SAFETY EVALUATION REPORT
OF AN APPLICATION FOR A LICENCE TO CONSTRUCT
BARAKAH UNITS 1 AND 2

PART 1: SUMMARY



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Federal Authority for Nuclear Regulation

P O Box 112021, Abu Dhabi, United Arab Emirates

info@fanr.gov.ae & www.fanr.gov.ae

PRODUCED BY: LICENSING PROJECT MANAGER, NUCLEAR SAFETY DEPARTMENT

SIGNATURE: ______________________ DATE: 9/July/2012

RECOMMEND APPROVAL: DIRECTOR, NUCLEAR SAFETY DEPARTMENT

SIGNATURE: ______________________ DATE: 9/7/12

APPROVAL: DEPUTY DIRECTOR GENERAL, OPERATIONS DIVISION

SIGNATURE: ______________________ DATE: 9/7/2012

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PART 1: SUMMARY

1.0 – INTRODUCTION

1.1 Purpose

The purpose of the Safety Evaluation Report of the Construction Licence Application for Barakah Units 1 and 2 is to provide formal documentation to the Board of Management of the Federal Authority for Nuclear Regulation (FANR) and other stakeholders on the framework, methodology, and conclusions of the review and assessment carried out by FANR staff of the application submitted by the Emirates Nuclear Energy Company (ENEC) for construction of Units 1 and 2 at the Barakah nuclear facility (the Construction Licence Application (CLA)).

1.2 Scope

This report addresses the review and assessment by FANR of the CLA submitted by ENEC on 27 December 2010 for Barakah Units 1 and 2, as supplemented by further correspondence and submittals.

The review and assessment have been carried out in compliance with the legal competences of FANR as established in United Arab Emirates (UAE) Federal Law by Decree No. (6) of 2009, "Concerning the Peaceful Uses of Nuclear Energy." The Law specifically states that construction of a nuclear facility is a regulated activity that must be licensed by FANR. As specified by this Law, FANR review of the CLA covered all matters relating to nuclear safety, nuclear security, radiation protection, and safeguards.

This report provides a summary of the regulatory review and assessment that FANR conducted in order to determine whether the proposed construction of the facility complies with applicable FANR regulations and meets relevant safety objectives, principles, and criteria.

The detailed technical evaluation of ENEC CLA is provided in Part 2 of the Safety Evaluation Report which contains supporting technical information. This detailed review has been carried out to a level that demonstrates that the requirements of the Law and FANR regulations for safety, nuclear security, radiation protection, and non-proliferation are met by the proposed construction of the facility.

It is expected that ENEC shall submit to FANR, in accordance with FANR Regulations, an Operating Licence Application (OLA) at a future stage in the development of the Barakah facility. The OLA will include the Final Safety Analysis Report (FSAR) and other supporting documents required by FANR for review. The FSAR shall describe final design and analysis of the performance of structures, systems, and components (SSCs) and will incorporate the pertinent information developed since the submittal of the CLA including the information that ENEC committed to provide as a condition of the Construction Licence (CL). The FSAR will include complete information concerning facility operation, including the organizational structure, responsibilities and authorities, managerial and administrative controls to be used to assure safe operation, plans for start-up testing and initial operations, plans for conduct of normal operations, including maintenance, surveillance, and periodic testing of SSCs, plans for coping with emergencies; and proposed technical specifications will be required. The FSAR is the principal document upon which the FANR will base its safety evaluation review to support the consideration for issuance of a facility Operating License (OL).

This report's scope also includes documenting the review of ENEC's *Safety Assessment Report for Braka Nuclear Power Plants (Lessons Learned from Fukushima Accident).* This assessment report is ENEC's response to a request from FANR, following the events at Fukushima, for providing within the framework of the CLA, a detailed report describing ENEC's assessment of how the recent experience at Fukushima and the lessons learned so far have been applied to address the robustness of the proposed Barakah facility and any potential modifications to improve safety.

The Environment Agency of Abu Dhabi (EAD) is responsible for conducting the review and assessment of the Environmental Impact Assessments (EIAs) and for issuing the permits required by separate statute. Therefore, the review and assessment of the EIAs and associated permitting actions are not in the scope of this report.

Since outset of this project, ENEC has used the name "Braka" as the official English translation of the Arabic name of both the site and the facility. However, on 28 June2012, ENEC informed FANR that the spelling of the official name in English of the site and the facility was being changed to "Barakah", without affecting the Arabic name. ENEC stated that the term "Braka" in previous documents prepared by ENEC and its contractors should be read as referring to "Barakah".

2.0 – BACKGROUND: NUCLEAR ENERGY PROGRAMME AND REGULATORY FRAMEWORK IN THE UAE

2.1 UAE National Policy for Development of Peaceful Nuclear Energy

The UAE government established in April 2008, the "Policy of the United Arab Emirates on the Evaluation and Potential Development of Peaceful Nuclear Energy" (the Nuclear Policy). The Nuclear Policy was based on a study of viable options to meet future energy needs, and focused on the potential benefits of nuclear power for the UAE people, the environment, and the economy.

The Nuclear Policy makes the following commitments in the development of nuclear energy in the UAE:

- Complete operational transparency
- Pursuance of the highest standards of non-proliferation
- Pursuance of the highest standards of safety and security
- Conformance to International Atomic Energy Agency (IAEA) standards in evaluating and potentially establishing a peaceful nuclear energy programme
- Development of peaceful domestic nuclear power capability in partnership with the governments and firms of responsible nations, as well with the assistance of appropriate expert organizations
- Assurance that the peaceful domestic nuclear power programme is developed in a manner that best ensures long-term sustainability

The Nuclear Policy statement is available for review at:

http://fanr.gov.ae/ar/media/get/20090430_uae-policy-white-paper.pdf

2.2 Status of UAE Nuclear Energy Programme

The UAE has moved forward on the commitments outlined in its Nuclear Policy through the adoption of the relevant international instruments for nuclear safety, security, and non-proliferation, and through the formal establishment of the Federal Authority for Nuclear Regulation (FANR) with Federal Law by Decree No. (6) of 2009 and the Emirates Nuclear Energy Corporation (ENEC) with Abu Dhabi Law No. (21) of 2009.

The UAE has made multiple bilateral government-to-government cooperative arrangements, and engaged with the IAEA in peer review and assessment activities. The bilateral agreements enabled the UAE to obtain scientific and technical information and assistance from other countries, and to acquire materials and equipment. On the industry level, ENEC joined the World Association of Nuclear Operators in October 2010 and participates in sharing experience through peer reviews and feedback reports.

The UAE has also established a high-level group of international experts, the International Advisory Board (IAB), to advise the government on progress in achieving and maintaining the Nuclear Policy objectives.

The UAE has chosen an advanced third-generation light water reactor (LWR), known as APR1400 to ensure safety at the highest levels. The APR1400 design is an advanced version of the Combustion Engineering (now Westinghouse) System 80+, a design certified by the United States Nuclear Regulatory Commission. On 27 December 2009, ENEC awarded a consortium led by Korean Electric Power Company (KEPCO) a contract to supply the UAE with four nuclear power reactors. The scope of the contract covers engineering, procurement, construction, fuel, and operations and maintenance support.

In December 2010, ENEC submitted an application with FANR for a licence to construct the first two units of a nuclear facility at the proposed site of Barakah in the Western Region of Abu Dhabi. The application included a comprehensive Preliminary Safety Analysis Report (PSAR) based on the Shin-Kori Units 3 and 4 facility in Korea, for which the Korean authorities issued a construction permit in 2008, and which serves as the reference plant for the UAE.

More information on the UAE nuclear programme is available in the UAE National Report to the 5th Review Meeting on the Convention on Nuclear Safety at:

http://www.fanr.gov.ae/Ar/AboutFANR/OurWork/Documents/CNS-National-Report-English.pdf

2.3 Role and Responsibilities of the Federal Authority for Nuclear Regulation

The United Arab Emirates Federal Law by Decree No. (6) of 2009, “Concerning the Peaceful uses of Nuclear Energy,” establishes the responsibilities and requirements for the development and regulation of the peaceful uses of nuclear energy in the UAE.

The Federal Authority for Nuclear Regulation (FANR) is the national regulatory authority for the licensing and oversight of nuclear-related activities in the UAE. The Law gives FANR independence and full legal competence to regulate and determine all matters relating to the regulations, control, and supervision of the nuclear sector in the UAE, and particularly to those related to safety, nuclear safety, nuclear security, nuclear radiation protection, and safeguards. FANR has full authority “to review and assess submissions on Safety, Security and Safeguards from Operators both prior to and after granting a Licence.” FANR is exclusively responsible for issuing all licences to practice any of the regulated activities in the UAE and to impose conditions on licences which will ensure the safety of the activity.

The regulatory framework empowers FANR as the UAE regulatory body to conduct reviews, assessments, and inspections of:

- The applicant’s evidence of and plans to meet regulatory requirements regarding its competence (including the competence of contractors) and capability and the safety of the nuclear facility and related activities

- The descriptions and claims in the documentation of the applicant

- The applicant's compliance with FANR's regulations, safety objectives, principles, requirements and criteria, safety cases and safety analyses, and conditions of the licence
- The continued competence and capability of the licensee (and of its contractors and subcontractors) to meet the actual authorisation, licence, or regulatory requirements

The Law authorizes the FANR Board of Management to make decisions on issuance of licences to conduct regulated activities. The Law prohibits any person from conducting a regulated activity (which includes all relevant activities relating to a nuclear installation) without a licence from FANR. FANR is the sole decision-maker in licensing, and its decisions are not subject to any external review. FANR is entirely independent of ENEC and any other entity charged with promotional responsibilities. Board members are forbidden by Law from engaging directly or indirectly in the conduct of any regulated activity and must not have any personal interest that conflicts with the interests of FANR.

The FANR staff is supervised by the Director-General of FANR. The Director-General reports to the FANR Board. A FANR organization chart is provided in Figure 1-1.

2.4 Role of Other UAE Organizations

The Barakah Units 1 and 2 construction licence application review is set within a larger framework that includes several other UAE organizations. The principal organizations include:

Environment Agency Abu Dhabi

Environment Agency Abu Dhabi (EAD) was created by Abu Dhabi Law No. (16) of 2005, "Concerning the Re-organization of the Environment Agency – Abu Dhabi." EAD is charged with protecting and conserving the environment and is responsible for implementing environmental policy and environmental laws for the Abu Dhabi Emirate and for supervising the implementation of the Abu Dhabi Environment, Health, and Safety Management System (EHSMS).

Before issuing Construction Environmental Permits (CEPs) or Environmental Operations Permits (EOPs) for projects in Abu Dhabi Emirate, EAD requires the submission by the proponent of an Environmental Impact Assessment (EIA).

Both a Non-Nuclear Environmental Impact Assessment (NN-EIA) and a Nuclear Environmental Impact Assessment (N-EIA) for the Barakah site have been prepared by ENEC for EAD review. FANR has an arrangement in place with EAD, through which it advises EAD on the radiological aspects of the N-EIA in conjunction with the PSAR review. The objective of the N-EIA is to provide a comprehensive assessment of the nuclear-related facilities at Barakah and associated impacts of the construction, operation, postulated accidents, and cumulative radiological impacts, and to present mitigation measures and monitoring plans to be implemented for four units. The non-radiological impacts of construction, operation, and decommissioning are addressed in the NN-EIA to be reviewed by EAD.

Critical National Infrastructure Authority

The Critical National Infrastructure Authority (CNIA) was created in May 2007 with the mission to secure Abu Dhabi's infrastructure and key assets. CNIA is an independently established entity based in Abu Dhabi and affiliated with the Abu Dhabi Executive Council. It is responsible for protecting the Emirate's vital facilities while working to maintain the highest standard of security to nurture the economic stability that comes from a safe and secure Abu Dhabi.

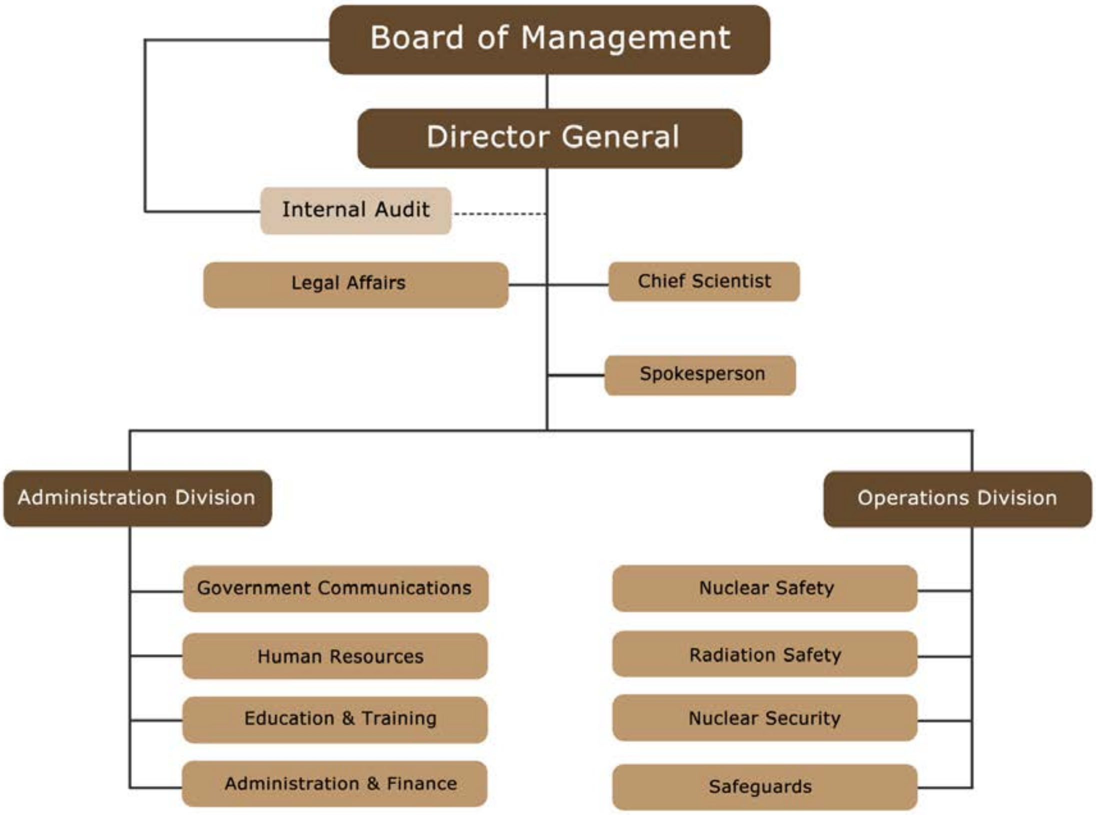
The functions and responsibilities of CNIA have been transferred, in accordance with Abu Dhabi Law No. (1) of 2012, to the Critical Infrastructure and Coastal Protection Authority (CICPA)and General Headquarter of the UAE Armed Forces. CICPA will define, maintain, and protect against the design basis threats for the Barakah Facility and will support ENEC implementation of physical protection in accordance with the Nuclear Law, national standards, and FANR regulations and guidance.

