankara will be all the more comfortable in its role as a regional power, even if this means remaining at odds with the country's partners in the West.

In the long term, the erosion of the military's influence over national security policy could increase further, making it far more likely that the nexus between civilian electoral politics and foreign policy will get stronger. With regards to the nuclear issue, Turkey's current positions on NPT Article IV rights and its opposition to some of the proposed NSG supply side controls won't likely change. Developing nuclear power is a long-term development goal tied to a number of tangential domestic issues like economic development and self-sufficiency, as well as country prestige. In this regard, Turkey's position mirrors closely the rhetoric from other non-nuclear states aspiring to develop a civil nuclear program. Turkey is among a number of states that object to stringent supply side controls to limit the spread of enrichment and reprocessing technology and the United States' "black box" and "turn key" proposals. These positions point to a future where Turkey's nuclear energy policy is fully integrated with efforts to develop nuclear energy.

Turkey's non alignment with its traditional partners in the West on a number of issues related to nuclear and non proliferation policy should not however be taken as an indication that the Turkish policy elites harbor designs of developing a nuclear weapons program. The level of democratic maturity reached in Turkey and the long standing anchoring of Ankara within the Western precludes such an outcome. Turkish policy makers take offense in such unfounded and simplistic allegations. From the foreign policy as well, the development of concealed nuclear weapons program is devoid of a rational. Turkey's goal is to enhance its position as a pivotal and central state based on an extension of its soft and smart power. This vision is surely incompatible with becoming the next rogue state of the region, which would be a sure recipe for losing elections in democratic societies. Even in a scenario where Iran would end up acquiring nuclear weapons despite all the efforts of the international community, the Turkish reaction would be to fully take part in the emerging strategy for containing Tehran.

Ankara remains committed to the global nonproliferation regime. However, recent actions clearly show that Turkey is not willing to make concessions on issues it sees as vital for its nuclear energy future. By doing so, Ankara has joined a number of nuclear aspirants seeking to establish indigenous nuclear capabilities regardless of international demands to curtail the spread of enrichment and reprocessing technologies. By 2020, Ankara is hoping that its first Russian built reactor will be online, providing power for Turkey's energy hungry market. As a byproduct of this audacious ambition, Turkey has stepped up rhetoric related to its Article IV rights, joining like-minded states through out the world. Far from being unique, Turkey's position reflects a number of new or non-nuclear states eager to diversify sources of energy and capitalize on the diffusion of nuclear energy.

The evolution of the nuclear industry from a handful of suppliers concentrated in the Western world to a diffuse industry spanning the globe, has increased potential suppliers and sources of nuclear know how for these nuclear aspirants. The diffusion has had a tangible affect on the international instruments designed to prevent proliferation. As access to nuclear technology increases and the number of suppliers grow, the influence of old nuclear powers has waned, creating a new block of nascent nuclear states determined to ensure their access to nuclear technology. Casting a shadow over these developments is Iran's controversial nuclear program. Moving forward these new and emerging nuclear nations will have to balance their nuclear desire, with international efforts to prevent the spread of dual use technologies.

The Turkish government's unwavering desire to achieve technical and energy self-sufficiency will tangentially affect every issue related to the government's nonproliferation policy, forcing it balance the stringent demands of the traditional powers with the newly emerging states. In this regards, Turkey will likely work diligently to ensure that the spirit of the NPT is not threatened by tighter supply side controls, while maintaining every NPT states right to access nuclear technology. However, on the security side, Turkey has maintained that its NATO participation is the centerpiece of its national security strategy, so it is likely that Turkey will continue to support, or at least help shape, NATO's future security strategies. In this context, Turkey recent nuclear policies reflect closely its states desire to balance relations with its traditional Western with its Middle Eastern neighbors. The current trajectory of Turkey's new foreign policy outlook is unlikely to change in the near-to-medium term, making it likely that Ankara will have to continue explaining its nuclear future to its new and old allies.

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Appendix I

Agreement Between the Government of the Russian Federation on Cooperation in Relation to the Construction and Operation of a Nuclear Power Plant at the Akkuyu Site in the Republic of Turkey

Ap-I

AGREEMENT BETWEEN THE GOVERNMENT OF THE REPUBLIC OF TURKEY AND THE GOVERNMENT OF THE RUSSIAN FEDERATION ON COOPERATION IN RELATION TO THE CONSTRUCTION AND OPERATION OF A NUCLEAR POWER PLANT AT THE AKKUYU SITE IN THE REPUBLIC OF TURKEY

PREAMBLE

The Government of the Republic of Turkey (the Turkish Party) and the Government of the Russian Federation (the Russian Party),

taking into account that both the Republic of Turkey and the Russian Federation are members of the International Atomic Energy Agency and are parties to the Treaty on the Non-Proliferation of Nuclear Weapons of 1 July 1968;

noting that the Republic of Turkey and the Russian Federation are parties to the Convention on Early Notification of a Nuclear Accident of 26 September 1986, the Convention on Nuclear Safety of 17 June 1994 and the Convention on the Physical Protection of Nuclear Material of 26 October 1979;

taking into account the Agreement between the Government of the Republic of Turkey and the Government of the Russian Federation on Early Notification of a Nuclear Accident and Exchange of Information on Nuclear Facilities of 6 August 2009;

also noting that, the Republic of Turkey is in the process of acceding to and the Russian Federation is a party to the Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management of 5 September 1997;

recognizing that the Republic of Turkey is a party to the Paris Convention on Third Party Liability in the Field of Nuclear Energy of 29 July 1960 and the Joint Protocol Relating to the Application of the Vienna Convention and the Paris Convention of 21 September 1988 and the Russian Federation is a party to the Vienna Convention on Civil Liability for Nuclear Damage of 21 May 1963;

seeking to make more efficient the cooperation between the Parties in the field of the peaceful use of nuclear energy based on the Agreement between the Government of the Republic of Turkey and the Government of the Russian Federation for Cooperation in the Energy Field of 15 December 1997;

following the provisions of the Agreement between the Government of the Republic of Turkey and the Government of the Russian Federation on Cooperation in the Field of Peaceful Use of Nuclear Energy of 6 August 2009 and the Protocol between the Ministry of Energy and Natural Resources of the Republic of Turkey and the Ministry of Energy of the Russian Federation on Cooperation in the Sphere of Nuclear Power of 6 August 2009;

noting the rights and obligations of the Parties under the Agreement between the Government of the Republic of Turkey and the Government of the Russian Federation on the Promotion and Reciprocal Protection of Investments of 15 December 1997; and referring to the Joint Statement of the Minister of Energy and the Natural Resources of the Republic of Turkey and the Vice Prime Minister of the Russian Federation Concerning Cooperation for Construction of a Nuclear Power Plant in the Republic of Turkey dated 13 January 2010,

have agreed as follows:

ARTICLE 1
DEFINITIONS

In addition to terms defined elsewhere in this Agreement, the following definitions shall apply throughout this Agreement:

Agreement means this agreement between the Government of the Republic of Turkey and the Government of the Russian Federation on Cooperation in relation to the Construction and Operation of a Nuclear Power Plant at the Akkuyu Site in the Republic of Turkey.

Authorized Organizations means the Competent Authorities, the Turkish Organizations and the Russian Organizations.

Competent Authorities means the authorities (and their replacements) designated by the Parties under Article 4 of this Agreement.

Project Agreements means each agreement in connection with the Project between:

(a) the Turkish Party or any entity that (as at the date of this Agreement or subsequently) is controlled (directly or indirectly) or majority owned (directly or indirectly) by the Turkish Party; and

(b) the Project Company, any Project Participant and/or the Russian Party,

including, but not limited to the Power Purchase Agreement for the Project Company.

IAEA means International Atomic Energy Agency.

Joint Protocol means the Joint Protocol Relating to the Application of the Vienna Convention and the Paris Convention of 21 September 1988.

MENR means the Ministry of Energy and Natural Resources of Turkey.

NPP means the nuclear power plant to be constructed at the Site as part of the Project including, without limitation, the nuclear island(s), the turbine island(s), the balance of plant and all ancillary infrastructure located on the Site.

Nuclear Fuel means nuclear fuel in the form of complete control and fuel assemblies.

Paris Convention means the Paris Convention on Third Party Liability in the Field of Nuclear Energy of 29 July 1960.

Parties means the Turkish Party and the Russian Party.

Power Purchase Agreement (PPA) means an agreement between Turkish Electricity Trade and Contracting Co. Inc. (TETAŞ) and the Project Company regarding the purchase and sale of the electricity generated by the NPP.

Project means the Akkuyu nuclear power plant project which shall include, without limitation, site investigations, design, construction, commissioning and operation for its entire operational life of the NPP, waste management and its decommissioning.

Project Company means a joint stock company established under the laws and regulations of the Republic of Turkey for the purpose of implementing the Project including but not limited to the operation of the NPP.

Project Participants means any member of the Project Company's supply chain including, without limitation, each contractor and subcontractor (of any tier) of the Project Company or any of its debt providers and direct or indirect equity investors.

Rosatom means the State Atomic Energy Corporation "Rosatom" of the Russian Federation.

Russian Organizations means any Russian state controlled organization which is authorized by the Russian Competent Authority for the relevant purpose.

Site means a ground area at Akkuyu in Mersin Province of the Republic of Turkey, which is, at the date of this Agreement, owned by Electricity Generation Co. Inc. of the Republic of Turkey (EÜAŞ) and to be allocated to the Project Company.