National Disaster, Crisis and Emergency Management Authority

The National Disaster, Crisis and Emergency Management Authority (NCEMA) was established to enhance the UAE resilience to respond to emergencies and crises and to ensure that they are managed through joint planning, training, and coordination with various agencies in the UAE. It was legislatively established by Federal Law by Decree No. (2) of 2011. As part of its national coordinating role, it is responsible for coordinating planning for the response to nuclear emergencies and ensuring that this planning is consistent with planning for other national emergencies. NCEMA is working with, as appropriate, first responders and other stakeholders directly involved in radiological emergencies. NCEMA is also working with FANR, ENEC, and other agencies on coordination of offsite planning efforts.

Figure 1

FANR Organization Chart



2.5 Regulatory Body of the Country of Origin

The UAE Nuclear Policy commitments call for the development of peaceful domestic nuclear power capability in partnership with the governments and firms of responsible nations, as well with the assistance of appropriate expert organizations.

The design of the Barakah Units 1 and 2 is based on the design for the Shin-Kori Units 3 and 4 that is now under construction by Korea Hydro and Nuclear Power Co. (KHNP) in the Republic of Korea. The Korean Ministry of Education, Science, and Technology (MEST), the nuclear regulatory authority in Korea, has issued a construction permit for the Shin-Kori Units 3 and 4 based on the technical review performed by Korean Institute of Nuclear Safety (KINS).

KINS was established as an independent expert organization supporting the nuclear regulatory framework in Korea to conduct nuclear safety regulation as entrusted by the Korean MEST in accordance with the Korean Atomic Energy Laws. Its major functions relevant to nuclear safety regulation are as follows:

- Conduct safety reviews in relation to the licensing and approval of nuclear installations
- Conduct regulatory inspections during manufacturing, construction, and operation of nuclear installations
- Perform research and development of the technical standards of safety regulation for nuclear installations
- Conduct licence examinations for the handling of nuclear materials and radioisotopes, and the operation of nuclear installations
- Receive and process notifications relevant to licensing formalities
- Conduct quality assurance examination and inspection

In line with the nuclear policy commitment mentioned above, and to facilitate the use of safety information from the reference plant in Korea, FANR has established agreements with KINS. The initial "*Implementing Agreement between FANR and KINS for the Exchange of Technical Information and Cooperation in Nuclear Safety and Radiation Protection Matters,"* signed May 25, 2010, was followed by the technical cooperation agreement "*Special Agreement between the Federal Authority for Nuclear Regulation and the Korea Institute of Nuclear Safety for the Exchange of Technical Information and Cooperation in Nuclear Safety and Radiation Protection Matters,"* signed July 22, 2010. The agreement provides for exchanges of technical information, as well as training and staff exchanges.

In October 2011, the newly established Nuclear Safety and Security Commission (NSSC) replaced MEST as dedicated regulatory body in Korea responsible for safety, nuclear security, and safeguards.

In undertaking the review and assessment of the construction licence application, FANR utilized where appropriate the safety evaluations performed by KINS for the Reference plants in Korea (Shin-Kori Units 3 and 4), together with on-going exchanges of technical information. FANR's objective in doing so has been two-fold: to enhance safety through collaboration with Korean experts, and to maximise the efficiency of its review by focusing on those topics specific to the UAE.

2.6 Independent Review of UAE Nuclear Regulatory Framework

During December 2011, an international team of senior experts conducted an Integrated Regulatory Review Service (IRRS) mission at FANR offices in Abu Dhabi, UAE. The review team was organized by the International Atomic Energy Agency (IAEA), following a request from UAE government. The purpose of the mission was to review the effectiveness of the UAE nuclear regulatory framework as implemented by FANR. The key objectives of the mission were to enhance nuclear and radiation safety and emergency preparedness.

The mission included a review of the UAE regulatory framework against IAEA nuclear safety standards and also included information exchange in the areas covered by the mission.

The IRRS team review mission covered the following areas: Responsibilities and functions of the UAE government; FANR's responsibilities and functions; FANR's management system; FANR's regulatory activities, including authorisations, reviews, inspections, and enforcement processes; and FANR's emergency preparedness and response activities.

The IRRS team also addressed FANR's response to the Fukushima event.

The IRRS team found that the UAE/FANR has suitable infrastructure in place to support currently regulated activities and plans for future activities. The team also identified several good practices and made recommendations where improvements are either necessary or desirable.

The report identified strengths including: UAE nuclear policy based on firm analysis of future electricity demand; the extensive use of IAEA standards in the development of FANR regulations and guidance documents; the effective use of peer reviews; and the development of an integrated management system for FANR.

In particular, the IRRS team reviewed the different aspects of the process, procedures, and organization of FANR for the authorisation of nuclear power plants; as well as for the review and assessment of nuclear power plants. In these two areas, the IRRS team was able to review the organizational arrangements and implementation details of the on-going activities of FANR in the review and assessment of Barakah Units 1 and 2 CLA. The IRRS concluded that:

> "*FANR has essential regulations and a review process for effectively conducting the review of the applications received to date.*"
>
> *"Review and assessment in FANR with the support of TSOs is organizationally a well arranged and managed process."*

The IRRS made a number of recommendations and suggestions for improvements to FANR in other areas. FANR has devised plans and is implementing actions to address the IRRS recommendations, and fully comply with IAEA guidelines and recommendations.

3.0 – ENEC APPLICATION FOR CONSTRUCTION OF A NUCLEAR FACILITY

This section provides a summary of the ENEC Application for the Construction of a Nuclear Facility. Information is presented on previous licences issued by FANR, the current request for authorisation, the contents of the application, the applicant, the designer and prime contractor, a summary description of the site, a summary description of the proposed facility and the facility programs, and a comparison of the facility and the reference plant.

3.1 Previous Licences Issued by FANR for the Barakah Nuclear Facility

ENEC has selected a site at a location in Western Region of the Abu Dhabi Emirate, at a location named Barakah for locating the first UAE nuclear facility (Nuclear Power Plants). Following ENEC submissions, subsequent review by FANR staff, and decision by the Board of Management, FANR issued a Site Selection Licence [Licence No. FANR/NF/2010/001] on 28 February 2010 and a Site Preparation Licence [Licence No. FANR/NF/2010/002A] on 8 July 2010. They provide authorisation to ENEC to conduct site investigation and preparation activities at the Barakah site, such as the installation of site infrastructure, and construction of parts of the facility not related to nuclear safety.

FANR has also issued a Limited Construction Licence [Licence No. FANR/NF/2010/003] on 8 July 2010 which authorizes the manufacturing, assembly, and testing of certain components as specifically delineated in the licence, including reactor vessels, steam generators, and other primary reactor system components. An amendment to the limited construction licence [Licence No. FANR/NF/2010/003/Rev 1] was issued by FANR on 2 March 2011, to add man-machine interface systems and cooling water intake and discharge structures to the list of authorized activities. A second amendment to the limited construction licence [Licence No. FANR/NF/2010/003/Rev 2] was issued by FANR on 6 March 2012, to add Stage 1 Early Civil Works as an authorized activity, including subgrade verification and mapping, dental work, mudmat concrete placement, encasement pipe installation, and structural granular backfill. A third amendment to the limited construction licence [Licence No. FANR/NF/ 2010/003/Rev 3] was issued by FANR on 8 May 2012, to add Stage 2 Early Civil Works as an authorized activity, including preparation and placement of reinforcing steel, embedment’s, embedded piping and plumbing, electrical conduits, electrical grounding, and stainless steel liner plate of sumps. In addition, the Physical Protection Plan for Construction Phase 1 has been approved by FANR.

3.2 ENEC Application for a Licence to Construct a Nuclear Facility

3.2.1 Authorization Requested

ENEC submitted an application to FANR on 27 December 2010 for the construction of the first two units of the nuclear facility at the Barakah site (Barakah Units 1 and 2). The application requested authorisation to conduct all regulated activities required to construct the plant, including:

"…the manufacture, possession, use, transport, import, storage, installation and testing of structures, systems, components comprising BNPP 1&2, including supporting and auxiliary equipment and associated facilities."

"…the transfer of technology and software and materials subject to reporting per the list of Nuclear Material, Equipment and Technology in INF/CIRC/254/Rev 9 part 1 and Part 2 Rev 7."

3.2.2 Contents of the Construction Licence Application

ENEC's CLA was accompanied by four Enclosures:

Enclosure 1--Preliminary Safety Analysis Report & Supplements

- Chapter 1 – Introduction and General Description of Plant
- Chapter 2 – Site Characteristics
- Chapter 3 – Design of Structures, Components, Equipment, and Systems
- Chapter 4 – Reactor
- Chapter 5 - Reactor Coolant System and Connected Systems
- Chapter 6 - Engineered Safety Features
- Chapter 7 - Instrumentation and Control
- Chapter 8 - Electric Power
- Chapter 9 - Auxiliary Systems
- Chapter 10 - Steam and Power Conversion System
- Chapter 11 - Radioactive Waste Management
- Chapter 12 - Radiation Protection
- Chapter 13 - Conduct of Operations
- Chapter 14 - Initial Test Program
- Chapter 15 - Accident Analyses
- Chapter 16 - Technical Specifications
- Chapter 17 - Management of Safety and Quality Assurance Program
- Chapter 18 - Human Factors Engineering
- Chapter 19 – Probabilistic Risk Assessment, Severe Accident and Aircraft Impact Assessment
- Chapter 20 – Physical Protection

- Chapter 21 - Safeguards
- Supplement 1 - Independent Verification Report on Departures/Changes
- Supplement 2 - Safety Issues and Use of Operating Experience

Enclosure 2--PSAR Addendums

- Addendum 1: Mini peer review report for Shin-Kori Units 3 and 4 Probabilistic Risk Assessment (PRA)
- Addendum 2: Independent Safety Verification Report: BNPP 1&2 PSAR
- Addendum 3: Shin-Kori Units 3 and 4 Construction Permit (Korean)

Enclosure 3--ENEC Quality Assurance Manual

Enclosure 4--Regulatory Commitments

Also part of the CLA, ENEC submitted under separate cover the “Braka Units 1 and 2 Physical Protection Plan for Construction” and the “Preliminary Safeguards Plan,” the “Preliminary Braka Units 1 and 2 Probabilistic Safety Assessment Summary Report,” and the “Aircraft Impact Assessment Report.” All of the latter documents were classified by ENEC as “Confidential, Not for Public Release.”

ENEC also submitted a separate report titled “BNPP 1&2 Severe Accident Analysis Report” on 29 June 2011.

The PSAR portion of the application submitted by ENEC is based on the design of the Shin-Kori Units 3 and 4 nuclear power plant in Korea, which is the reference design for Barakah Units 1 and 2. Therefore, while the PSAR relies primarily on the reference plant, it also identifies and addresses departures from the reference design which are unique to the Barakah site.

3.2.3 The Applicant

The applicant is the Emirates Nuclear Energy Corporation (ENEC). ENEC was created by Abu Dhabi Law No. (21) of 2009 signed by H.H. Sheikh Khalifa Bin Zayed Al Nahyan, Ruler of Abu Dhabi, on 20 December 2009.

ENEC is responsible for implementing the UAE nuclear energy program. ENEC is an independent legal entity which has the full legal capacity to conduct its activities and achieve its objectives with the financial and administrative independence to manage its affairs. ENEC’s responsibilities include the deployment, ownership, and operation of nuclear power plants in the Emirate of Abu Dhabi.

For this purpose, ENEC has entered into a contract with the Korean Electric Power Company (KEPCO) to be the primary contractor to provide design and manufacturing services for the delivery of the pressurized water reactor facilities for Barakah Units 1 and 2. The first unit is planned to be operational by 2017.