Turkish Organizations means any Turkish state controlled organization which is authorized by the Turkish Competent Authority for the relevant purpose.

Unit 1, Unit 2, Unit 3 and Unit 4 means the first, the second, the third and the fourth VVER 1200 (AES 2006 Design) type power units of the NPP.

ARTICLE 2
APPROVAL OF THE PROJECT

The Parties hereby approve the implementation of the Project in accordance with this Agreement. Unless otherwise provided by this Agreement, the Parties shall implement this Agreement in accordance with Turkish national laws, regulations, including all Turkish license requirements.

ARTICLE 3
PURPOSE AND SCOPE

1. The Parties shall cooperate in relation to the Project.
2. Such cooperation shall apply, but not be limited to, the following matters:
   2.1. designing and constructing the NPP;

2.2. developing and constructing the infrastructure, including, without limitation, infrastructure related to grid connections, required for the Project's implementation;

2.3. managing the Project's implementation;

2.4. ensuring the reliable quality of the Project at all stages of the design, construction and operation of the NPP;

2.5. the commissioning of the NPP;

2.6. the safe and reliable operation of the NPP;

2.7. the purchase and sale of the electricity generated by the NPP;

2.8. the upgrading, testing and maintenance of the NPP;

2.9. the provision of spare parts to address wear and tear in connection with the NPP during its whole operating life;

2.10. the development and use of diagnostics and inspection arrangements with respect to equipment operation for the NPP;

2.11. the training and retraining of operating personnel for the NPP;

2.12. the development and use of technical training facilities, including simulators, for the training of operating personnel for the NPP;

2.13. scientific support in connection with the safety of the NPP;

2.14. physical protection of the NPP;

2.15. the integrity and physical protection of nuclear and radioactive materials at or in transit to or from the NPP;

2.16. the supply of fresh nuclear fuel;

2.17. decontamination and safe management of radioactive waste from the operation of NPP;

2.18. designing, manufacturing, developing and fabricating systems, equipment, components and materials for use in the construction and operation of the NPP;

2.19. safety management with respect to spent nuclear fuel arising from the operation of the NPP;

2.20. transportation of spent nuclear fuel;

2.21. emergency response planning with respect to the NPP;

2.22. the decommissioning of the NPP;

2.23. the nuclear fuel cycle, including the establishment and operation of nuclear fuel fabrication facilities in the Republic of Turkey;

2.24. technology transfer; and

2.25. exchange of information and experience in the field of licensing and supervision of nuclear facilities and activities and nuclear and radiation safety and security.

3. The matters of cooperation contemplated by this Article shall be undertaken by Turkish Organizations and Russian Organizations without financial burden on the Turkish Party. Cooperation regarding the nuclear fuel cycle, including the establishment and operation of nuclear fuel fabrication facilities in the Republic of Turkey and technology transfer will be carried out on separate terms to be agreed upon by the Parties.

ARTICLE 4

COMPETENT AUTHORITIES

1. For the purpose of implementing this Agreement, the Parties have designated the following Competent Authorities:

1.1. on the part of the Russian Party, Rosatom; and

1.2. on the part of the Turkish Party, MENR.

2. The Parties shall promptly notify each other through diplomatic channels if they designate a replacement Competent Authority or change the name of the Competent Authority then nominated.

3. The cooperation contemplated by this Agreement shall, in addition to the Competent Authorities, be carried out by Turkish Organizations and Russian Organizations.

ARTICLE 5

PROJECT COMPANY

1. The Russian Party shall cause the initiation of the necessary procedures for the establishment of the Project Company within 3 (three) months as of the date of signature of this Agreement.

2. The Project Company shall be owner of the NPP, including the electricity generated by it.

3. The Project Company shall be established in the form of a joint stock company under the laws and regulations of the Republic of Turkey with the shares in the Project Company being initially 100 (one hundred) per cent owned directly or indirectly by the companies authorized by the Russian Party.

4. The cumulative shares of the Russian Authorized Organizations in the Project Company shall not be less than 51 (fifty one) per cent at any time. The distribution of the remaining minority shares of the Project Company will at any time be subject to the consent of the Parties with the purpose of protecting national interests in issues of national security and the economy.

5. Issues relating to the corporate governance of the Project Company, including, but not limited to distribution of shares, appointment of directors, form of shareholders investment, restrictions with respect to the transfer of shares and the funding mechanisms applicable to the Project Company and the Project shall be subject to the consent of the Turkish Party with the purpose of protecting national interests in issues of national security and the economy.

6. The responsibility to insure risks covering investment and operation periods of this Project belongs to the Project Company.

The Russian Party will take on the responsibility in case of failure of the Project Company to designate the successor to the Project Company, which will possess all necessary competences and capabilities, to assure the fulfilling of its obligations regarding this Agreement. The Turkish Party respectively will take all the necessary measures, as permitted by applicable laws and regulations of the Republic of Turkey, to assure for the timely and proper issuance of all the necessary permits and licenses in accordance with the laws and regulations of the Republic of Turkey.

After the PPA expiry dates for each Power Unit, but not earlier than 15 (fifteen) years after the commercial operation date of each Power Unit, the Project Company shall, for NPP power Unit 1, Unit 2, Unit 3 and Unit 4, give to the Turkish Party 20 (twenty) per cent of net profit of the Project Company on a yearly basis throughout the lifetime of the NPP.

ARTICLE 6

IMPLEMENTATION OF THE PROJECT

1. The Russian Party shall cause the Project Company to duly apply for obtaining all the documents, permits, licenses, consents and approvals necessary to start the construction of the NPP within one year after the entry into force of this Agreement. If the Project Company does not apply for necessary documents, permits, licenses, consents and approvals mentioned in this item of Article 6, this Agreement and land allocation to the Project Company shall be terminated. with no liability to the Turkish Party.

2. The Project Company with the full support of the Russian Party shall put into commercial operation Unit 1 within seven years from the date of issuance of all documents, permits, licenses, consents and approvals necessary to start the construction The Project Company with the full support of the Russian Party shall put into commercial operation Unit 2, Unit 3 and Unit 4 with one year intervals consecutively after the start of the commercial operation of Unit 1. In case of earlier or later entry into commercial operation of the NPP units, the responsibilities of the Parties shall be determined in the PPA accordingly.

3. The general contractor for the construction of the NPP shall be JSC "Atomstroyexport" (ASE).

4. The Parties agree that Turkish companies shall be widely employed by ASE as members of its supply chain for the supply of commodities, the rendering of services and the implementation of works in connection with the construction phase of the Project. The Project Company shall take into account the nature and special safety requirements of new build nuclear power plant projects when employing members of its supply chain.

5. The Parties agree that Turkish citizens shall be trained free of charge and widely employed for the purpose of operating needs of the NPP. Such training shall include, but not be limited to, the establishment, without financial burden on the Turkish Party, of an on-site full scope simulator.

6. The Parties shall, as permitted by the applicable laws and regulations of the Republic of Turkey and the Russian Federation, support and cooperate with the Project Company in connection with the Project.

ARTICLE 7

LAND ALLOCATION AND ACCESS

1. The Turkish Party shall allocate the Site with its current license and existing infrastructure, free of charge, to the Project Company until the end of the decommissioning process of the NPP. Additional land on which the NPP will be built and which is owned by the Turkish State shall also be allocated to the Project Company free of charge. If necessary the Project Company shall make the necessary payments for this additional land to the Forestry Fund.

2. The Turkish Party shall facilitate the Project Company with the expropriation, under the applicable laws and regulations of the Republic of Turkey, of all other land owned by private parties required in connection with the Project. The Turkish Party, as permitted by the applicable laws and regulations of the Republic of Turkey, shall guarantee access to such land for the employees, contractors, agents, representatives or other persons seeking such access on behalf, or with the consent, of the Project Company. The Project Company shall give to the Turkish Party the lists containing information of the identities of such persons before their arrival to such land. The Turkish Party will also facilitate, as permitted by applicable laws and regulations of the Republic of Turkey, the issuance of the necessary permits for the employment of foreign nationals in the Republic of Turkey related to the Project. The Turkish Party will reserve the right to reject access for certain persons to such land due to national security concerns.

ARTICLE 8

LICENSING, APPROVALS AND REGULATIONS

1. The NPP shall be licensed and inspected in accordance with the laws and regulations of the Republic of Turkey in terms of nuclear safety and radiation protection.

2. The Project Company shall obtain all other necessary licenses, permits and approvals from governmental organizations as may be required by applicable laws and regulations of the Republic of Turkey.

3. The Turkish Party shall, as permitted by applicable laws and regulations of the Republic of Turkey, take all necessary measures to facilitate, subject to compliance by the Project Participants with the laws and regulations of the Republic of Turkey, the grant of all approvals, permissions, licenses, registrations and consents required by any Project Participant under the laws and regulations of the Republic of Turkey in connection with the Project including, without limitation, in relation to the delivery of goods, execution of works or performance of services which are contemplated by this Agreement.

4. The Project Company will be subject to the applicable laws, regulations and codes in the Republic of Turkey with regard to electricity transmission system connection, system operation and electricity market operation.

The NPP will participate in the balancing of the Turkish transmission system to the extent consistent with technical parameters to be agreed in Project Agreements.