3.2.4 The Designer and Prime Contractor

KEPCO is the designer of the reference plant and Barakah Units 1 and 2, and is the prime contractor for construction and operations for ENEC. KEPCO, a Korean government owned company, has installed nuclear generation capacity of over 17,000 MW and operates 20 commercial nuclear power units. KEPCO will supply the full scope of works and services for Barakah Units 1 and 2 including engineering, procurement, construction, nuclear fuel, and operations and maintenance support utilizing:

1. KEPCO subsidiaries participating as subcontractors including:

- Korea Hydro and Nuclear Power Co., Ltd. (KHNP), which will play a key role as the Engineering, Procurement and Construction (EPC) contractor and operator
- KEPCO Engineering and Construction Co., Inc. (KEPCO E&C), which will provide the nuclear power plant design and engineering service
- Korea Nuclear Fuel Co., Ltd. (KNF), which will provide the nuclear fuel
- Korea Plant Service and Engineering Co., Ltd. (KPS), which will be involved in plant maintenance

2. Other major nuclear equipment suppliers including:

- Westinghouse of the U.S.
- Toshiba of Japan
- Samsung, Hyundai, and Doosan Heavy Industries of Korea

3.3 Site Description

Location

The site identified by ENEC in the application is located at a location known as Barakah in the Western Region (Al Gharbia) of Abu Dhabi Emirate on the Arabian Gulf, approximately 251 km west-southwest of the city of Abu Dhabi, 48 km east-southeast of the town of Sila’a-Ba’aya, and 53 km west-southwest of the town of Ruwais.

The regional terrain is flat desert, characterized as arid subtropical. Geologically, the site area has been tectonically inactive for nearly 100 million years.

No towns lie within 20 km of the site. The closest population area is Sila’a-Ba’aya, with a reported (2005) population of 7,000 inhabitants, while the town of Ruwais has a reported (2005) population of 15,511 inhabitants.

The plant site borders a restricted military area to the east, with a posted fence along the eastern plant site boundary and Highway E11 along the Arabian Gulf coast. There are no industrial facilities, commercial airports, or railroads in the vicinity of the plant.

General Site Arrangement

The two Reactor Containment Buildings are situated next to the Arabian Gulf. The reactor units consist of a nuclear island and a turbine island. The nuclear island, structurally designed to meet Seismic Category I requirements, includes the Reactor Containment Building and the Auxiliary Building, together with a shared Compound Building between the two units.

The Reactor Containment Building is a pre-stressed, concrete cylindrical structure with a hemispherical dome. A safety-related reinforced concrete base mat is common among the structures of the nuclear island. The interior wall surface and basemat area of the containment is lined with steel for leak-tightness. The Reactor Containment Building completely encloses the reactor system and acts as a biological shield and a barrier to the release of radioactive material. The interior of the Containment Building is compartmentalized for equipment missile protection and radiation shielding during maintenance work activities. Access to the Containment Building is through an equipment hatch and personnel airlocks.

The Auxiliary Building houses the main control room, emergency diesel generators, and fuel handling and storage area for each reactor unit, as well as various safety system components and containment penetration areas. The Auxiliary Building is a rectangular-walled structure constructed of reinforced concrete situated on the common nuclear island base mat.

The turbine island includes the Turbine and Switchgear Buildings. The Turbine Building houses the main turbines and the generator.

The Compound Building provides access control to both units, plus a hot machine shop, and a radioactive waste treatment and waste drum storage/removal area.

Electrical Transmission System

The electrical power to be generated by Barakah Units 1 and 2 will be transmitted from the station switchyard to the Emirates National Grid (ENG) interconnection. TRANSCO, a subsidiary of Abu Dhabi Water and Electricity Authority, is responsible for operating the high voltage power distribution system within the Emirate of Abu Dhabi.

The TRANSCO grid system supplies electrical power over 400 kV transmission lines at an alternating current (AC) frequency of 50 Hz. Six offsite 400 kV transmission lines from the grid will connect from three remote substations via overhead lines to the Barakah Units 1 and 2 switchyard for availability to station auxiliary loads. The 400 kV switchyard is connected to the two station main transformers via underground buses and to the four standby auxiliary transformers via underground cable.

3.4 Plant Description

The application states that each of the proposed Barakah Units 1 and 2 is a two-loop pressurized water reactor (PWR) nuclear steam supply system supplied by KEPCO, rated at 4,000 MWt with a corresponding electrical output of approximately 1,390 MWe.

A summary of the information contained in the application on Barakah Units 1 and 2 plant systems is provided in the paragraphs below.

Reactor

The reactor core within the reactor vessel is comprised of 241 fuel assemblies, 93 top-entry control element assemblies, and 61 bottom-entry incore instrumentation assemblies. Each fuel assembly consists of 236 fuel rods loaded with enriched uranium dioxide (UO_2) or burnable absorber ceramic pellets.

Reactor Coolant System

The reactor coolant system consists of the reactor vessel with two attached reactor coolant loops, each with a steam generator, two reactor coolant pumps, and associated cold leg and hot leg piping. A pressurizer is connected to one of the hot legs.

The two steam generators are vertically mounted U-tube heat exchangers, with integral moisture separators and steam dryers. Reactor coolant enters the steam generators tubes and converts the secondary coolant to steam in the shell-side of the steam generators. The reactor coolant exits through two outlet nozzles in the bottom plenum and returns to the reactor vessel through four reactor coolant pumps which are vertically-mounted, single stage motor-driven centrifugal pumps.

The pressurizer is a vertical, cylindrically-shaped pressure vessel mounted on a hot leg of the reactor coolant system. The pressurizer utilizes immersed electric heaters and upper spray nozzles to control reactor system pressure. Pilot operated safety relief valves provide overpressure protection for the reactor coolant system, with pressurizer relief discharge to the in-containment refuelling water storage tank.

Steam and Power Conversion

The secondary system includes the main steam, condensate and feedwater systems, and the turbine-generator. The main steam system delivers steam produced by the two steam generators to the turbine-generator for conversion of heat energy to electrical energy.

Steam exhaust from the turbine is then condensed in a single-pass tube surface-type condenser and collected for delivery by the condensate and feedwater pumps to the secondary side of the steam generators.

Engineered Safety Features and Emergency Systems

Engineered safety features (ESFs) are designed to provide protection in the event of an accident or incident and to mitigate the potential release of radioactive material.

The safety injection system (SIS) provides borated water injection directly into the reactor vessel to cool the reactor core and ensure shutdown of the reactor. The SIS is comprised of four independent active trains of equipment powered by two electrical divisions. Each train consists of one safety injection pump and one passive safety injection tank. Each of the four safety injection pumps take suction from the in-containment refuelling water storage tank (IRWST) and discharge directly into the reactor vessel through four direct vessel injection (DVI) nozzles.

The IRWST is an annular-shape volume around the lower periphery of the Containment Building. The IRWST is the source of water for the SIS and the containment spray system (CSS), as well as the primary heat sink for pressurizer pilot operated safety relief valve discharge. It also provides borated water to support refuelling operations.

The CSS is designed to reduce the pressure and temperature of the Containment Building following a loss-of-coolant accident or main steam line break inside containment. The CSS also serves to remove radioactive fission products from the containment atmosphere following a loss-of-coolant accident.

The containment isolation system (CIS) provides the function of isolating non-safety-related fluid systems that penetrate the Containment Building following a design-basis accident. Containment building isolation valves are provided on piping that is either part of the reactor coolant pressure boundary or is open to the containment atmosphere. Containment isolation is initiated automatically upon sensed containment high pressure or upon SIS actuation.

The safety depressurization and vent system (SDVS) provides a safety-grade means of reducing reactor system pressure when rapid depressurization is required. The SDVS utilizes four pilot operated safety relief valves mounted on the pressurizer to discharge steam to the IRWST. The system also provides a capability to vent non-condensable gases from the reactor vessel upper head and the pressurizer steam space.

The auxiliary feedwater system (AFWS) is a safety system that provides an independent means of supplying feedwater to the steam generators during emergency conditions when main feedwater is unavailable. The AFWS is comprised of two separate mechanical divisions and four independent trains of equipment. Each division consists of one full capacity centrifugal motor-driven pump, one full capacity centrifugal turbine-driven pump, and one auxiliary feedwater storage tank.

Instrumentation & Controls

Safety-related instrumentation is provided for automatic reactor shutdown, reactor core cooling, containment isolation, containment and reactor system heat removal, and control room displays. The plant protection system (PPS) includes process sensors, calculators, and logic circuits designed to protect the reactor by automatic shutdown and actuation of engineered safety features such as SIS, CSS, and AFWS. The PPS consists of four independent, redundant instrumentation channels that are physically and electrically isolated. Digital computer-based processors in each channel evaluate sensed data and generate a logic-level trip signal when the predefined setpoint is reached, and the safety system is actuated based on a 2-out-of-4 coincident logic. Digital core protection calculators evaluate reactor core local power density and departure from nucleate boiling ratio (DNBR) for reactor trip actuation. In PSAR Section 7.1, “Introduction,” the applicant states that no credible single failure in the manual, automatic, or common portions of the plant protective system will prevent initiation of protective action.

A diverse protection system (DPS) augments the PPS to provide defence-in-depth protection against the occurrence of an anticipated transient without scram (ATWS) event. The DPS provides a diverse reactor trip function based on measured high pressurizer pressure or measured high containment pressure utilizing a 2-out-of-2 actuation logic. The DPS will also initiate the AFWS when the measured water level in either steam generator drops to a low level, and additionally provides for separate diverse manual actuation of ESF functions.

Electrical Systems

Electrical power for the plant safety systems is normally supplied from offsite sources through either the main transformer or onsite generation through two unit auxiliary transformers for each unit. Two standby auxiliary transformers per unit provide an alternate source of offsite power, while two divisional emergency diesel generators (EDGs) per unit and an alternate AC (AAC) diesel generator provide emergency backup. An additional diesel generator per unit is provided as a backup power source for non-safety-related loads.

Fuel Handling and Storage Systems

Handling systems and storage facilities for nuclear fuel are provided in each unit Auxiliary Building. The new fuel storage pit is designed to hold new fuel assemblies in a dry condition. Storage racks hold the new fuel in place and ensure a safe configuration.

A water-filled pool constructed of concrete with interior stainless steel walls provides for the storage of spent fuel assemblies. Stainless steel storage racks are designed to safely hold up to 20 years of spent fuel generation plus space for a full core offload and a fresh batch of fuel. A fuel transfer canal connects the spent fuel pool to the Containment Building for refuelling operations.

A fuel transfer system is used to move fuel assemblies between the Auxiliary Building and containment via the fuel transfer canal. A refuelling machine is used to insert and remove fuel assemblies from the reactor, while a similar spent fuel handling machine is used to move fuel assemblies within the spent fuel pool. A fuel elevator is used to lower new fuel from the refuel floor into the spent fuel pool.

Plant Cooling Water Systems

Plant water systems include: the essential service water (ESW) system, the component cooling water (CCW) system, the ultimate heat sink (UHS), the condensate storage and transfer system, the turbine generator building closed cooling water system, the chilled water (CW) system, and the makeup demineralizer system.

The ESW system utilizes water from the Arabian Gulf (the plant UHS) to remove heat from plant SSCs. The ESW system consists of two safety-related divisions of two pumps and three CCW heat exchangers capable of removal of 100 percent of the station safety-related heat load. The four ESW pumps are provided with upstream traveling screens for debris removal.

Other Auxiliary Systems

Plant process auxiliaries include a compressed air system for instrumentation and equipment applications, systems for sampling liquids and gases, equipment and floor drainage system, and chemical and volume control system (CVCS).

The CVCS maintains the chemistry and volume of reactor coolant system water, and is used to adjust reactor coolant boron concentration for reactivity control.

Heating, ventilation, and air conditioning (HVAC) systems are provided for personnel comfort and safety and for equipment protection. The control room, fuel handling area, and emergency diesel generator rooms are among the areas whose HVAC systems are designed as safety-related systems.

A plant fire protection system consisting of fire detection and alarm systems, fixed automatic sprinklers, fire barriers, and stationed manual firefighting equipment is provided. Automatic carbon dioxide systems are installed in the diesel generator and fuel tank rooms, and in the cable spreading rooms.

Radioactive Waste Management System

Radioactive waste is managed through the liquid, gaseous, and solid waste management systems housed in the Compound Building. The liquid waste management system, consisting of storage tanks, filters, and pumps, is common to both reactor units. Liquid waste is collected in segregated waste collection tanks, processed to reduce activity level, and transferred to a monitor tank prior to sampling and discharge to the circulating water discharge conduit.

The solid waste management system is utilized to process wet solid radioactive waste, as well as dry radioactive waste. Wet solid waste products include spent resins from plant demineralizers and ion exchangers, and liquid stream spent filters. Spent resins are stored in spent resin tanks for holdup prior to processing. Dry active waste products include contaminated clothing, sweepings, and HVAC filters. Packaged solid waste is held in a shielded drum storage area prior to shipment to an onsite storage facility or a disposal site.

The gaseous waste management system collects, processes, and monitors radioactive gases from in-plant sources such as the CVCS, reactor drain tank, and HVAC headers. The gaseous waste management system utilizes charcoal delay beds, high efficiency particulate air (HEPA) filters, and dryers to process gaseous waste prior to monitored discharge via vents. Hydrogen and oxygen concentrations are monitored at various process points to preclude presence of an explosive mixture.

3.5 Facility Programs

The application for the Barakah Units 1 and 2 CLA included several additional documents which support the design and safety information provided in the PSAR. These include:

Physical Protection Plan

A summary of the Physical Protection Plan (PPP) is addressed by the applicant in Barakah Units 1 and 2 PSAR Chapter 20. The actual PPP was submitted as part of the CLA as a separate document due to the confidential nature of its content. The PPP will be implemented in phases to provide the desired level of protection for the different phases of the project.

Phase 1 – Construction until the installation of the first Item Important for Safety as defined in the PPP

Phase 2 – Construction until the delivery of the nuclear fuel

Phase 3 – Operation of the unit

The PPP submitted by the applicant as a part of the CLA provides a holistic overview of the entire physical protection program for all three phases.

Safeguards Plan

ENEC has provided in PSAR Chapter 21, “Safeguards,” a summary of the Preliminary Safeguards Plan (PSP) for Barakah Units 1 and 2. The actual PSP was submitted as part of the CLA as a separate document due to the confidential nature of its content. The summary within PSAR Chapter 21 includes a statement of the purpose of the PSP, recognition of the non-proliferation commitments of the UAE, and recognition that the contents of the PSP must continue to be updated. Further information regarding the content of the PSP is presented in Section 5.24 of this report.

Emergency Plan

ENEC provided an overall description of the Operational Emergency Plan (OEP). The OEP identifies critical areas of the plan still under development. ENEC stated that the OEP will incorporate appropriate aspects of the reference plant emergency plan, will be prepared in general accordance with U.S. NRC regulations, and will comply with FANR regulations. The detailed OEP will be submitted for FANR review and approval prior to plant operation.

ENEC states in the PSAR that the OEP will embrace the 16 Emergency Planning Standards detailed in U.S. NRC NUREG-0654 and briefly describes how each standard will be addressed. The concepts for declaring emergency situations, communicating with offsite officials, warning the public and taking actions to prevent or mitigate accidents were also described.

The FANR staff safety evaluation of the OEP is provided in PART 2 of the Safety Evaluation Report.

Management System and Quality Assurance Program

ENEC's management system, safety culture arrangements, and quality assurance programme are documented in Chapter 17 of the PSAR. PSAR Section 17.3, "Overview of ENEC Quality Assurance Program," refers to the ENEC Quality Assurance Manual (EQAM) as the top-tier quality assurance (QA) document that provides the applicant's overall philosophy for quality and safety, and states that the EQAM complies with the requirements of American Society of Mechanical Engineers (ASME) NQA-1 1994.

ENEC states that its quality assurance program provides for the control of activities that affect the quality of safety-related structures, systems, and components, and is also applied in a graded manner to non-safety-related equipment and activities that support safe plant operations.

The EQAM defines ENEC's QA program requirements, including: ENEC organizational responsibilities; design control; procurement document control; instructions, procedures, drawings; document control; control of purchased material, equipment, services; identification and control of materials; control of special processes; inspection; test control; control of measuring and test equipment; handling, storage, shipping; inspection, test, operating status; non-conformances; corrective action; quality assurance records; and audits.

ENEC states that the current scope of the EQAM addresses only those activities associated with the construction licence covering site selection, design, procurement, and construction, and that additional aspects will be added to the EQAM as the project advances.

The FANR staff detailed safety evaluation of the applicant's management system and quality assurance program is provided in the PART 2 of the Safety Evaluation Report.

3.6 Comparison of Barakah Units 1 and 2 to Reference Plant

General Description of Reference Plant

The reference plant for Barakah Units 1 and 2 is Shin-Kori Units 3 and 4, which is currently under construction in the Republic of Korea. Shin-Kori Units 3 and 4 are based on the APR1400 standard design pressurized water reactor plant. The PSAR for Shin-Kori Units 3 and 4 was approved by KINS in 2008.

Significant differences between the reference plant and Barakah Units 1 and 2 are discussed later in this section.

Summary of KINS Safety Evaluation Report for Shin-Kori Units 3 and 4

A brief summary of the KINS Safety Evaluation Report (SER) for Shin-Kori Units 3 and 4 is provided in the section below.

The KINS SER for the Korea Hydro and Nuclear Power Company construction licence application for Shin-Kori Units 3 and 4 includes a technical review and evaluation of the PSAR, quality assurance program manual, environmental impact assessment report, and statement of the applicant's technical capabilities. The intent of the KINS review and evaluation of the Shin-Kori Units 3 and 4 application was to verify that the preliminary design of the nuclear reactors and associated facilities, compatibility of the site, and radiological environmental impact of the construction and operation of the facility met the regulatory requirements. The KINS SER provides a summary description of each section of the PSAR, followed by a listing of the applicable regulatory review requirements, a technical evaluation, and conclusions regarding acceptability relative to the applicable regulations.

The KINS review determined that the Shin-Kori Units 3 and 4 design, location, structures, and equipment met regulatory requirements and do not present any harm to the environment or public from radioactive materials. KINS concluded in its SER for Shin-Kori Units 3 and 4 that the "… structures and equipment of the nuclear power reactor and related facilities are compliant with the technical standards defined by the Ordinance of the Ministry of Education, Science and Technology."

Major Differences Between Barakah Units 1 and 2 and Reference Plant Design

Supplement 1 of the Barakah Units 1 and 2 PSAR identifies the departures from the reference plant design. Design departures are attributed to either: UAE regulatory requirements, site-specific characteristics, or site-specific design differences. Site-specific characteristics and site-specific design differences include:

- Higher ultimate heat sink temperature of Arabian Gulf water
- Higher ambient air temperatures
- Effects of dust and sandstorms
- Lower electric grid voltage and frequency

Major design differences between Barakah Units 1 and 2 and the reference plant are summarized in the following paragraphs.

The Barakah Units 1 and 2 Containment Building walls and the Auxiliary Building walls are thicker for further protection against the effects of large commercial aircraft impact. This design change is made to comply with FANR regulatory requirements that utilize recent international guidance for aircraft hazards analysis.

The electrical capacity of the emergency diesel generators is increased from 8,000 kW to 8,700 kW to accommodate the increased loads resulting from higher seawater and ambient temperatures at the Barakah site. Similarly, the electrical capacity of the AAC diesel generator is increased from 7,200 kW to 8,700 kW. These design changes are a result of Barakah site-specific characteristics.

The component cooling water heat exchanger building HVAC, essential service water intake structure HVAC, and circulating water intake structure HVAC systems include the addition of air handling units, because open air cooling is not practical at the Barakah site. Similarly, air handling units are added to the plant electrical and instrumentation and control (I&C) rooms. These design changes are a result of Barakah site-specific characteristics.

The emergency diesel generator area HVAC system includes the addition of air handling units and cubicle coolers to minimize intake of dust and sand, and to provide necessary cooling. This design change is a result of Barakah site-specific characteristics.

The number of essential service water pumps designed to be operating during normal shutdown is changed from one pump per division to two pumps per division due to the higher seawater temperature at the Barakah site. This design change is a result of Barakah site-specific characteristics.

The Barakah Units 1 and 2 fire protection water distribution system utilizes high density polyethylene underground pipe instead of iron pipe due to ground soil conditions at the Barakah site. This design change is a result of Barakah site-specific characteristics.

The HVAC intake and exhaust structures are modified to include sand trap louvers to reduce dust and sand content of the air in the area of affected structures, systems, and components. This design change is a result of Barakah site-specific characteristics.

The Barakah Units 1 and 2 reactor coolant pump parameters are changed due to the UAE grid frequency of 50 Hz relative to 60 Hz for the reference plant. This design change is a result of Barakah site-specific design difference from the reference plant site.

The rotational speed of the Barakah Units 1 and 2 main turbine generators is changed to 1,500 rpm relative to the reference plant 1,800 rpm due to the UAE grid frequency of 50 Hz relative to 60 Hz for the reference plant. This design change is a result of Barakah site-specific design difference from the reference plant site.

The Barakah Units 1 and 2 circulating water system intake and discharge conduits are enlarged to accommodate the higher seawater temperature relative to the reference plant. This design change is a result of Barakah site-specific characteristics.

The major differences between Barakah Units 1 and 2 design and the reference plant design have been evaluated by the FANR staff and documented in Section 5 of this report.

4.0 – LICENSING REVIEW METHODOLOGY

4.1 Summary of UAE Law Provisions on Licensing

UAE Federal Law by Decree No. (6) of 2009, "Concerning the Peaceful Uses of Nuclear Energy," establishes the framework and provisions for the licensing of a nuclear facility in the UAE.

Article 5 of the Law provides that FANR shall determine all matters relating to nuclear safety, nuclear security, radiation protection, and safeguards, and shall have the power to establish processes for dealing with licence applications. Article 23 of the Law prohibits the conduct of regulated activities, which include site selection and preparation, construction, commissioning, and operation of a nuclear facility, without a licence issued by FANR.

Prior to FANR granting a licence to conduct a regulated activity, the applicant is required according to Article 28 of the Law to submit detailed evidence of safety to be reviewed and assessed by the Authority in accordance with defined procedures. FANR is required to issue guidance on the format and content of such applications for a licence.

Article 32 of the Law requires that FANR conduct a thorough regulatory review and assessment of the applicant's technical submission in order to determine whether the facility complies with applicable safety objectives, principles, and criteria. The Authority must satisfy itself that the available information demonstrates the safety of the facility, that the information provided by the applicant is accurate and sufficient to enable confirmation of compliance with regulations, and that any technical solutions proposed by the applicant are proven or qualified by experience or testing. Following regulatory review, FANR shall either grant a licence or refuse a licence. A granted licence may be issued with conditions or restrictions on the licensee's subsequent activities. Article 28 of the Law stipulates that the Authority's bases for its licensing decision be formally documented.

Articles 43 through 56 of the Law also stipulate requirements for the licensee in areas such as plant physical protection, emergency preparedness, and radiation protection. Further, the licensee is required to establish a management system for safety, and adopt policies and procedures to define and adhere to appropriate quality assurance requirements. Prior to commissioning of the nuclear facility, the applicant must submit an onsite emergency plan to the Authority for approval.

4.2 Summary of Applicable Regulations

By authority of UAE Federal Law by Decree No. (6) of 2009, "Concerning the Peaceful Uses of Nuclear Energy," Article 11, FANR has established regulations applicable to the construction, commissioning, and operation of a nuclear facility in the UAE. Some of the key aspects of the FANR regulations applicable to a construction licence application are briefly described in the paragraphs that follow.

FANR-REG-01, "Management Systems for Nuclear Facilities"

FANR-REG-01 defines the requirements for management systems applicable to the siting, construction, commissioning, operation, and decommissioning of a nuclear facility. The regulation states the purpose of management systems is to achieve and enhance safety, emphasizing that safety shall be paramount within the organization, overriding all other demands.

Regulatory requirements for a strong safety and security culture are specified, including the facility management's role in reinforcing a learning and questioning attitude at all levels of the organization, providing a means to continually improve the organization's safety and security culture, and ensuring that security measures appropriately balance any conflicting objectives of safety and operations.

FANR-REG-01 specifically obliges the facility senior management to be responsible for an effective management system, and to demonstrate commitment to such system. Clear communications of organizational values, behaviour expectations, and employee involvement are required of management at all levels within the organization. Senior management is also required to establish organizational strategies, goals, and plans consistent with management system objectives, with measureable objectives for implementation throughout the various levels of the organization. Periodic evaluation of the individual processes is required to ensure effectiveness of the management system and to identify opportunities for improvement.

FANR-REG-01 also includes elements pertaining to the quality assurance program requirements delineated in Article 44 of UAE Law by Decree No. (6), including product quality assurance and control, documentation and records management, purchasing, and a deficiency reporting and corrective action program.

FANR-REG-02, "Siting of Nuclear Facilities"

FANR-REG-02 establishes requirements for the evaluation of sites for nuclear facilities, including full characterization of site conditions, and evaluation of external hazards and environmental impact. The purpose of the site evaluation is to ensure protection of the public and the environment from the radiological consequences of radioactive releases that may result from operation of the facility.

The regulation specifies that traditional deterministic methods complemented with a risk-informed methodology be used to assess site characteristics and emergency planning issues. Specific requirements for the evaluation of external hazards are provided to address earthquakes and surface faulting, meteorological events, sandstorms, flooding, and geotechnical occurrences. The regulation also requires that human induced external events be evaluated, including aircraft crashes, chemical hazards, and impact of ships on the facility water intake structures.

FANR-REG-02 also requires that the dispersion of radioactive material through the atmosphere and contamination of the surface and ground waters be evaluated for potential impact on the local population. Information on the regional populations is required to be collected and kept up-to-date for the life of the facility, and such data is to be analysed for potential radiological impact of normal operational discharges and accidental releases.

FANR-REG-03, "Design of Nuclear Facilities"

FANR-REG-03 establishes requirements for the design of structures, systems, and components (SSCs) important to safety. It also provides requirements for a comprehensive safety assessment to include deterministic analysis and probabilistic risk assessment.

As a specified general requirement, FANR-REG-03 requires that SSCs important to safety be designed in accordance with internationally recognized codes and standards and that designs be proven by experience or testing. Lessons learned from other facilities, as well as research results, must also be taken into account in the design of SSCs.

The regulation requires that the principle of defense-in-depth be incorporated into the design, including multiple physical barriers to the uncontrolled release of radioactive materials, conservative design practices, and operational safety margin. SSCs important to safety are required to be classified according to their safety function, and be designed and constructed such that their quality and reliability is commensurate with their importance to safety. The regulation further requires that the design be analysed for design-basis events and severe accident conditions.

FANR-REG-03 requires that the facility be designed to operate within a defined range of acceptable plant parameters with a minimum set of plant support systems operational, and that deterministic analyses be performed to confirm adequacy of such defined operational limits and equipment availabilities. FANR-REG-03 also requires the applicant to assess the plant capabilities for accidents more severe than the design-basis accidents and to identify measures to prevent them from occurring or mitigate their consequences should one occur.