ARTICLE 9

PROJECT FUNDING

With a view to assisting the financing of the design and construction of the NPP, the Russian Party shall provide ASE with financing on preferential terms for purchasing goods (works and services) of Russian origin to be used in the Project.

ARTICLE 10

POWER PURCHASE AGREEMENT

1. The Turkish Party shall cause TETAŞ to enter into the PPA, with the Project Company for the purchase of fixed amount of electricity with respect to Unit 1, Unit 2, Unit 3 and Unit 4 within thirty days after issuance of Energy Market Regulatory Authority license for electricity production for the Project Company.

2. The Project Company shall present to TETAŞ, at least one year before the start of the commercial operation date of Unit 1 the monthly electricity generation amounts for all the units of the NPP for the whole duration of the PPA.

Furthermore, the Project Company shall present, each year in April, a table of the "settlement period" electricity generation amounts for the next year as stipulated by the PPA. The Project Company will present the first such table four months before the commercial operation date of each unit of the NPP.

3. In case of excess power production per unit than the volume obliged for the entire period of the PPA, such excess power production shall be purchased in compliance with the provisions of the PPA.

4. In case of less production than the volume stipulated in the PPA, the Project Company shall fulfill its obligations by providing the lacking volume of electricity.

5. TETAŞ shall guarantee to purchase from the Project Company the fixed amount – 70 (seventy) per cent for Unit 1 and Unit 2 and 30 (thirty) per cent for Unit 3 and Unit 4 - as stipulated in the PPA of the electricity planned to be generated by the NPP during 15 (fifteen) years from the date of commercial operation of each power unit at weighted average price of 12.35 (twelve point thirty five) US cents per kWh (not including Value Added Tax).

6. The Project Company will sell 30 (thirty) per cent of the electricity planned to be generated by Unit 1 and Unit 2 and 70 (seventy) per cent of the electricity planned to be generated by Unit 3 and Unit 4 on the free electricity market itself or via an energy retail supplier.

7. The unit price shall consist of the investment cost, fixed operating cost, variable operating cost and fuel cost. The details of the unit price shall be as follows:

7.1.all capital expenditure (including, without limitation, license fees, development fees and costs and arranging fees in respect of any financing) incurred by the Project Company in connection with bringing Unit 1, Unit 2, Unit 3 and Unit 4 of the Project into commercial operation is returned within 15 (fifteen) years from the date of the entry into commercial operation of these Units ;

7.2.all operational expenditure (including, without limitation, license fees, costs and any reserves (whether internal or external, voluntary or compulsory) relating to fuel supply and the fuel cycle, the transportation, storage and disposal of spent fuel and waste, decommissioning and the return to use of the site), insurance premiums and taxes of the Project Company, and costs in respect of modernization of Unit 1, Unit 2, Unit 3 and Unit 4, incurred or to be incurred in connection with the Project during the term of the PPA is funded on an as incurred basis (for the avoidance of doubt a reserve made in respect of a future cost is incurred when the reserve is made);

7.3. the scheduled debt service (i.e. interest, principal and fees) payable in relation to any debt financing obtained to wholly or partially fund bringing Unit 1, Unit 2, Unit 3 and Unit 4 of the Project into commercial operation is funded on an as incurred basis;

7.4. the investments made by the direct and indirect investors in the Project Company in connection with bringing Unit 1, Unit 2, Unit 3 and Unit 4 of the Project into commercial operation are repaid on a straight-line basis within 15 (fifteen) years of the entry into commercial operation of that Unit.

8. No escalation shall be applied to the unit price components. No increase in the unit price shall be demanded within the period of the PPA. Changes in costs incurred as a result of changes in the Turkish laws and regulations after the signing date of this Agreement shall be reflected to TETAŞ in proportion to the percentage of the electricity purchased by TETAŞ according to the PPA.

9. The Project Company shall pay a separate amount 0.15 US dollar cent per kWh to the account for spent fuel, radioactive waste management and 0.15 US dollar cent per kWh to the account for decommissioning for electricity purchased by TETAŞ within the framework of the PPA. With regards to the electricity sold outside the framework of the PPA, the Project Company will make the necessary payments to relevant funds stipulated by the applicable Turkish laws and regulations.

10. Annual variation of electricity price within the tariff scale agreed between TETAŞ and the Project Company, being an integral part of the PPA, shall be calculated by the Project Company in order to ensure the payback of the Project, taking into account the price limit at the maximum level of 15.33 (fifteen point thirty three) US cents per kWh.

11. If any of the units of the NPP shall be taken into operation after the programmed date stipulated in this Agreement, except for the force majeure situations envisaged in the PPA, the price of the electricity to be sold will be adjusted according to the conditions of the PPA.

ARTICLE 11
TAXATION

1. All taxes and duties in connection with the Project shall be levied in accordance with the applicable laws and regulations of the Parties' States, taking into account this Agreement and the Agreement between the Government of the Republic of Turkey and the Government of the Russian Federation for the Avoidance of Double Taxation with Respect to Taxes on Income of 15 December 1997.

2. The Parties shall ensure that, unless otherwise provided in this Agreement, all laws and regulations of the Republic of Turkey with regard to taxation be respected.

ARTICLE 12
FUEL, WASTE MANAGEMENT AND DECOMMISSIONING

1. Nuclear Fuel shall be sourced from suppliers on the basis of long-term agreements entered into between the Project Company and the suppliers.

2. Subject to separate agreement that may be agreed by the Parties, spent nuclear fuel of Russian origin may be reprocessed in the Russian Federation.

3. The Parties shall, as permitted by the applicable laws and regulations of their respective States, assist the Project Company with obtaining all relevant approvals, permissions, licenses, registrations and consents required in connection with the trans-boundary movement of nuclear materials, including, without limitation, the trans-boundary movement of Nuclear Fuel, spent nuclear fuel or any other radioactive material.

4. The Project Company is responsible for decommissioning and the waste management of the NPP. Within this framework, the Project Company will make the necessary payments to relevant funds stipulated by the applicable Turkish laws and regulations.

ARTICLE 13
INTELLECTUAL PROPERTY RIGHTS

1. In this Article 13:

1.1. "intellectual property" has the meaning set forth in article 2 of the Convention establishing The World Intellectual Property Organization, signed in Stockholm on 14 July 1967 and amended on 2 October 1979 and includes, without limitation, industrial property and confidential information;

1.2. "industrial property" has the meaning set forth in article 1 of The Paris Convention for the Protection of Industrial Property of 20 March 1883, as revised in Stockholm on 14 July 1967 and as amended on 28 September 1979; and

1.3. "confidential information" means all information relating to a secret of production (know-how), including scientific and technical information and technological and manufacturing information and which has actual or potential commercial value owing to its unavailability to a third party.

2. All matters associated with the protection of intellectual property which is created, used or transferred in connection with the implementation of the Project, shall be addressed in the applicable contracts between the parties involved.

3. Except to the extent provided otherwise under any contract in connection with the Project, all rights to intellectual property used or created in connection with the implementation of the Project shall vest in Rosatom which shall provide a license to use such intellectual property to the Project Company for the purpose of the Project Company's implementation of the Project.

4. All information regarding joint developments in relation to the Project shall not be disclosed to any third party other than where such disclosure is necessary for the implementation of the Project and where consent of the Parties is reached.

ARTICLE 14
TERMS OF DISCLOSURE

1. Nothing in this Agreement shall require either of the Parties, or any other entity involved in the implementation of the Project, to exchange information that constitutes state secrets of the Republic of Turkey or state secrets of the Russian Federation.

2. Nothing in this Agreement shall restrict either of the Parties, or any other entity involved in the implementation of the Project, from exchanging, in accordance with this Agreement, both open access and restricted information in connection with the Project.

3. Any information provided by one Party to another Party under this Agreement or which is produced as a result of the performance of this Agreement and which is considered to be restricted by the Turkish Party or MENR or considered to be restricted by the Russian Party or Rosatom, will be clearly defined and marked in the following manner:

3.1. documents containing information which the Russian Party or Rosatom considers to be restricted shall, in compliance with the laws and regulations of the Russian Federation, be marked «Конфиденциально» «Confidential»; and

3.2. documents containing information which the Turkish Party or MENR considers to be restricted shall, in compliance with the laws and regulations of the Republic of Turkey, be marked «Özel» «Confidential».

4. The Parties and those entities implementing the Project within the framework of this Agreement, shall limit the number of people that have access to restricted information to the maximum extent possible and shall ensure that such restricted information shall only be used or distributed to the extent necessary for the implementation of the Project. No restricted information shall be disclosed or conveyed to a third party that is not involved in the implementation of the Project without the prior written consent of the Party for which the information is restricted.

5. The Turkish Party shall treat all restricted information of the Russian Party as though it was the Turkish Party's own restricted information. The Russian Party shall treat all restricted information of the Turkish Party as though it was the Russian Party's own restricted information.

6. All restricted information shall be protected in compliance with the domestic laws and regulations of the Parties' States.

ARTICLE 15

INTERNATIONAL NUCLEAR FRAMEWORK

1. Export of nuclear materials, equipment, special non-nuclear materials and corresponding technologies as well as nuclear related dual use materials and equipment under this Agreement shall be implemented in accordance with the obligations of the Parties arising from the Treaty on the Non-proliferation of Nuclear Weapons of July 1, 1968 and other international treaties and arrangements under multilateral mechanisms of export control to which the Republic of Turkey and the Russian Federation are Parties and members.