FANR-REG-04, "Radiation Dose Limits and Optimization of Radiation Protection for Nuclear Facilities"

FANR-REG-04 establishes radiation dose limits for occupational exposure and for members of the public. The regulation specifies that design and operational measures be taken to ensure occupational and public exposure to radiation as low as reasonably achievable. Dose limitations are required to be established in line with international good practice.

FANR-REG-05, "Application of Probabilistic Risk Assessment at Nuclear Facilities"

FANR-REG-05 requires an applicant to conduct a PRA to support its construction licence and operating licence submittals. The regulation specifically requires the PRA to utilize realistic state-of-the-art methodologies to analyse internal and external events for all modes of operation, and that the PRA results be used to complement the design, construction, and operation of the nuclear facility.

FANR-REG-06, "Application for a Licence to Construct a Nuclear Facility"

FANR-REG-06 provides the requirements for an applicant to construct a nuclear facility. The regulation requires information demonstrating that the Nuclear Facility will be designed and constructed in compliance with applicable laws and regulations, and information about general financial and technical qualification of the applicant. The regulation requires identification of any reference facility and evidence of reference facility approval by the regulatory authority in the country of origin. The identification of proposed departures from the reference facility and an independent safety assessment of such departures are also required.

A PSAR is specified in FANR-REG-06 to include a complete description of the proposed facility, including the applicant's management system for managing safety; plant safety analyses; plans for commissioning the facility; preliminary information on the operational limits and conditions defining the safe operating envelope; and preliminary plans for protecting the public, workers, and the environment in the event of a nuclear or radiological emergency. A description of the plant physical protection plan for the construction phase of the project is also required. Specific requirements for the plant physical protection plan are provided in FANR-REG-08.

FANR-REG-08, "Physical Protection for Nuclear Material and Nuclear Facilities"

FANR-REG-08 provides requirements for a physical protection program in order to prevent, mitigate, and respond to acts of radiological sabotage and theft of nuclear material.

FANR-REG-10, "Regulation for the System of Accounting for and Control of Nuclear Material and Application of Additional Protocol"

FANR-REG-10 provides the requirements for establishing the State System of Accounting for and Control of Nuclear Material at the Licensee level, in order to ensure timely detection of loss, theft, diversion, unauthorized production, or possession; and it provides the basis for meeting international obligations and commitments under the Safeguards Agreement and the Additional Protocol.

FANR-REG-11, "Radiation Protection and Radioactive Waste Management for Nuclear Facilities"

FANR-REG-11 defines requirements for a facility radiation protection program and radioactive waste management, including environmental monitoring.

The regulation requires that the radiation protection program be consistent with the applicant's management system, and that the program address organizational responsibilities, work area classification and radiation access control, worker health surveillance, and personnel training. FANR-REG-11 emphasizes the use of engineered features, along with administrative controls and protective clothing for worker radiation protection.

FANR-REG-11 defines specific requirements for the predisposal management of radioactive waste, including radioactive waste product identification, characterization, and packaging; storage and monitoring of radioactive waste; provisions for discharge; and design and construction requirements for radioactive waste management facilities. The regulation also requires that an environmental monitoring program be implemented to ensure that public exposure to radiation is adequately assessed.

FANR-REG-12, "Emergency Preparedness at a Nuclear Facility"

FANR-REG-12 specifies requirements for preparations and planning for a response to a nuclear emergency, excluding responsibilities of offsite agencies.

The regulation specifies that a performance-based emergency plan be developed and maintained which demonstrates with reasonable assurance that mitigation actions and protective measures can be effectively taken in the event of an emergency. An emergency response data system, for automated transmission of safety-related plant parameters to the emergency operations facility, is also required by FANR-REG-12. The applicant's emergency plan requires FANR approval.

FANR-REG-17, "Regulation for the Certification of Operating Personnel at Nuclear Facilities"

FANR-REG-17, entitled "Regulation for the Certification of Operating Personnel at Nuclear Facilities," establishes the training qualifications and certification requirements for plant operating personnel, and states that only personnel certified by FANR may perform the duties of a reactor operator (RO) or senior reactor operator.

The regulation specifies the minimum requirements for an operations personnel training program, including technical knowledge of the nuclear facility, management competencies and communications skills, and familiarity with accident symptoms and accident response. Requirements for training program resources such as classroom facilities, training material, and training simulator are also described.

4.3 Summary of Applicable Regulatory Guidance

FANR regulatory guides (RGs) are issued to describe acceptable methods for complying with FANR regulations. The following paragraphs summarize the regulatory guides applicable to the Barakah Units 1 and 2 CLA. Regulatory Guides are not substitutes for regulations, and compliance with them is not required. Methods of complying with the requirements in regulations different from the guidance set forth by the regulatory guide can be acceptable, if the alternatives provide assurance that the requirements are met.

FANR-RG-001, "Content of Nuclear Facility Construction and Operating Licence Applications"

FANR-RG-001 provides guidance for the content of the detailed information required to be submitted in support of a licence application per FANR-REG-06. The guidance provided in FANR-RG-001 is based in part on IAEA Safety Guide GS-G-4.1, "Format and Content of the Safety Analysis Report for Nuclear Power Plants," U.S. NRC Regulatory Guide 1.206, "Combined License Applications for Nuclear Power Plants," and U.S. NRC Regulatory Guide 1.70, "Standard Format and Content of Safety Analysis Reports for Nuclear Power Plants."

The regulatory guide states that safety analysis reports (SARs) are important documents that FANR assesses in determining the adequacy of the plant design and suitability as a licensing basis. Content of the SARs is delineated by section, with reference to the applicable IAEA Safety Guide or U.S. NRC Regulatory Guide.

For a construction licence application, FANR-RG-001 provides that the application should provide sufficient information about the proposed approach to allow a complete safety review of the construction activities.

FANR-RG-002, "Application of Management Systems for Nuclear Facilities"

FANR-RG-002 describes acceptable methods for complying with FANR-REG-01. The regulatory guide refers to several international standards for specific guidance, including IAEA Safety Guide GS-G-3.1, "Application of the Management System for Facilities and Activities," IAEA Safety Guide GS-G-3.5, "The Management System for Nuclear Installations," and American National Standards Institute (ANSI)/ American Society of Mechanical Engineers (ASME) NQA-1, "Quality Assurance Requirements for Nuclear Facility Applications."

FANR-RG-003, "Probabilistic Risk Assessment: Scope, Quality and Applications"

FANR-RG-003 provides guidance for implementing the requirements of FANR-REG-05. The guidance states that the PRA should represent the design and site-specific features of the facility, and address all initiating events that challenge the facility, including internally and externally initiated events, and cover all modes of plant operation. Also, the PRA should provide a Level 1 analysis of core damage frequency and a Level 2 analysis of large release frequency.

The regulatory guide further states that the PRA should be used as much as practicable during the design and construction to establish performance goals for SSCs, complement the application of quality assurance for SSCs based on their safety significance, and prioritize construction inspection and testing activities.

FANR-RG-003 recognizes that the detail and scope of the PRA will evolve as the plant progresses from design to construction to operation. For the construction licence, it should be demonstrated that the PRA bounds the hazards for the proposed site, with simplified and bounding assumptions applied as appropriate. A peer review of the PRA at the construction stage is also recommended to increase the confidence in the quality of the PRA. The regulatory guide provides reference to a number of international industry standards that address PRA scope and quality.

FANR-RG-004, “Evaluation Criteria for Probabilistic Safety Targets and Design Requirements”

FANR-RG-004 defines evaluation criteria that FANR uses in assessing adequacy of the plant design requirements and the probabilistic safety targets. The evaluation criteria provided in the regulatory guide are identified with the design requirements specified in FANR-REG-03.

FANR-RG-005, “Guidelines for the Design, Construction and Operation of Nuclear Power Plants”

FANR-RG-005 sets forth guidance for implementation of the Authority’s regulations for Siting, Design, Construction, Commissioning, and Operating a nuclear power plant. The guide identifies relevant SAR chapters and provides reference to particular U.S. NRC Regulatory Guidance which is considered acceptable to the Authority.

The U.S. NRC Regulatory Guides referred to in FANR-RG-005 describe methods and/or criteria acceptable to the Authority for meeting and implementing specific requirements in the Authority’s regulations.

4.4 FANR Licensing Process

4.4.1 Licensing Process and Licensing Management

In preparation for the construction licence application, FANR developed a review plan reflecting its established licensing process supported by a procedure and Review Instructions to provide guidance for reviewing the application and the PSAR.

CP.2 FANR Licensing Process

FANR licensing process CP.2, is a part of FANR’s Integrated Management System. The process provides the basic logic sequence of steps and actions, responsibilities, and output products for FANR to deal with a licence application. The main steps of the process are:

1. Receipt of Application - registering application, completeness check, acknowledge reception, assignment of Lead Review Department

2. Issuance of Plan, with responsibilities and schedule for conducting the review

3. Initial Evaluation and Requests for Additional Information

4. Final Evaluation and Licence Recommendation

5. Licensing Decision

6. Issue Documents According to Decision

Licensing Management Procedure

The methodology used by the FANR staff to carry out the licensing process is provided in FANR "Licensing Management Procedure," Revision No. 1, dated 04 November 2010.

The procedure gives FANR reviewers and Technical Support Organizations general guidance on the roles and responsibilities, actions steps, and the outputs required to execute the FANR licensing process, for an application to construct or to operate a nuclear facility. FANR has prepared 21 Review Instructions covering 19 chapters and two supplements included in the Barakah Units 1 and 2 PSAR.

The Project Initiation step sets the necessary grading of the application and other arrangements in order to benefit from the Regulatory Body of the Country of Origin (RBCoO) safety evaluation reviews.

A Licence Application Review Panel (LARP) oversaw collaboration between FANR and the RBCoO, to understand the country of origin's regulatory framework, to compare safety objectives and requirements, and to be acquainted with the extent and depth of the RBCoO licensing reviews for the reference facility, including the review technical basis.

The LARP assigned the categories of each review item as either Review Category 1 or 2 in accordance with the criteria shown below. Review Category 1 requires a detailed independent review of the applicable sections of the Barakah Units 1 and 2 PSAR. Review Category 2 allows a more limited review if the RBCoO review is consistent with FANR regulations and technical requirements.

Review Category 1 was assigned to those areas of review that meet any of the following criteria:

- the area of review involves a new technology relative to the reference plant, with significant impact on nuclear safety, or
- new information with significant implications on nuclear safety has arisen since issuance of the KINS SER for the reference plant, or
- SSCs or operational activities associated with the area of review contribute significantly to facility risk, or
- the conditions associated with the area of review are specific to the UAE.

Review Category 2 was assigned to those areas of review that meet all of the following criteria:

- the documentation submitted by the applicant is sufficiently complete, and
- the submittal demonstrates the KINS regulatory requirements are consistent with and meet those of FANR, and

- the technical basis provided by the KINS safety evaluation is clearly described and acceptable to FANR, and

- there are no design or operational changes from the reference plant that significantly impact nuclear safety.

For each PSAR section to be reviewed, the LARP identified the basis for categorization and scope of the review. The LARP then issued the Licence Application Categorization Report (LACR), which was then used for determining the FANR review category for each section of the PSAR.

The FANR Licensing Management Procedure also provides the methodology used by the FANR staff to review, evaluate, and document. Details are summarized in Section 4.5 below.

BARAKAH Construction Licence Application review - Project Management Plan

To conduct the review and assessment of the CLA for Barakah Units 1 and 2, FANR established a Project Management Plan (PMP) in accordance with the standards in the FANR Integrated Management System. The plan defines and communicates FANR management approval of the objectives and scope of the project, responsibilities and functions, implementation approach, environment within which the project operates, and baseline commitments of the project. It provides for a well-defined, clear, transparent, and traceable process. The plan also identifies the other major stakeholders of the project, their roles and responsibilities. The plan also provides controls and requirements for quality, change management, and technical conflict and issue resolution.

The PMP was instrumental in monitoring and controlling the project and promoting communications among the various teams and task leaders, including the Technical Support Organization (TSO) personnel.

4.4.2 Technical Support Organizations

FANR has contracted with a number of Technical Support Organizations (TSOs) to assist the FANR technical staff in the review and assessment of the construction licence application. TSOs were selected on the basis of their organization and technical staff qualifications, capability, and specific credentials in conducting safety evaluations of nuclear facilities for other established nuclear regulatory bodies. The principal TSOs are:

BNES-ISL Consortium

The Baynuna Nuclear Energy Services of Abu Dhabi (BNES) - Information Systems Laboratories, Inc. (ISL) Consortium consists of the companies listed below:

- Information Systems Laboratories, Inc. of Rockville, Maryland (ISL) is part of the current Technical Support Organization for the U.S. Nuclear Regulatory Commission (NRC) Office of New Reactors for the AP1000 and the US-APWR Design Centers. In addition to providing a range of technical support required to review licence applications, ISL has also provided assistance to the NRC in the preparation of Safety Evaluation Reports for the licence applications being reviewed by the NRC for the AP1000 and the US-APWR Design Centers. For the FANR TSO work, ISL leads the BNES-ISL consortium.

- Baynuna Nuclear Energy Services of Abu Dhabi (BNES) is a subsidiary of The Baynuna Group, a UAE company. BNES specializes in contract management, technical training, and technology transfer to UAE nationals.

- Chesapeake Nuclear Services of Annapolis, Maryland (ChesNuc), is a firm specializing in radiation protection, nuclear waste management, and emergency planning, providing risk management, safety analysis and management, licensing, and operational support, both nationally and internationally.

BNES-ISL has provided technical review support to FANR in the following areas:

- Chapter 1 - Introduction and General Description of Plant

- Chapter 2 - Sections 2.4.13, “Accidental Releases of Radioactive Liquid Effluent in Ground and Surface Waters,” and 2.4.14, “Technical Specification and Emergency Operation Requirements”

- Chapter 3 - Design of Structures, Components, Equipment, and Systems

- Chapter 4 - Reactor

- Chapter 5 - Reactor Coolant System and Connected Systems

- Chapter 10 - Steam and Power Conversion System

- Chapter 11 - Radioactive Waste Management

- Chapter 12 - Radiation Protection

- Chapter 13 - Section 13.3, “Emergency Planning”

- Chapter 19 - Section 19.3, “Aircraft Impact Assessment”

- Chapter S1 - Independent Safety Verification

- Chapter S2 - Safety Issues and Use of Operating Experience

NT Consortium

NT is a consortium consisting of the companies listed below:

- Numark Associates, Inc. of Washington, D.C. (NUMARK) serves as a Technical Support Organization for the U.S. Nuclear Regulatory Commission Office of New Reactors (NRO), providing a range of technical expertise to assist NRC in reviewing new reactor licence applications, primarily for the U.S. EPR, including Design Certification (DC), Combined Construction and Operating License (COL), environmental, and other reviews. In addition, NUMARK has assisted the NRC NRO in the preparation of Safety Evaluation Reports pertaining to both the U.S. EPR design certification and the site-specific COLs that reference the U.S. EPR design certification. Other NUMARK services to the U.S. NRC have included support to the Office of Research in the updating of regulatory guidance documents; support to the Office of Nuclear Reactor Regulation in developing and conducting training classes for inspectors; and support to independent confirmatory analysis of gas-cooled reactor evaluations. For the FANR TSO work, NUMARK leads the NT consortium.

- AMEC Nuclear Safety Solutions Limited (AMEC NSS) of Toronto, Canada, a subsidiary of AMEC of London, England, is the largest nuclear consultancy in Canada providing risk assessment and management, safety analysis and licensing, operational support, and other services, both nationally and internationally.

- TÜV NORD Nuclear (including the resources of TÜV NORD SysTec in Hamburg, Germany, and TÜV NORD EngSys Hannover, in Hannover, Germany) is an expert Technical Support Organization that provides technical support to nuclear regulatory agencies in the German Federal States of Schleswig-Holstein, Lower Saxony, Mecklenburg-Western Pomerania, Saxony-Anhalt, Hesse, and Brandenburg.

- The Technical Research Centre of Finland (VTT), based in Helsinki, Finland is the principal technical support organization to the Finnish Radiation and Nuclear Safety Authority (STUK). The work performed for STUK, the nuclear regulatory body in Finland, comprises work for presently operating reactor units (Loviisa 1-2 and Olkiluoto 1-2) and work for the new unit (Olkiluoto 3) which is under construction.

NT has provided technical review support to FANR in the following areas:

- Chapter 6 - Engineered Safety Features
- Chapter 7 – Instrumentation and Control
- Chapter 8 - Electric Power
- Chapter 9 - Auxiliary Systems
- Chapter 13 - Conduct of Operations
- Chapter 14 - Initial Test Program
- Chapter 15 - Accident Analyses
- Chapter 16 - Technical Specifications
- Chapter 17 - Management of Safety and Quality Assurance Program
- Chapter 18 - Human Factors Engineering
- Chapter 19 – Probabilistic Risk Assessment, Severe Accident and Aircraft Impact Assessment

In addition, NT is providing integration services to FANR which consists of regulatory support, development of processes and procedures, scheduling, document control, and technical editing.

RISKAUDIT Consortium

RISKAUDIT is a consortium consisting of the companies listed below:

- RISKAUDIT IRSN/GRS International, based near Paris, France is a non-profit European Economic Interest Grouping with 20 years of experience in managing projects in the field of nuclear safety and radiation protection. RISKAUDIT provides technical support and regulatory assistance for projects financed by the European

Commission and supports nuclear regulatory authorities and their TSOs in different countries worldwide. RISKAUDIT leads this consortium for the FANR TSO work.

- Institut de Radioprotection et de Sûreté Nucléaire (IRSN) is France's unique technical support organization for studies, research, and training in the field of nuclear safety, security, and radiation protection. It covers nuclear and radiological safety, transport, and safeguard of radioactive and nuclear materials, human and environment protection against ionizing radiation, and protection against actions of malevolence. IRSN is the permanent technical nuclear safety advisor to the French Nuclear Safety Authority, the Autorité de Sûreté Nucléaire (ASN).

- Gesellschaft für Anlagen- und Reaktorsicherheit (GRS) mbH is Germany's central technical and scientific expert organization in the nuclear field and supports German and international nuclear regulatory authorities with analyses, assessments, and expert opinions for reactor safety, radiation and environmental protection, and waste management. GRS advises the Federal Ministry for the Environment, Nature Conservation and Nuclear Safety, the Federal Ministry of Economics and Labor, the Federal Office for Radiation Protection, and the European Commission.

RiskAudit has provided technical review support to FANR in the following area:

- Chapter 2- Site Characteristics

4.4.3 IAEA Review of FANR Site Evaluation

Upon request from the Government of UAE, an IAEA Site and External Events Design (SEED) Review Mission was conducted from 21-24 November 2011 at FANR. The objective of the mission was to review selected sections of FANR's initial safety evaluation report (SER) on Barakah site characterization. The review was conducted by the International Seismic Safety Centre (ISSC) using the IAEA Safety Standards as basis to verify conformity with related IAEA Safety Standards.

The IAEA mission reviewed selected sections of FANR's initial SER relating to population distribution, meteorology, radiological dispersion, human induced events, coastal flooding, seismic hazards, geotechnical, and ultimate heat sink.

As a general conclusion, the IAEA review team stated that a comprehensive review process has been followed by FANR, and the site studies carried out for the Barakah site followed international criteria and practices. The SER was found to address the appropriate safety issues and to be in general compliance with the IAEA safety standards. The site was noted to have several positive features, and coastal flooding was identified as the only critical issue for the Barakah site.

As a result of the review, detailed comments and recommendations for improvement were made by the IAEA team. FANR has implemented the recommendations provided by the IAEA in the final SER. The review undertaken by the IAEA team provides assurance that the SER being prepared by FANR addresses the appropriate safety issues in the area of site characterization, and the scope and methodology applied conform to applicable IAEA safety standards.

4.5 Review Methodology

FANR conducted a comprehensive technical review and safety evaluation of the Barakah Units 1 and 2 PSAR utilizing a graded approach with focus on the most safety-significant areas, taking into consideration the following principal requirements:

- Siting, including consideration of severe external hazards
- Defence-in-depth, including multiple fission product barrier design
- Safety system functionality, including reactivity control and coolant system performance
- Accident prevention and mitigation
- Radioactivity control
- Emergency preparedness
- Management system and quality assurance for construction
- Safeguards
- Security

The objective of FANR's review of the application to construct Barakah Units 1 and 2 was to determine whether the Facility complies with the relevant regulatory safety objectives, principles, and criteria. In doing this, FANR has acquired an understanding of the design of the facility, the safety concepts on which the design is based, and the operating principles proposed.

In implementing the review, as explained in Section 4.4.4 above, the FANR review process has taken into account the information available from the review carried out by the KINS in licensing the reference plant. FANR applied different review approaches depending on whether a PSAR section had been identified as Review Category 1 or Review Category 2.

Review Category 1 involves an in-depth, independent evaluation of the information provided by the applicant to determine whether the applicable safety criteria and regulatory requirements are met. FANR technical specialists review items in accordance with the applicable FANR Review Instruction and reach a conclusion independently but with cognizance of the RBCoO information. The extent and depth of review is commensurate with safety importance of item. Requests for Additional Information (RAIs) are used to gather supplementary information from the applicant to complete the assessment.

Review Category 2 requires FANR to evaluate the information provided by the applicant to determine whether it provides an adequate basis for accepting the KINS evaluation, consistent with the Review Category 2 criteria. Review Category 2 allows FANR to consider the safety evaluation performed by the RBCoO for the reference plant. As part of this process, FANR examines the Korean and FANR Regulations applicable to the review topic to verify that regulations are consistent and that the PSAR meets FANR requirements. FANR also examines the KINS SER for the reference plant to verify the existence of a clear description and explanation of technical basis and acceptance criteria used by the RBCoO. The utilization of the Review Category 2 methodology, however, does not relieve FANR from making its own conclusion that applicable FANR regulatory requirements are met.

In conducting its safety review of the Barakah Units 1 and 2 CLA, FANR employed TSOs to provide a diverse team of international technical specialists with an extensive range and in-depth level of expertise to supplement the FANR staff. The safety reviews were coordinated through a FANR licensing project manager following a structured process, including periodic team meetings at FANR in Abu Dhabi, regular project status reporting, and routine day-to-day interaction between the technical specialists and the FANR staff. In addition, FANR and the TSOs met with the applicant as needed to clarify requests for additional information submitted by FANR and the applicant's responses to such requests.

For each area of review, the respective technical review team member evaluated the material provided by the applicant and where applicable the safety evaluation performed by KINS, and made a determination of whether the area of review is sufficiently described and acceptable relative to the FANR regulatory requirements. In cases where additional information was required in order for FANR to complete its evaluation, a formal request for additional information (RAI) was prepared and issued by FANR to the applicant. The applicant's response to the RAI was reviewed by FANR and its TSO review team, and if sufficient and acceptable, the issue was closed. In some instances, FANR found the applicant's response acceptable for issuance of the construction licence, but the issue was deferred for further evaluation during the operating licence stage of the project. In a few cases, a technical issue was dispositioned by FANR through a conditional acceptance. The closure categories utilized by FANR in this review for dealing with issues raised by means of RAIs are provided below:

- Closed – The issue has been resolved following the clarifications and/or additional information provided by ENEC.
- Conditional Acceptance – The issue has been satisfactorily addressed for the construction licence application. However, further action is required of ENEC following issuance of the construction licence but prior to, or as a part of, the operating licence application submittal, for providing additional information to demonstrate fulfilment of assumed commitments.

Upon completion of the safety reviews and closure of open items, FANR prepared SERs to document its evaluation findings and conclusions. The SER provides the technical, safety, and regulatory basis for FANR's decision regarding the construction licence application. A summary of the evaluation report findings in carrying out the review of Barakah Units 1 and 2 PSAR is provided in Section 5 of this report.

4.5.1 Review Instructions

FANR utilized internal Review Instructions specific to each area of review to conduct its review and evaluation of the PSAR as required by CP.2. The Review Instructions provide acceptance criteria to meet FANR regulations and identify applicable guidance documents, including FANR regulatory guides, U.S. NRC regulations and regulatory guidance documents, ASME standards, IAEA safety guides, and Institute of Electrical and Electronics Engineers (IEEE) standards. Each Review Instruction tabulates the FANR regulations and guides applicable to each section of the PSAR. In addition, the Review Instructions provide guidance for preparation of the review findings and conclusions.

The Review Instructions used for the review of the Barakah CLA include:

1. FANR-RI-001 Introduction and General Description of the plant
2. FANR-RI-002 Site Characteristics

3. FANR-RI-003 Design of Systems, Structures, Components and Equipment
4. FANR-RI-004 Reactor
5. FANR-RI-005 Reactor Coolant and Connected Systems
6. FANR-RI-006 Engineered Safety Features
7. FANR-RI-007 Instrumentation and Control
8. FANR-RI-008 Electric Power
9. FANR-RI-009 Auxiliary Systems
10. FANR-RI-010 Steam and Power Conversion System
11. FANR-RI-011 Radioactive Waste Management including storage prior to disposal
12. FANR-RI-012 Radiation Protection
13. FANR-RI-013 Conduct of Operations
14. FANR-RI-014 Construction Test and Initial Test Program
15. FANR-RI-015 Transient and Accident Analysis
16. FANR-RI-016 Technical Specifications
17. FANR-RI-017 Management Systems/Quality Assurance-Construction Licence
18. FANR-RI-018 Human Factors
19. FANR-RI-019 PRA & Severe Accident Analysis
20. FANR-RI-021 Category 2 Review
21. FANR-RI-S1 Country of Origin Approval and Independent Verification Report on Departures/Changes
22. FANR-RI-S2 Lessons Learned and Technical Development

4.5.2 Documenting the Review

Standard templates were used by the FANR staff for Review Category 1 and 2 SERs. The templates provide a consistent documentation format to ensure that the evaluation is comprehensive and addresses compliance with the applicable FANR regulations. The standard content of each SER is provided below:

Area of Review – provides a brief summary of the PSAR area being reviewed

SER Review Interfaces – identifies items in other sections of the PSAR that need to be reviewed for consistency and accuracy with the PSAR section being reviewed in each SER section

Regulatory Basis – provides the applicable FANR regulations that are to be complied with, and this section constitutes the licensing basis for Barakah Units 1 and 2

Technical Review – documents the FANR technical evaluation

ENEC Conditional Acceptance Items – identifies items that can be deferred for review by FANR or implementation by ENEC. These items are evaluated by FANR to ensure that they do not impact the compliance with the applicable FANR regulations required for issuance of a Construction Licence.

Conclusions – provides a definitive statement as to whether the FANR regulations for the SER section of review have been met.

Appendix – provides the Requests for Additional Information issued by the FANR staff to support the review process and the disposition of those RAIs.