2. Nuclear materials, equipment, special non-nuclear materials and corresponding technologies received under this Agreement as well as nuclear and special non-nuclear materials, and equipment produced thereof or as a result of their use:

2.1 shall not be used for the manufacturing of nuclear weapons and other nuclear explosive devices or for achieving any military purpose;

2.2 shall be provided with physical protection in accordance with the national legislation of the receiving Party's State and at a level no lower than the levels recommended by the IAEA "Physical Protection of Nuclear Material and Nuclear Facilities" (INFCIRC/225/Rev.4);

2.3 shall be exported or re-exported or transferred from the jurisdiction of the receiving Party's State to any other country under the conditions of this Article and only upon previous written consent of the other Party.

3. With regards to nuclear materials received under this Agreement as well as nuclear materials produced as a result of utilization of nuclear materials, equipment, special non-nuclear materials and corresponding technologies received under this Agreement, the provisions of the Agreement between the Government of the Republic of Turkey and the International Atomic Energy Agency for the Application of Safeguards in connection with the Treaty on the Non-proliferation of Nuclear Weapons dated 30 of June 1981 shall be applied during the entire period of their actual presence in the territory or under the jurisdiction of the Republic of Turkey and the provisions of the Agreement between the Union of Soviet Socialist Republics and the International Atomic Energy Agency for the Application of Safeguards in the Union of Soviet Socialist Republics in connection with NPT dated 21 of February 1985 shall be applied to the extent applicable during the entire period of their actual presence in the territory or under the jurisdiction of the Russian Federation.

4. Nuclear material transferred under this Agreement and material obtained through the use of nuclear material, equipment, special non-nuclear material transferred under this Agreement on the territory of the receiving Party's State, shall not be enriched above 20 (twenty) per cent for uranium-235 and shall not be reprocessed radio-chemically with a purpose to separate plutonium without previous written consent of the transferring Party.

5. Nuclear related dual use equipment and materials as well as corresponding technologies used for nuclear purposes transferred by either Party under this Agreement and their reproductions shall be used only for declared purposes not connected with the manufacture of nuclear explosive devices.

6. Equipment, materials and corresponding technologies in paragraph 5 of this Article shall neither be used in nuclear fuel cycle activities or in any other facilities which are not subject to respective IAEA safeguards agreements; nor be copied, modified, re-exported or transferred to third parties without written consent of the other Party.

ARTICLE 16

NUCLEAR LIABILITY

Third party liability for nuclear damage, which may arise in connection with cooperation under this Agreement will be regulated in compliance with the international agreements and instruments to which the Republic of Turkey is or will be a party and national laws and regulations of the Turkish Party.

ARTICLE 17
DISPUTE SETTLEMENT

1. Disputes between the Parties regarding the application and/or interpretation of this Agreement shall be settled by means of consultation and negotiation between MENR and Rosatom.

2. If required, MENR and Rosatom at the suggestion of one of them, shall hold meetings in order to review each of their recommendations on the implementation of this Agreement and the resolution of any disputes that may have arisen.

3. If a dispute is not settled in this way within six months from the beginning of negotiations, it shall be submitted to an arbitration tribunal upon the request of either Party.

4. Such arbitration tribunal shall be constituted for each individual case in the following way. Each of the Parties shall appoint one member of the tribunal within two months from the date of the receipt of the request of arbitration procedure. Those two members of the tribunal shall then select a national of a third State who on approval by both Parties shall be appointed as the Chairman of the arbitration tribunal within two months from the date of appointment of two other members.

5. If within the periods specified in the paragraph 4 of this Article the necessary appointments have not been made, either Party may, in the absence of any other arrangement, appeal to the President of the International Court of Justice of the UN to make these appointments. If the President of the International Court of Justice of the UN is a national of either Party or if he is otherwise prevented from discharging the said function, Vice-President of the International Court of Justice of the UN shall be invited to make the necessary appointments. If the Vice-President of the International Court of Justice of the UN is the national of either Party or if he is otherwise prevented from discharging the said function, the member of the International Court of Justice of the UN next in seniority who is not national of either Party shall be invited to make the necessary appointments.

6. The arbitration tribunal shall reach its decision by a majority of votes. Such decision shall be final and binding upon both Parties. Each Party shall bear the expenses of its own member of tribunal and of its representation in the arbitral proceedings, the expenses connected with the activity of the Chairman of the arbitration tribunal and remaining expenses shall be borne by the two Parties in equal shares. The arbitration tribunal can, however, provide in its decision that one of the Parties shall bear a higher proportion of expenses and such decision shall be binding upon both Parties. The arbitration tribunal shall independently determine its own procedure.

7. Unless the Parties agree otherwise, the arbitration tribunal shall sit in The Hague, and use the premises and facilities of the Permanent Court of Arbitration.

8. The arbitration tribunal shall decide the dispute in accordance with this Agreement and applicable rules and principles of international law.

9. In case of any contradictions between this Agreement and any other agreements expressly contemplated by this Agreement, the provisions of this Agreement shall prevail.

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ARTICLE 18

ENTRY INTO FORCE, MODIFICATION AND TERMINATION

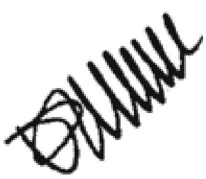
1. The Agreement shall enter into force on the date of the receipt of the last written notification by the Parties through diplomatic channels on the completion of internal State procedures required by their national legislation. This Agreement shall be valid until the decommissioning of the NPP is completed.

2. The Parties may terminate this agreement at any time by way of one year prior notice to one another. If the Parties so agree, the termination of the Agreement shall not affect the ongoing implementation of the Project (including, without limitation, the ongoing operation of the NPP) or the implementation of programs or projects that have been initiated during the validity of the Agreement but not completed by the date of the termination of the Agreement.

3. If this Agreement is terminated, the obligations of the Parties stipulated in Articles 5, 8, 11,12, 13, 14, 15, 16, 17 and 18 of the Agreement shall survive such a termination unless the Parties agree otherwise.

4. Amendments to this Agreement may be made by the written agreement of the Parties. Such amendments shall come into force in accordance with paragraph 1 of this Article.

Signed in Ankara on May 12, 2010 in two original copies, each in Turkish, Russian and English. Should any dispute concerning the interpretation of the text of this Agreement arise, the English version shall prevail.

For the Government of the Republic of Turkey	For the Government of the Russian Federation
	
Taner YILDIZ **Minister of Energy and Natural Resources**	**Igor I. SECHIN** **Vice Prime Minister of the Russian Federation**

Appendix II

Water Cooled Water Moderated Reactor and Its Evolutionary Designs

Ap-II

Prof. Dr. Hasan Saygın

Introduction

As a result of rapidly rising concerns over energy security and climate change, interest in nuclear energy was rekindled in the past few years. Nuclear power has a significant potential for reducing carbon emission and improving energy dependency and hence contributing to energy security. However, it has also the potential for catastrophic accidents and consequently widespread environmental damage, unlike any other form of energy, as demonstrated by Fukushima Nuclear Accident most recently. Additionally with rising risk of nuclear proliferation, nuclear terrorism appears as a greater threat. The creation of huge quantities of long-lived radioactive waste is continuing to be the most formidable problem preventing further development of use of nuclear power.

The future of nuclear energy depends on a consistent, demonstrated record of operational safety. The efforts in this area are therefore directed toward designing advanced and innovative plants. New nuclear power plants (NPPs) must be much safer than current reactors and also economically competitive with alternative energy technologies. New nuclear-fission technologies aimed at meeting these challenges are currently being researched worldwide.

Reactor suppliers in North America, Japan, Europe, Russia and elsewhere have a dozen new nuclear reactor designs at advanced stages of planning, while others are at a research and development stage.

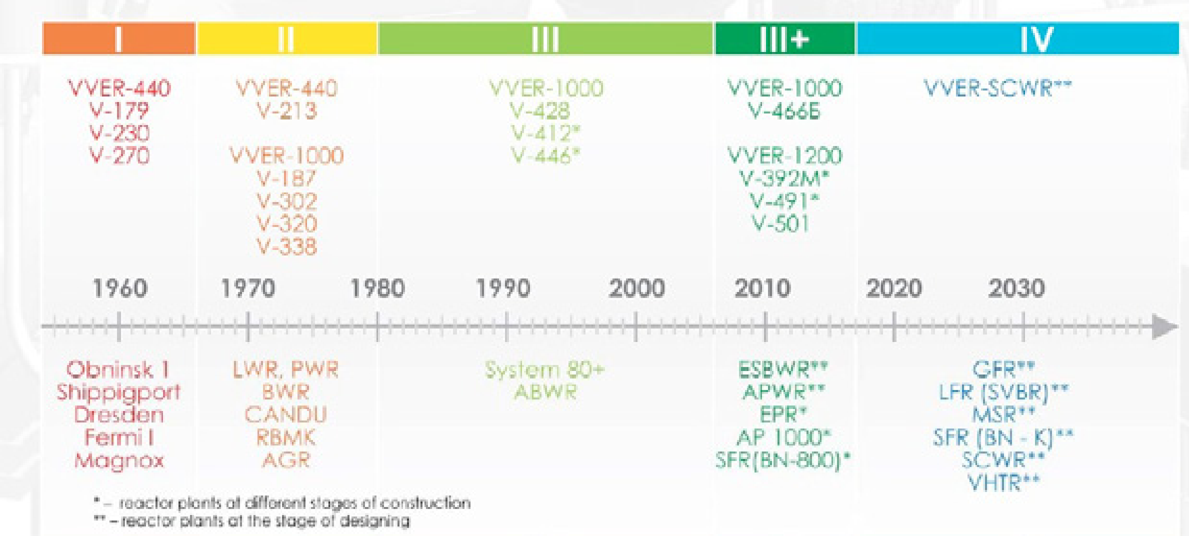
Current advanced reactors are called Generation III (and 3+). Turkey's first nuclear power plant to be built, owned and operated by Russia is one of these type reactors. The agreement foresees the construction of four 1200 MWe Water Cooled Water Moderated Reactor (VVER) units at the Akkuyu site. This paper will provide an overview of the VVER series of nuclear reactors.

Soviet Designed Water Cooled Water Moderated Reactors (VVERs)

A VVER(Voda-Vodyanoi Energetichesky Reaktor) or WWER (Water-cooled Water-Moderated Power Reactor) is the Soviet/Russian version of Western Pressurized (Light) Water Reactors (PWRs). The number following the abbreviation letters describing reactor type usually indicates the rated power of the unit (For Example, VVER-1000 designates a unit with 1000 MW electrical power). VVERs were initially different from typical PWRs of western concept, however they are currently coming on line, with many safety innovations based on western designs. Figure 1 illustrates VVER generations and corresponding Western-designed reactors.

The first protypes were constructed in the sixties. Later serial VVER- 440 and VVER-1000 types were designed and built in the Soviet Union, in several Estern European Countries and in Finland. At present, 53 water-cooled nuclear reactors of the Russian VVER technology are operated in Russia and abroad, in Armenia, Bulgaria, China, Czech Republic, Finland, former East Germany, Hungary,

Figure 1 VVER generations and corresponding Western-designed reactors.



Slovakia, Ukraine, India and Iran ,28 of which are VVER 1000s. There are mainly 3 standardized designs of VVERs: Two 6 loop- 440 Megawatt [440-230 (older) and 440-213 (newer)] and 4 loop-1000 Megawatt output designs. The first series VVER-440 V230 had only limited emergency injection systems and no containment. In the later VVER-440/213 NPPs the safety systems were improved, passive components were included and the confinement function was covered by special building designs. The more sophisticated design, the VVER-1000, has many common features with Western designed PWRs, including a full pressure containment and cluster type control rods.

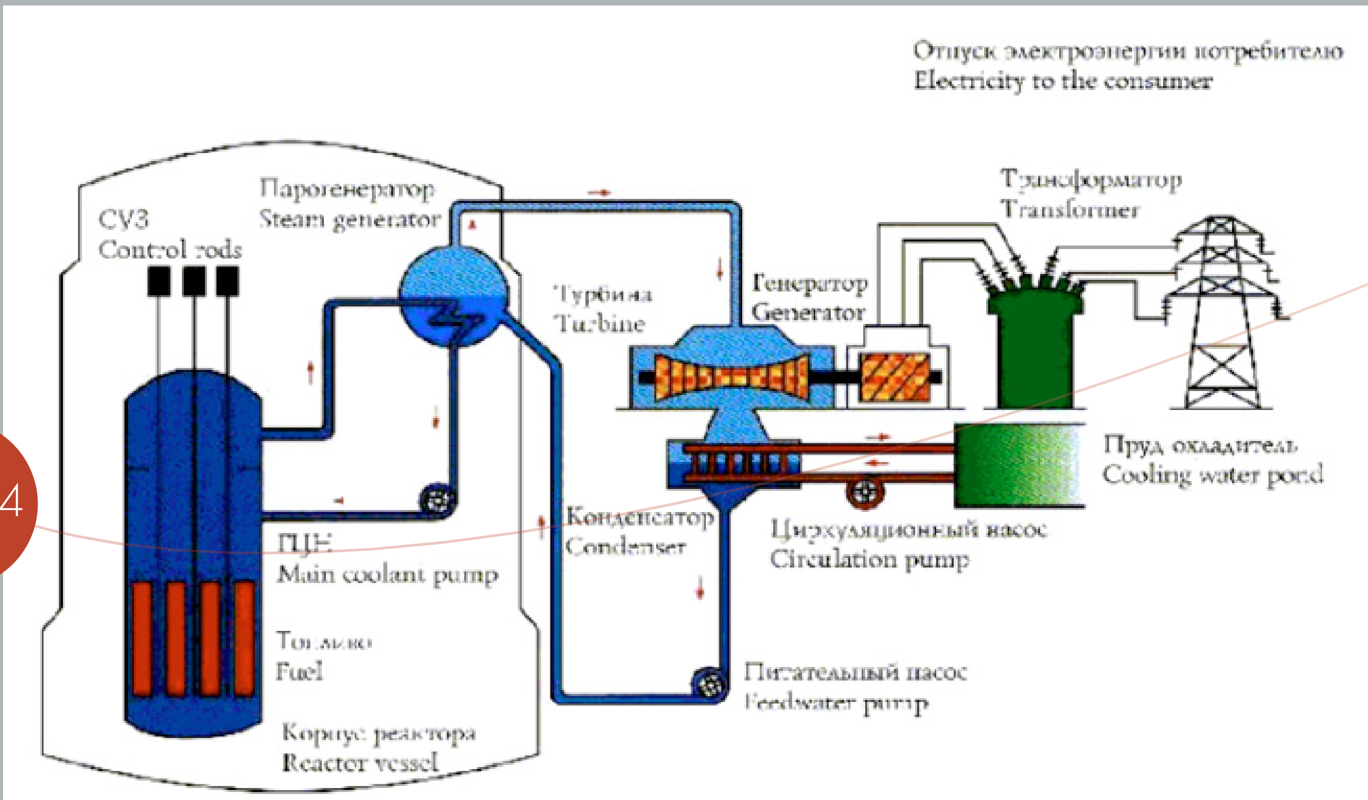
Table 1 Evolutionary development of VVER Reactors in Russia.

Reactor type	Reactor plant model	Whole power plant
VVER-300	V-478	(under development, based on VVER-640), Gen III+
VVER-440	V-230	
	V-213	
VVER-640	V-407	(under development), Gen III+
VVER-600	V-498	(under development, based on V-491), Gen III+
VVER-1000	V-320	most Russian & Ukraine plants
	V-338	Kalinin 1-3, Temelin 1&2, S. Ukraine 2
	V-446	based on V-392, adapted to previous Siemens work, Bushehr
	V-413	AES-91
	V-428	AES-91 Tianwan, based on V-392, Gen III
	V-412	AES-92 Kudankulam, based on V-392, Gen III
	V-392	AES-92 - meets EUR standards, Gen III, Belene contract?, Armenia
	V-466	AES-91/99 Olkiluoto bid, Belene proposal, Gen III+
VVER-1200	V-392M	AES-2006 Novovoronezh, Gen III+
	V-491	AES-2006 Leningrad, Gen III+
VVER-1200A	V-501	AES-2006, Gen III+
VVER-1300	V-488	AES-2006M, Gen III+
VVER-1500	V-448	(under development), Gen III+

Basic Design Characteristics and Common Features of VVERs

The VVERs are vessel type pressurised light water reactors of Soviet design in which water is used both as coolant and moderator for resulting in a thermal neutron spectrum.

Figure 2 Schematic diagram of a VVER NPP**s**[1].



Basic Principles of VVER NPPs as follows[2]:

- Heat generated from the nuclear fission reactions within the the fuel assemblies is removed by the coolant (water or water-steam mixture). The coolant is heated while it flows in fuel assemblies due to the energy of nuclear fission in the fuel. The coolant enters the reactor through input nozzles, passes a ring gap between the reactor vessel and the core-well, and, through a perforated bottom plate, enters fuel assemblies installed in the reactor core. The coolant then passes through the perforated plate, enters the inter-tube space of the protection tubes block, then goes to the ring gap between the core well and the vessel and through outlet nozzles exits the reactor vessel to the "hot leg"

1- IAEA "WWER-1000, Reactor Simulator Workshop Material" Training Course Series, No. 21, 3th Edition, VIENNA, 2009.

2- Same source.

- The heated coolant is transported along the part of the primary circulation circuit called “hot leg” to the steam generator by means of the circulating pumps.
- The steam generator is a heat exchanger in which the heat from the primary circuit coolant transfers to feed water of the secondary circuit to form steam.
- After the steam generator, the coolant is transported along the part of primary circulation circuit called “cold leg” back to the reactor vessel.
- There are four circulation loops in the primary circuit of the NPP with WWER-1000 reactor. The coolant is pumped by four main circulation pumps, installed one in each loop.
- In the secondary circuit, steam formed in the steam generators is transported to the “balance of plant systems”. Most of the steam formed in the steam generators is sent to the turbine, with a much smaller part to feed water heating.
- After the turbine, steam is dumped to the condenser and condensed.
- From the condenser the water is transported through the low-pressure heaters to the deaerator for removal of non-condensable gases.
- From the deaerator feed water is transported through high-pressure heaters to the steam generator.

The main parts of the VVER reactors are

- Reactor,
- Primary circuit,
- Pressurizer and primary circuit pressure compensating system,
- Primary circuit feed and bleed system, including boron regulation,
- Secondary circuit steam lines and feed water pipelines,
- Control and protection system,
- Safety systems.