4.5.3 Requests for Additional Information (RAIs)

In the review of the PSAR, the FANR staff determined in some cases that there was the need for a Request for Additional Information (RAI). The RAIs were formally sent to the applicant, and the applicant was required to provide a formal response. Each response to an RAI was then evaluated by the FANR staff to determine if the additional information provided was adequate. In general, the RAI and its response supplement the information in the PSAR, thus this information in many cases is or will be incorporated into the PSAR at a subsequent revision of the PSAR.

In addition, a process was also put into place for a Request for Information (RFI) from KINS when additional detail was needed beyond what KINS documented in their SER for Shin-Kori Units 3 and 4.

A database has been arranged for storing and retrieving the more than 1600 RAIs issued by FANR together with the responses provided by ENEC, and the evaluation of the response by the FANR staff. A list of the RAI correspondence is provided in the full version of the Safety Evaluation Report.

4.5.4 Compliance with FANR Regulation

The Barakah Units 1 and 2 PSAR Section 3.14, "Conformance with Federal Authority for Nuclear Regulation (FANR) Regulations," summarizes how the application complies with the applicable FANR regulations and includes references to sections of the PSAR where more detailed information is given. FANR has evaluated PSAR Section 3.14 to ensure that the applicant has provided sufficient information to ensure conformance with each of the applicable FANR regulations.

4.5.5 Conditional Acceptance of ENEC Commitments

It is recognized by FANR that not all the design or operational information is available at the construction application stage. FANR also recognizes that the entire design information is not needed for issuance of a Construction Licence, and pieces of information can reasonably be left for later consideration to be satisfactorily resolved at or before the latest date stated for completion of the construction of the Barakah 1 and 2. Therefore, commitments and undertakings made by ENEC in the PSAR and in RAI responses to provide information or to complete actions after the issuance of the Construction Licence are evaluated by the FANR staff for Conditional Acceptance. These commitments fall into the following four categories.

- Provide an update to the PSAR including information from RAI responses
- Provide the information in the Final Safety Analysis Report or in one of the other documents that is provided with the Operating Licence Application (OLA) which will be evaluated during the next phase of the FANR review for Barakah Units 1 and 2
- Provide information at a certain date after Construction Licence issuance

- Provide information or take action at or prior to a certain event in the construction process

FANR will subsequently evaluate the submissions resulting from these commitments by the applicant.

5.0 – SUMMARY OF REVIEW FINDINGS AND CONCLUSIONS

5.1 PSAR Review by the FANR Staff

This section presents a summary of the technical review findings and evaluations of the different chapters of the PSAR that is part of the CLA.

The detailed SERs for the different PSAR sections containing the technical evaluation and basis for the conclusions are documented in PART 2 of the Safety Evaluation Report.

In conducting its review of the Barakah Units 1 and 2 PSAR, FANR divided the PSAR into 223 separate topics generally consistent with the sections of the PSAR, and a separate evaluation was carried out for each of them. Some of these evaluated items encompass a chapter of the PSAR, while others deal with sections or even subsections of the PSAR. In performing these reviews, the FANR staff has required the applicant to respond to approximately 1,600 Requests for Additional Information (RAIs). FANR has also asked KINS for support and clarifications about a number of specific technical matters considered in licensing the reference facility. Also, 110 Requests for Information (RFIs) have been provided to KINS.

A summary of the results and conclusions of these reviews is presented in the following sections. The detailed evaluations are presented in PART 2 of this Safety Evaluation Report.

5.2 Acceptance Review of the Construction Licence Application

FANR conducted an acceptance review of the CLA. The objective of the assessment of the application inclusive of the PSAR was to determine its suitability for use by FANR in the regulatory review and assessment required by Federal Law by Decree No. (6), Article 28. Based on this assessment, FANR concluded that the application has sufficient information to begin the review and assessment, subject to some conditions.

A number of sections/chapters of the PSAR were considered to be sufficiently complete to allow FANR to proceed with the routine review and assessment process. Some sections/chapters of the PSAR were considered sufficient for FANR to begin the review and assessment, but additional information was indicated that would be needed in order to complete the evaluation. Finally, a few incomplete sections of the application were identified, some already identified by ENEC in the submittal, that did require additional information before substantial review work could begin.

FANR also requested ENEC to provide some 200 documents incorporated by reference to the PSAR, or referenced in the PSAR. A preliminary list of requested topical meetings was also provided to ENEC, as well as, the planned timeline of the main activities and milestones for FANR to conduct the review of the Barakah Units 1 and 2 CLA.

5.3 Review of Compliance with General Requirements

In the application letter ENA/FANR/10/0044L/LNP, “Construction License Application, Braka Nuclear Power Plant Units 1 and 2 (BNPP 1&2),” December 27, 2010, ENEC provided information about compliance with applicable laws of the state and the regulations of the Authority stating that the Facility will be “designed, constructed and operated in accordance with the UAE Nuclear Law and FANR Regulations,” which is further supported by reference to information provided in PSAR Chapters 14 and 17. ENEC provided details covering its legal establishment through Law No. (21) of 2009 as a juridical entity approved by the Government of Abu Dhabi, and covering its ownership and management structure with identification of directors and principal officers empowered to act in its behalf.

ENEC’s application letter provided information about its financial and technical qualifications to complete the proposed activities in accordance with applicable laws and regulations. Reference was made to Article 6 of Abu Dhabi Law No. (21) of 2009 which states that the share capital for ENEC is “paid in full” by the Government of Abu Dhabi and that the ENEC Board acting through the Executive Council shall be authorised to reduce, increase, or otherwise amend or restructure the Corporations Capital in the manner that might assist the Corporation in achieving its objectives. The application letter states that ENEC and Khalifa University are cooperating in education, training, and recruitment to ensure that human resources needs are met during all stages of development.

Chapter 1 of the PSAR describes the primary contractors responsible for the siting, design, construction, and operations of the nuclear power plant. In addition, Chapter 17 of the PSAR and the supplementary application materials further describe these organizations and their responsibilities. A schedule outlining the major construction phases and milestones is provided in PSAR Table 1.1-2.

FANR concludes that the application letter along with supplemental application materials demonstrate the compliance with relevant regulatory requirements, contained in FANR-REG-06, Article 4.

5.4 Chapter 1 – Introduction and General Description of Plant

Chapter 1 of the PSAR describes the project organization, schedule, site, and facility design. The facility description includes plant layout drawings; a comparison with facilities of similar design; identification of references incorporated into the application; and a listing of industry codes, standards, and regulatory guides applied to the facility. The Barakah Units 1 and 2 design is based on the Shin-Kori Units 3 and 4 nuclear power plant currently under construction in the Republic of Korea (Korea). The plant consists of a 2-loop pressurized water reactor (PWR) contained within a pre-stressed cylindrical concrete containment. The thermal output of each reactor plant is 4,000 MWt within an electrical generating capacity of 1,390 MWe for each unit. The plant design life is 60 years. All of these key design features are identical to the Shin-Kori Units 3 and 4 (reference plant).

The PSAR describes a number of changes to the reference plant design that accommodate the differences between the Barakah and reference plant site environmental conditions. In addition, a number of design changes are necessary to accommodate the UAE electrical power grid which operates at a frequency of 50 Hertz (Hz) as compared to the 60 Hz system in Korea. Barakah Units 1 and 2 have a requirement to be able to withstand impacts of a large commercial aircraft , which has resulted in changes to certain structural design features.

The design is based on generally accepted industrial codes and standards and regulatory guidance from both Korea and the United States, primarily Korean Electric Power Industry (KEPIC) Codes, American Society of Mechanical Engineers (ASME) Codes, and U.S. Nuclear Regulatory Commission (USNRC) Regulatory Guides and the Korean Institute of Nuclear Safety (KINS). The classification methods are consistent with the guidance in the U.S. and the Republic of Korea.

FANR concludes that Chapter 1 of the PSAR, along with supplemental application materials, demonstrates the compliance with relevant regulatory requirements, contained primarily in FANR-REG-06. No significant issues require further assessment following issuance of the construction licence and before the submission of the Operating Licence Application (OLA). Since the Barakah facility is based on the reference plant design, many of the codes, standards, and regulatory guides have been updated since the reference plant design was completed. The use of the earlier editions of codes, standards, and regulatory guides is reviewed by FANR in Chapters 2 through 21 on a case-by-case basis focusing on any safety issues resulting from use of an earlier version of the document.

5.5 Chapter 2 – Site Characteristics

Chapter 2 of the PSAR describes the characterization of the Barakah site and its location in terms of Geography and Demography, Nearby Industrial, Transportation, and Military Facilities, Meteorology, Hydrologic Engineering, Geology, Seismology, and Geotechnical Engineering.

The PSAR provides information on the geography and demography of an area extending to a radius of 80 kilometres (km) in any direction from the Barakah site center-point, defined by the Emirates Nuclear Energy Company (ENEC) as the midpoint on a line connecting the center-points of Unit 1 and Unit 2.

The exclusion area boundary (EAB) is an elliptical area shape with a center that coincides with center-point of the site. The EAB for the site encompasses both units. The low population zone (LPZ) for the site is also an elliptical shape that is formed by joining two circles of 3 km radius that surround each reactor unit. ENEC is the owner of the reactor site and the land within the EAB and has legal authority over all activities that are conducted permitted within the EAB.

The cumulative population, including both the resident and transient population in the years 2005 (census data), 2017 (expected year for initial operation of the first unit), and 2078 (expected year for phase-out) within the LPZ, within 20 km of the site, and within 80 km from the center of the proposed site is described in the PSAR.

The PSAR describes meteorological characteristics for the site and surrounding area including information on normal and extreme values of local meteorological parameters based on onsite measurements, potential influence of the plant and its facilities, as well as, local meteorological conditions for design and operating basis and local and regional meteorological data collected at the proposed site location and further away during the period from March 2009 through February 2010.

The PSAR states that sand and dust storms phenomena do not exist at the reference plant location in Korea but are a relevant meteorological phenomenon for Barakah. ENEC descriptions of these phenomena include a characterization of the phenomena in the United Arab Emirates as would be expected to exist at the Barakah site. This characterization includes expected particle size distribution, expected particulate concentrations, and the frequency of occurrence of dust and sand storms conditions.

The PSAR describes the hydrological setting of the site and the interaction of the site with the hydrosphere, including hydrologic causal mechanisms, which establish the design basis with respect to floods and water supply requirements. This includes, surface water and groundwater uses, which may be affected by operation of Barakah Units 1 and 2, as well as historical flooding at the site, and in the vicinity of the site.

The probable maximum surge and seiche flooding (PMSS) are described to determine the extent to which safety-related systems require protection. In addition, the potential for tsunami flooding and any potential hazards resulting from the effects of a probable maximum tsunami (PMT) on the structures, systems, and components important to safety are considered in the plant design.

The basic geologic, seismic, and geotechnical characteristics of the Barakah site and the surroundings are described in different zones. These characterization zones and their distance to which they extend from the reactors are site (1 km), site area (8 km), site vicinity (40 km), and site region (320 km). This information supports evaluations of the site-specific seismic generated ground motion response spectra, the potential for capable faults, the stability of subsurface materials and foundations, and slopes.

The site region (320 km radius) includes most of the United Arab Emirates (UAE), Abu Dhabi Emirate, a portion of south-eastern Saudi Arabia, Bahrain, and Qatar. The site lies in an area referred to as the Stable Platform of the Arabian Peninsula. The geology of the site vicinity (40 km) is characterized by flat-lying sedimentary rocks in a carbonate-dominated geologic environment. Both regional and site-specific studies indicate no evidence of tectonic or geologic instability within the site vicinity. The review of man-induced geologic hazards associated with oil and gas exploration and development, such as subsidence, fracturing, and induced seismicity is described in the PSAR.

FANR concludes that Chapter 2 of the PSAR along with supplemental application materials demonstrates the compliance with relevant regulatory requirements, contained primarily in FANR-REG-02. FANR concludes that the site has been properly characterized for the environment facility and that the site is suitable for use as a location for operation of two large nuclear power plants as described in the Barakah Units 1 and 2 PSAR.

FANR will review an update of the ENEC characterization of sand and dust storms using data that ENEC will collect and evaluate at the Barakah site during construction.

5.6 Chapter 3 – Design of Structures, Components, Equipment, and Systems

Chapter 3 of the PSAR describes the design of plant structures (e.g., containment, auxiliary buildings), piping, mechanical equipment, and component supports. Chapter 3 also describes design parameters that need to be considered (e.g., seismic, external missiles, wind, flood) in the design of plant structures, systems, and components. The environmental and seismic qualification programmes, the safety classification process, and the design standards, codes, and methods applicable to Barakah Units 1 and 2 are identified in the PSAR.

The Barakah design approach as described in the PSAR is to demonstrate that design parameters used for the reference plant establish a bounding set of conditions for the Barakah site. In some cases, this was possible, for example for wind and precipitation. However, in other cases this was not possible, for example for temperature and flood. Two particular items not bounded by the reference plant design are (1) design requirements for large aircraft impact, which have resulted in design changes to the Containment and Auxiliary Buildings, and (2) the seismic response parameters for design of equipment and equipment supports which are not, in all cases, bounded by the reference plant seismic response parameters.

Environmental differences between the conditions at the reference plant and Barakah identified in the PSAR will be factored into the programme for environmental qualification of equipment and materials. The major considerations in this area are the sand and dust environment and the corrosive environment for buried structures. The seismic qualification of equipment follows practices in USNRC regulatory guidance.