VVER-1200 Reactors

VVER-1200 (NPP-2006/AES-2006) Reactors are evolutionary advanced versions of the VVER-1000 type reactors. They have been designed with the aim of building a standardized Russian nuclear power plant of Generation III+ featuring improved technical and economic performance characteristics. The goal was to attain up-to-date safety and reliability characteristics with the optimization of construction costs. There are two different NPP 2006 designs, from two different design organizations (Hirsch and Wenisch 2010).

- St. Petersburg design office: NPP-2006 VVER-1200/V491(AES-92).
- Moscow design office: NPP-2006 VVER-1200/V392M

Figure 3 VVER -1200 Nuclear Power Plant (from side view) (Altshuller 2006).

Improvements in the major characteristics of VVER-1200 reactors are as follows:

Table 2 Comparison of VVER 1200 and VVER 1000 reactors characteristics[3]

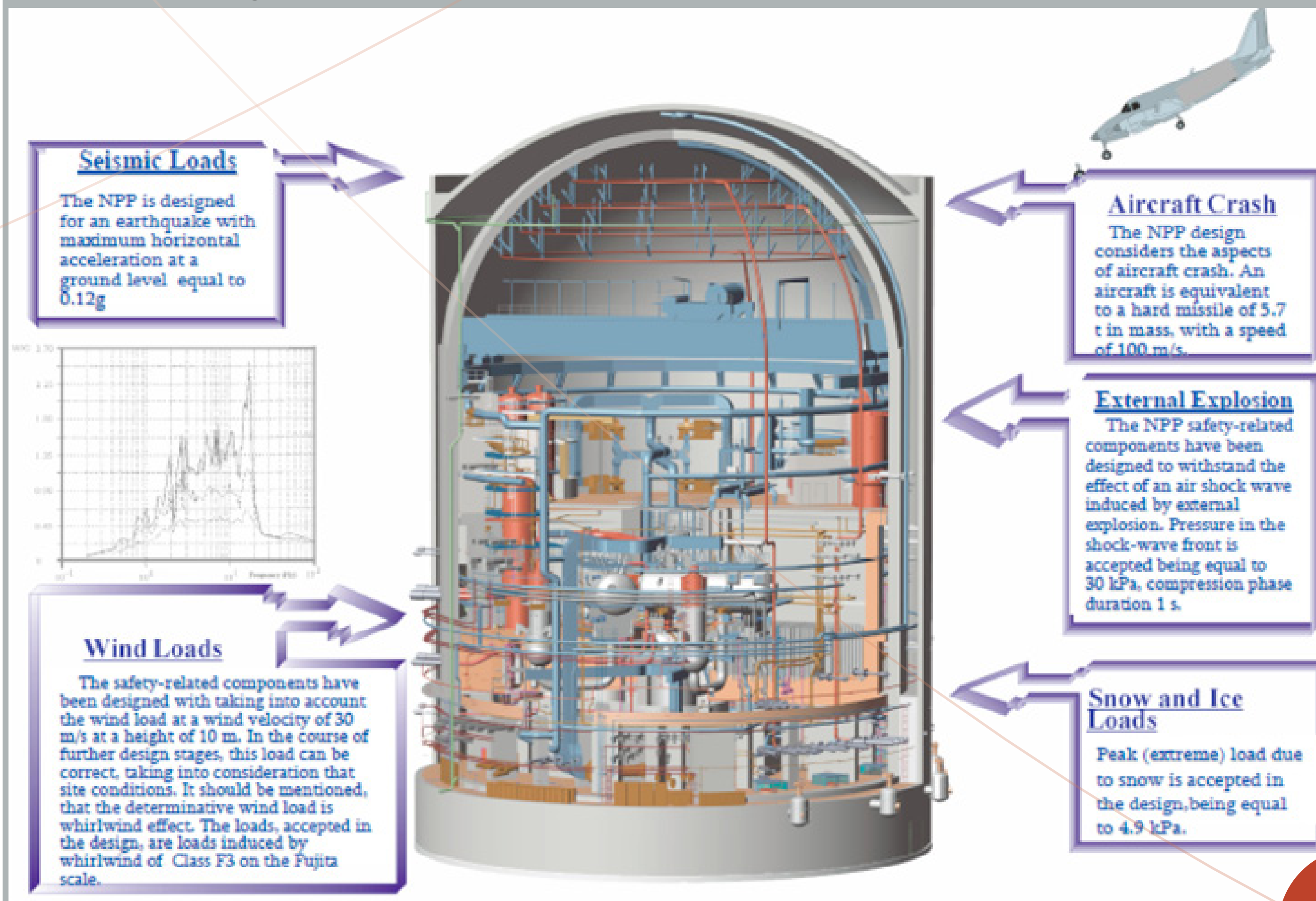
Characteristics	VVER 1000	VVER 1200	Change (%)
Electric power (MWe)	1000	1198	+19.8
Annual output (TWh)	7.5	9.1	+21.3
Design service life (years)	30	50-60	+67-100
Specific material consumption (relative)	1.00	0.85	-15
Reactor lifetime	40	60	50
Load factor	0.80	0.92	15
Period between reloadings (months)	12	12/18	

3- Russia's next VVER Tables http://www.neimagazine.com/journals/Power/NEI/October_2009/attachments/Tables.pdf

Safety Systems Design

The VVER NPP 2006 designs include passive heat removal system and double containment. Double containment is very important feature as seen from the experience with the Chernobyl Reactor.

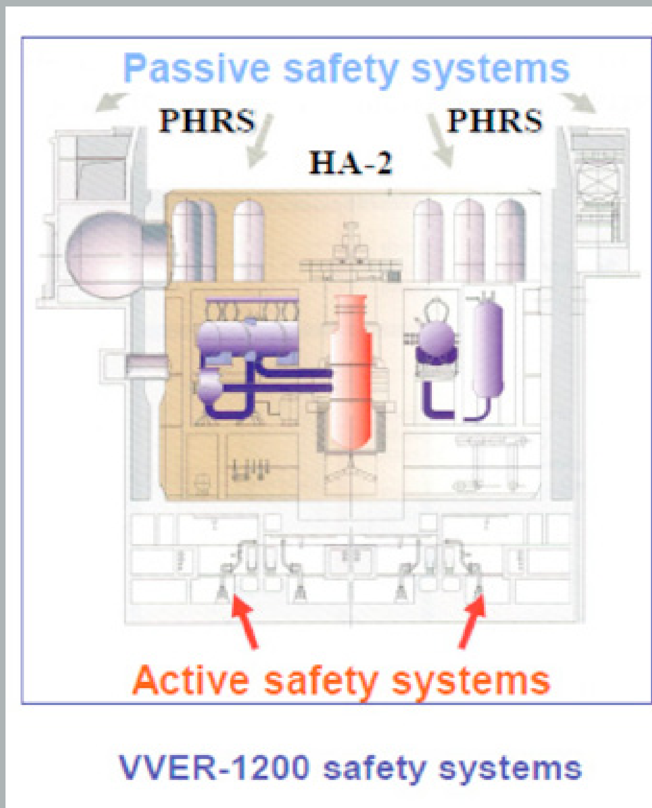
Figure 4 Protection against external hazards(Altshuller 2006).



The secondary containtment system protects the reactor core from external events and helps to contain radioactivity in the event of a core-related accident—and thus reduces the potential for large radioactive releases. (Figure 22)

Passive systems are considered as a means of simplifying safety systems and thereby reducing cost, improving reliability, mitigating the effect of human errors and equipment failures, increasing the time operators have available to cope with accident conditions, and reducing reliance on power supplies. Adequate testing of passive systems is important to determine conditions that affect their performance, to establish their reliability. This is especially important for the relevant low pressure and low driving forces associated with passive systems (Morozov and Soshkina 2008).

Figure 5 Safety systems of VVER-1200 (Böck)



VVER-1200 provides for use of passive safety systems for necessary core cooling. They consist of hydro-accumulators of the first and second stages and the passive heat removal system (PHRS). Safety sytems in VVER-1200 design is shown in Figure 26.

In the case of leakage in the primary circuit PHR system assures the transition of steam generators to operation in the mode of condensation of the primary circuit steam. As a result, the condensate from SG arrives to the core providing its additional cooling.

There are two major functions of passive passive core cooling systems in case of Loss-of- Coolant Accidents (LOCA). First of all, they have to ensure the evacuation of the heat stored in the fuel rods during normal operation, and retention of sufficient water in the Reactor Pressure Vessel (RPV) during the first, blowdown phase of postulated LOCAs. This is achieved by keeping adequate thermal-hydraulic conditions in the core and replenishing the coolant lost during the blowdown process. In this respect, the presence of larger water inventories in the RPV during normal operation are beneficial. Second task is the evacuation of the decay heat from the core in the RPV and from the the primary system tt the end of the blowdown phase, then the state of the primary system is stabilized (Morozov and Soshkina 2008).

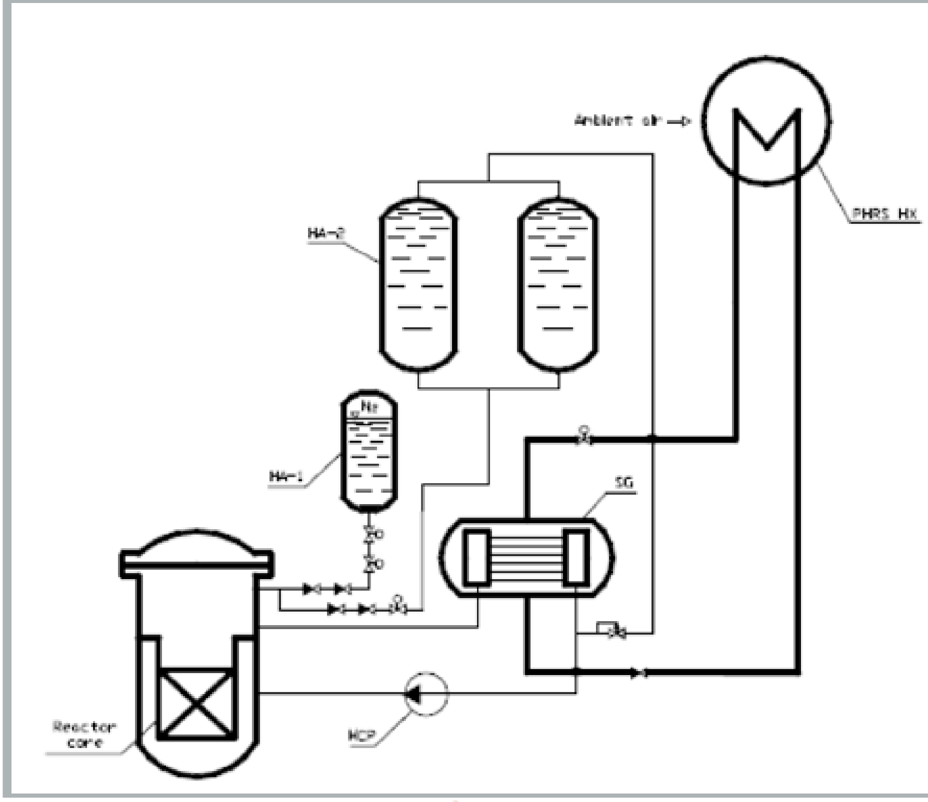
VVER-1200 passive ECCS (Figure 27) includes.

- System of the first stage hydroaccumulators (HA-1).

- System of passive core reflooding from the hydroaccumulators of the second stage (HA-2).

- Passive residual heat removal system (PHRS).

Figure 6: Schematic diagram of the VVER-1200 (V-392M) passive core cooling system.

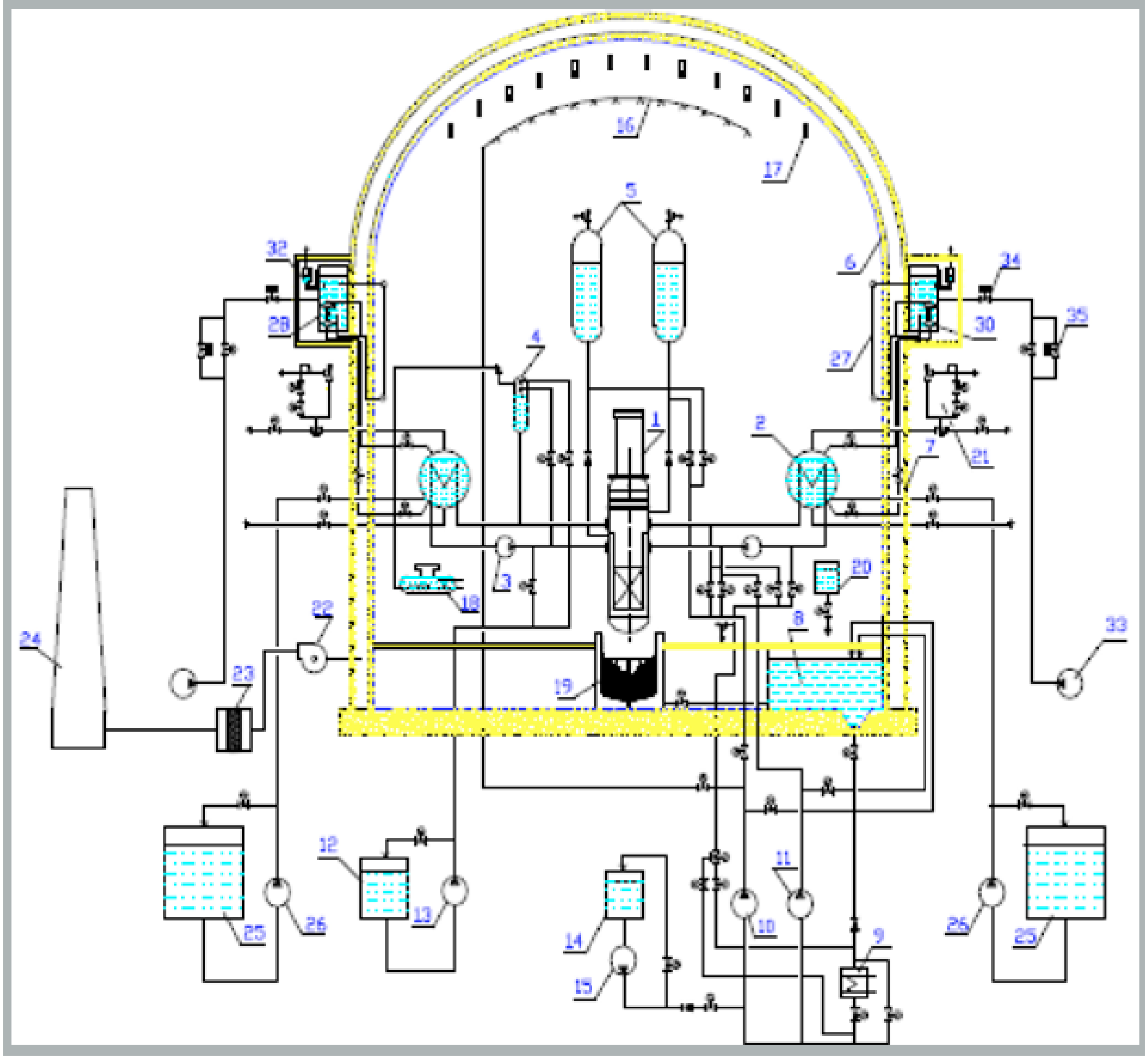


The system of the hydroaccumulators of the 1st stage provides delivery of water into the reactor for cooling and flooding of the core under LOCAs, when pressure in the primary circuit falls below 5.9 MPa. The total inventory of water in the hydroaccumulators equals to 200 cu.m, that ensures therequired makeup of the reactor at the initial period of the accident. Pipelines from hydro-accumulators are connected directly to the reactor vessel. At normal operation conditions each hydroaccumulator is separated from the reactor by two check valves placed in tandem. When pressure in the reactor falls below the pressure of nitrogen in the hydro-accumulator, the check valves open and b water flows into reactor (Morozov and Soshkina 2008).

The HA-2 system are intended for passive supply of water into the reactor core for long-term (up to 24 hours) fuel cooling during LOCA in the primary circuit accompanying by failure of an active part of the emergency core cooling system (for example, during LB LOCA with station blackout). The system consists of four groups (eight tanks) of hydroaccumulators under atmospheric pressure. The total inventory of the coolant is 960 cu.m. It is chosen to provide 24 hours reactor make-up in the case of maximum leak from the main circulation pipeline. In the discharge line, the second-stage hydroaccumulator are attached to the pipelines connecting the first-stage hydroaccumulators to the reactor. The discharge pipelines are provided with the check valves to avoid pressure increase in the hydroaccumulators under stand-by mode. The upper parts of second stage hydro-accumulators are connected by special non-returnable opening check valves to the cold legs of the main circulation pipelines in the zones close to steam generator headers. These special check valves are adjusted to open when pressure in the circuit decreases below 1.5 MPa, afterwards pressure in the hydroaccumulators increases up to the primary pressure and water flows into the reactor under action of hydrostatic pressure. Temporary profiling of water flow from the hydroaccumulators used to provide necessary supply in accordance with decreasing heat decay power is performed by selection of the orifice plates located in the drainage line (Morozov and Soshkina 2008).

A PHRS system is included in the design to remove heat from the reactor plant. The design basis of the PHRS is that in a case of a station blackout, including loss of emergency power supply, the removal of residual heat should be provided without damage of the reactor core and the primary system boundary during unlimited time. The system consists of four independent circuits of natural circulation, each of them being connected to the respective loop of the reactor plant via the secondary side of the steam generator. Each train has pipelines for steam supply and removal of condensate, valves, and an air-cooled heat exchanger outside the containment. The steam that is generated in the steam generators due to the heat released in the core, condenses and rejects its heat to the ambient air. The condensate is returned back to the steam generator. Heat removal capacity through three channels under the worst external conditions (temperature of ambient air is +50 °C) amounts to not less than 2 % of nominal reactor power (Morozov and Soshkina 2008).

Figure 7 Shematic presentation of VVER-1200 Safety Systems Components (Altshuller 2006).



Safety systems components include

1 –reactor,
2 – steam generator,
3 – RCP,
4 – pressurizer,
5 – HT ECCS ,
6 –containment,
7 – outer containment,
8 – tank-pit (low concentration borated water storage),
9 – heat exchanders,
10 – low pressure safety injection pump,
11 – High pressure safety injection pump,
12 – high concentration borated water storage tank,
13 – safety boron injection pump,
14 – chemical feed tank,
15 – chemical feed pump,
16 – core spray header,
17 – passive hydrogen recombiner,
18 – bubbler,
19 – Core melt localizing facility ,
20 – Alkali emergency storage tank,
21 – Main Steam Valve Unit ,
22 – ventilation unit for emergency underpressure in annulus
23 – filter,
24 – ventilation stack ,
25 – Demineralized water storage tank,
26 – Emergency feedwater pump,
27 – Containment PHRS condenser,
28 – PHRS tank,
30 – SG PHRS heat exchanger,
32 – hydraulic seal,
33 – Pump for PHRS tanks makeup,
34 – Level controller in PHRS tanks
(passive action),
35 – valve for makeup of PHRS tanks
(for BDBA under de-energizing conditions) .

Table 3 List of parameters, characteristics and target indicators of V-392M and V-491 designs (Morozov and Soshkina 2008).

Parameter	Value
Installed nominal electric capacity of the unit (MWe)	1200
Nominal thermal capacity of RI (MWt)	3212
Nominal thermal capacity of reactor (MWt)	3200
Primary coolant pressure (MPa)	17.64
Steam generator pressure (MPa)	7.0
Coolant temperature at reactor inlet at nominal power operation (^{0} C)	298.2
Coolant temperature at reactor outlet circulation loops at nominal power operation (^{0} C)	328.9
Service life	
Plant service life (years)	60
RI major equipment service life (years)	60
RI replaceable equipment service life (years)	≥ 30
Plant construction Time (years)	4.5
Performance	
Load Factor (%)	Up to 90
Power utalization factor(%)	Up to 92
RI Equipment avaibility factor (%)	99
Efficiency,net (%)	35.7
Fuel	
Fuel cycle duration (years)	4-5
Refuelling intervals (months)	12-18
FA maximum burn up (MWdays/kgU)	Up to 60-70
Time between outages (years)	4.8
Average annual scheduled outages (for refueling, routine maintanance), (days)	16-40
Duration of refuelling outages (days)	≤16
Number of unscheduled reactor shutdowns over a year	≤ 1.0
Safety	
Steam generator tube pluggage margin (%)	2
Severe core damage ptobability per reactor per year	$\leq 10^{-4}$
Probability of limitting emergency release per reactor per year	$\leq 10^{-7}$
Efective response time of passive safety and accident management systems without operator's interference and power supply (hours)	≥ 24
Design basis earthquake and safe shutdown earthquake (DBE and SSE)	6 and 7*
Primary piping diameters where leak-before-break (LBB) concept applies (mm). *Note: RI major equipment is designed to withstand 8 points SSE.	351x36 426x40 990x70

VVER 1200 Designs : V-302M and V-491

The VVER-1200 Reactor has two different versions designed by the Podolsk, Moscow-based Experimental Design Bureau Gidropress, which is an affiliate of Atomenergoprom. The two designs of the VVER 1200 reactor, V-392M and V-491, are broadly similar, but based on different engineering approaches to reactor safety systems. Both designs have a rather large number of common structural components, equipment and piping, as well as common main engineering solutions to design bases and common characteristics of the reactor systems and equipment. In terms of the combination of active and passive safety barriers, both of them meet the reliability level of Generation III+ technologies (Morozov and Soshkina 2008).

V-392M's and V-491's designs have inherent competitive advantages. In the new modernised V-392M design, passive safety systems prevail. To provide the safety, protection passive systems which don't depend upon human errors are widely usd in this model. Among these are hydrotanks of the secondstage and passive heat removal system. On the contrary, in the V-491 design active safety systems prevails. V-392M has therefore two active safety channels, while V-491 has four active safety channels. Their turbine hall layouts are also different.

Table 4 Comparison of V-392M and V-491 safety systems (Morozov and Soshkina 2008).

	V-392M Design	V-491 Design
Number of CPS rods	121	121
ECCS active section	Combined, two –channel high and low pressure system with ejector pumps and internal reduncy within channels	Segregated, four channel high and low pressure systems with redundancy of 4x100% each of them
ECCS passive section	Passive four-channel system	Passive four-channel system
Emergency boric asid injection system	Two channel system with redundancy of 2x100% and redundancy of 2x 50 % within channels.	Four-channel sytem with redundancy of 4x50%c
Emergency feedwater supply system	Unavailable	Four-channel system with redundancy of 4x100 % and emergency feedwater storage tanks
Emergency SG cooldown systems	Closed two-channel system with redundancy of 2x100%	Unavailable.
Emergency passive core flooding system (GE-2)	Passive four -channel system with two tanks in each channel	Unavailable
Passive heat removal system	Passive four-channel system with two air-cooled heat exchangers in each channel	

Also, engineering solutions to safety systems and beyond-design-basis accident (BDBA) management systems differ. In the V-392M there is a focus placed on avoidance of redundancy aiming at higher cost-effectiveness of the plant construction and operation. This goal is met through higher nominal power, primary and secondary parameters, better fuel consumption and operating characteristics (Morozov and Soshkina 2008).

The layout principles of VVER-1200/ 491 as follows (Altshuller 2006)

- Adjoining nuclear island buildings to the reactor building or locating them not far from it.
- Physical division of buildings into safety trains separated by fire-resistant structural barriers.
- Reducing the number of communication lines and the volume of communication between buildings by locating them in an optimal configuration in relation to one another
- Enhancing NPP physical protection by locating redundant equipment in various buildings.
- Ensuring controlled access to nuclear island buildings.
- Optimizing system layout and system location in buildings to increase process efficiency and reduce construction costs.

Conclusions

The VVER is a pressurized light water reactor of Russian design operating on the same basic principles as a Western PWR reactor. It uses similar technological systems. Although modern VVER type reactor installations are closest to Western designed PWRs reactors as to their design , there are certain differences between them. The most important different design features are the horizontal steam generators and the hexagonal fuel assembly and core structures.

Main design principles of VVER-type reactors:

- A moderate heat intensity of the reactor core providing consirerable margins relative to heat transfer crisis on fuel rods during different transients including accident regimes,
- An internal passive safety based on self-protection principle which plays an important role in providing safety.

A high degree of reliance on the self protection principle, as compared to those with PWR reactors, is one of the most important features of VVER type reactors. In particular the following characteristics are to be highlighted

- Volumes of the coolant above the core in the primary circuit and in the presurizer are increased.
- The horizontal steam generator in the second circuit contains a considerable volume of water,
- No structural holes are allowed below the upper level of the core.

Due to a relatively low energy intensity of the core and a large store of a coolant in the primary and secondary circuits, it is claimed that VVER-type reactors retain the conditions of safe reactor operation for a longer time under emergency conditions and the dryout of the reactor core does not take place; thus, operator's intervention is not required.

Russia has incrementally improved the VVER Reactors while retaining the basic design.

Table 5 VVERs by Countries

Country	First Unit Commission	Number of built units	Number of units in operation	VVER-440/VVER-1000
Russia	1964	18	16	6/10
East Germany	1966	6	0	5/0
Bulgaria	1974	6	6	4/2
Armenia	1976	2	1	2/0
Finland	1977	2	2	2/0
Slovakia	1978	6	6	6/0
Ukraine	1980	13	13	2/11
Hungary	1982	4	4	4/0
Czech	1985	6	6	4/2
China	2005	2	2	0/2
Iran	2008	1		0/1
India		2		0/2

Source : World Nuclear Association, "Nuclear Power in Russia", (http://www.world-nuclear.org/info/inf45.html)

At present, 53 water-cooled nuclear reactors of the Russian VVER technology are operated in Russia and abroad, in Armenia, Bulgaria, China, Czech Republic, Finland, former East Germany, Hungary, Slovakia, Ukraine, India and Iran; 28 of these are VVER 1000s.

A third-generation standardized VVER-1200 reactor of 1150-1200 MWe as an evolutionary development of the proven VVER-1000, with longer life, greater power, and greater efficiency (36.56% instead of 31.6%) is under development. It incorporates enhanced safety features for better protection against earthquakes and aircraft impact including passive safety features, double containment and core damage frequency of 1x10-7.

Two different designs of the VVER 1200 reactor, V-392M and V-491, which are broadly similar, but based on different engineering approaches to reactor safety systems are currently under construction. The V-491 and V-392M design are scheduled for operation at the Leningrad Nuclear Power Plant II and Novovoronezh Nuclear Power Plant II respectively. The lead units are being built at Novovoronezh II, to start operation in 2012-13 followed by Leningrad II for 2013-14.

However, a standardized design has not been identified for VVER-1200 Reactors. The final choice between these two versions is expected to be made based on results of the construction of the first VVER 1200 reactors The selected reactor design will become the basis of a massive plan fo the construction of standard nuclear power plants in Russia: by 2030 the nuclear share should exceed 25% in the country's energy mix.

For its first nuclear power plant to be built, Turkey has chosen VVER-1200/V491 in which active safety systems are predominant. These active systems are said to be very efficient, as positive experience with VVER V 320 demonstrates. VVERs relying on active and passive safety sytems are likely to be at safety level comparable to that of EWRs. However, it should be emphasized that there are no VVER-1200 in operation. They only exist on paper so far. Hence there is as of yet no operating experience that can be relied on. New and unexpected problems can emerge in the course of the constuction and/or operation due to unexpected plant defects or human error or unforeseen physical or chemical processes.

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