The PSAR describes the process used to classify structures, systems, and components (SSCs) with respect to seismic, system quality group, quality class, electrical, and safety classifications. The classification methods are consistent with the guidance in the U.S. and the Republic of Korea.

The standards, codes, and methods used in the design of mechanical equipment and supports are described throughout this chapter including piping (inclusive of leak-before-break analysis methods), pumps, valves, and supports.

FANR concludes that Chapter 3 of the PSAR, along with supplemental application materials, demonstrates the compliance with relevant regulatory requirements, contained primarily in FANR-REG-03. FANR will conduct further review of the qualification methods for important-to-safety air operated valves and snubbers during construction to confirm implementation of satisfactory seismic design and qualification approaches prior to equipment installation.

5.7 Chapter 4 – Reactor

Chapter 4 of the PSAR describes the mechanical design of the fuel, neutron transport behaviour, and fission distribution in the reactor fuel, heat transfer, and fluid mechanics in the reactor core and the design of reactor core structural supports (reactor internals) and control element drive system design. The fuel system consists of 241 fuel assemblies each containing 236 fuel rods. The fuel design is low enriched uranium dioxide pellets contained within zirconium metal alloy (ZIRLO) cladding. The PSAR states that the fuel design expected for use at Barakah Units 1 and 2 has been used with satisfactory performance in Korean reactors since 2006. The fuel is designed for the maximum fuel rod average burn-up of 60,000 MWD/MTU.

The reactor neutron transport behaviour for the Barakah Units 1 and 2 core design is evaluated using analytical methods, tools, and data first developed for the Combustion Engineering reactor designs in the United States in the 1970s and 1980s. The Korean pressurized water reactors have been adapted from designs and methods used in the Combustion Engineering System 80^+ reactors. Barakah Units 1 and 2 specific reactor physics measurements will be performed during initial reactor operation to confirm the analytical predictions.

The PSAR description of the evaluation of the heat transfer and fluid mechanics behaviour in the reactor core includes the use of the KCE-1 critical heat flux (CHF) correlation developed for Shin-Kori Units 3 and 4. The reactor internal geometry is similar to that of the Combustion Engineering System 80+ design and the Korean Yonggwang nuclear plant (YGN Units 3 and 4). Flow model testing for System 80+ and YGN Units 3 and 4 have been used by ENEC to confirm the flow distribution inside the Barakah Units 1 and 2 reactor vessel. The analytical methods, tools, and data used for the Barakah Units 1 and 2 design are considered adequate. These methods and data are to be conservatively applied and validated against actual plant reactor physics parameter measurements to confirm their conservatism.

The reactor internals and control element drive system are similar in design and materials to those used in the Korean reactors. The difference in electrical power grid frequency between the UAE and Korea will cause a change in reactor coolant pump characteristics.

FANR concludes that Chapter 4 of the PSAR, along with supplemental application materials, demonstrates the compliance with relevant regulatory requirements, contained primarily in FANR-REG-03. FANR concludes that no significant issues require further assessment during construction and before the submission of the OLA.

5.8 Chapter 5 - Reactor Coolant System and Connected Systems

Chapter 5 of the PSAR describes the design of the reactor coolant system (RCS), including the reactor pressure vessel (RPV), reactor coolant pumps (RCPs), steam generators, piping, pressurizer, valves, and the shutdown cooling system (SCS). In addition, the RCS in-service inspection, testing, and leak detection provisions are described in Chapter 5.

The RCS pressure boundary is classified as important-to-safety and is designed using KEPIC codes. The design of the RPV, steam generators, pressurizer, piping, valves, and SCS are essentially identical to those for Shin-Kori Units 3 and 4. However, the RCPs design for Barakah Units 1 and 2 is different than the reference plant due to the difference between the frequency of the Korean electrical power grid and the UAE (60 Hz versus 50 Hz).

The RPV is designed to prevent brittle failure due to pressurized thermal shock, and the embrittlement of RPV material is to be monitored via a material surveillance program. Over pressure protection of the RCS is provided by relief valves and limits on system temperature and pressure. RCS leakage is monitored, and limits are established on acceptable leakage.

In-service inspection of the RCS is to be conducted in accordance with the KEPIC code. The detailed in-service inspection program will be described in the FSAR in the operating licence application submittal. In-service testing of RCS components such as valves will also be conducted in accordance with the KEPIC code.

The SCS connects to the RCS for the purpose of decay heat removal when the reactor is shut down. The SCS is classified as important-to-safety and consists of two independent divisions, each capable of removing 100 percent of the decay heat.

FANR concludes that Chapter 5 of the PSAR, along with supplemental application materials, demonstrates the compliance with relevant regulatory requirements, contained primarily in FANR-REG-03.

5.9 Chapter 6 - Engineered Safety Features

Chapter 6 of the PSAR describes engineered safety features (ESFs) and identifies the purposes of the ESFs in mitigating the consequences of design basis accidents by maintaining the integrity of the fuel, the reactor coolant pressure boundary, and the Containment Building; and in limiting the accidental release of radioactive material so that doses to the general public and workers meet the FANR regulatory requirements.

A number of systems comprise the engineered safety features. The containment isolation system is designed to isolate the containment environment from the external environment by closing isolation valves in a number of systems that have components inside and outside of containment. The containment spray system acts to reduce containment pressure to protect the integrity of the containment as a fission produce barrier.

The combustible gas control system, including the passive autocatalytic hydrogen gas recombiners (PARs), are designed to prevent detonation of combustive gases inside of containment, thereby protecting the integrity of containment as a fission product barrier. The design pressure of the Reactor Containment Building has 10 percent margin beyond the peak pressure that may occur in a design basis accident.

The safety injection system, consists of physically and electrically separate safety injection tanks, safety injection pumps, pipes, valves and which injects water into the reactor vessel in the event of a loss of reactor coolant accident (LOCA). The system is designed to cope with a large break loss of coolant accident (LBLOCA).

The heating, ventilation, and air conditioning (HVAC) of the Main Control Room (MCR) is designed to maintain habitability of the MCR in case of a leak of radioactive materials or toxic chemicals or a fire. The dose due to radiation exposure to a person working in the MCR is reported not to exceed the occupational dose limit even during a LBLOCA.

The safety depressurization system (SDS) is designed to vent non-condensable gases and steam from the reactor coolant system during design basis accidents other than LOCA. The system is also designed to rapidly discharge reactor coolant from the reactor coolant system to the refuelling water storage tank (RWST) through manual operator action for severe accidents (beyond design basis accidents).

The refuelling water storage tank is located in the Reactor Containment Building and serves as the supply of borated water for the containment spray system and safety injection system, and is the supply source for reactor cavity flooding in total loss of feedwater (TLOFWT).

FANR concludes that Chapter 6 of the PSAR, along with supplemental application materials, demonstrates the compliance with relevant regulatory requirements, contained primarily in FANR-REG-03.

FANR will conduct further review of the performance of the holdup volume tank, debris protection of the holdup tank, and containment sump strainers during construction.

5.10 Chapter 7 - Instrumentation and Control

Chapter 7 of the PSAR describes the instrumentation and control (I&C) systems. The I&C systems monitor and perform safety-related functions to protect against unsafe reactor operation during operational states and accident conditions. PSAR Chapter 7 identifies Barakah I&C systems and provides their design bases.

The I&C system design includes the functions necessary to operate the nuclear power plant safely under operational states and to maintain it in a safe condition under accident conditions. These functions, implementing systems, software, and equipment have been properly classified to identify their importance to safety. In addition, the applicant has committed to use appropriate quality standards for I&C systems for the design, fabrication, construction, and testing of I&C systems and equipment commensurate with the importance of the safety functions performed.

The applicant has adequately described the functions provided to monitor variables and systems over their anticipated operating ranges, to maintain these variables and systems within their prescribed operating ranges, to automatically initiate the operation of systems and components to assure that fuel design limits are not exceeded as a result of anticipated operational occurrences, and to sense accident conditions and initiate the operation of systems and components important to safety.

A major focus of the review effort was on the extensive use of digital software and hardware I&C applications. The applicant's available software life cycle documentation (such as plans, programs, and procedures), the proposed software classification methodology, and associated approach to design the various I&C systems applications comply with regulatory requirements and conform to regulatory and industry guidance.

At the design basis level (i.e. conceptual design), FANR staff determined that the digital I&C design provides: (a) Adequate data communication isolation between non-safety control systems and safety systems of the same safety system; (b) adequate provisions for communication between divisions of the same safety systems; and (c) adequate protection of safety functions against common-cause software failures. FANR will conduct a thorough evaluation of the digital I&C systems detailed design to be submitted by the applicant during the construction phase and following the operating licence application.

The design of safety-related I&C systems complies with the following aspects of the regulatory criteria: design basis requirements for systems and components; system access control; use of recognized codes and standards; conformance to the defence-in-depth design approach; system and function safety classification; Technical Specification values; provisions for independence and diversity; compliance with the single failure criterion and fail-to-safety principle; interaction between safety and security; equipment qualification; provision for calibration, testing, and maintenance; computer-based systems; and protection system reliability. In some cases, versions of industrial standards cited by applicant were not the most recent ones. The applicant has committed to perform conformance evaluations against current guidance.

FANR concludes that Chapter 7 of the PSAR, along with supplemental application materials, demonstrates the compliance with relevant regulatory requirements, contained primarily in FANR-REG-03.

5.11 Chapter 8 - Electric Power

Chapter 8 of the PSAR describes the onsite electrical power systems. This description states that plant safety-related systems are normally supplied from offsite sources through either the main transformer or onsite generation through two unit auxiliary transformers for each unit. In addition, two standby auxiliary transformers per unit provide an alternate source of offsite power, while two divisional emergency diesel generators (EDGs) per unit and an alternate AC (AAC) diesel generator provide emergency backup. An additional diesel generator per unit is provided as a backup power source for non-safety-related loads, mainly for turbine generator loads.

The onsite AC power system provides the generation and distribution systems necessary to distribute the required AC power to the electric loads in the plant. It includes the connection from the switchyard, the main generator, the large power transformers, switchgear, and cabling necessary to connect the plant loads. The onsite direct current (DC) power system provides the power sources and distribution systems necessary to distribute the required DC power to the electric loads in the plant. It includes the Class 1E and non-Class 1E batteries and the 120 V AC systems fed from the inverters.

An AAC source provides protection against station blackout (SBO), (i.e., the complete loss of AC onsite and offsite power), with the exception of station battery backed plant inverters (and the AAC source itself), to the essential and nonessential switchgear buses in a nuclear power plant.

FANR concludes that Chapter 8 of the PSAR, along with supplemental application materials, demonstrates the compliance with relevant regulatory requirements, contained primarily in FANR-REG-03. The initial analysis of UAE electrical network confirmed that the offsite power system is designed with sufficient independence, capacity, and capability to meet regulatory requirements. The transmission network is connected to the onsite power system by a minimum of two physically independent and reliable circuits.

FANR will conduct further review of high voltage switchyard design and grid stability analysis reports during construction.

5.12 Chapter 9 - Auxiliary Systems

Chapter 9 of the PSAR describes a number of auxiliary systems including fuel storage and handling, water systems, process auxiliary systems, heating, ventilating and air conditioning systems, and other auxiliary systems which are essential for the safe shutdown of the plant and for the personnel comfort and equipment operational performance.

The design basis for these systems as compared to the reference plant has been affected by site-specific conditions such as seawater temperature, ambient air temperature, and dust and sand storm.

The average seawater temperature at the Barakah site is higher than that of the reference plant site. This results in different design capabilities for cooling systems such as the essential service water system, ultimate heat sink, and component cooling water system. For example, the cooling capacity of the heat exchangers and pump flow has been increased with respect to the reference plant.

The average ambient air temperature at the Barakah site is higher than that of the reference plant site. Accordingly, ENEC has changed the design basis capabilities of the affected HVAC systems, or introduced new chiller systems in order to accommodate the higher ambient temperature.

Dust and sand storms are common weather phenomena at the Barakah site, which is not the case at the reference plant. The design of HVAC systems has been altered to cope with these environmental conditions. The design of HVAC systems for Barakah Units 1 and 2 includes sand trap louvers, sand separation units, pre-filter and medium filter units in series upstream of the HVAC Air Handling Units.

FANR concludes that Chapter 9 of the PSAR, along with supplemental application materials, demonstrates the compliance with relevant regulatory requirements, contained primarily in FANR-REG-03. The appropriate considerations of unique environmental conditions at the Barakah site are being incorporated into affected systems.

FANR will conduct further review of HVAC system design features relative to sand and dust storms during construction.

5.13 Chapter 10 - Steam and Power Conversion System

Chapter 10 of the PSAR describes the design of components and systems necessary for converting thermal energy to electric energy including the turbine-generator, main condenser, main steam line, condensate and feedwater systems. In addition, systems intended for environmental protection, such as the seawater bypass system, are described in this chapter. These components and systems are all identified as non-nuclear safety related. Chapter 10 also describes the auxiliary feedwater (AFW) system, which is designed to remove heat from the reactor if the normal heat removal path through the main condenser is not available. The AFW is nuclear safety related.

The design of the systems described in Chapter 10 of the PSAR is largely identical to the reference plant design. Changes in design from the reference plant are described including differences due to higher seawater temperatures at the Barakah site (e.g., larger main condenser) and the difference in electrical grid frequency (e.g., electrical pumps, main electrical generator). Barakah Units 1 and 2 have a seawater bypass system (not in the reference plant design) which mixes seawater with cooling water being discharged from the plant to reduce the thermal environmental effects on the Arabian Gulf in the immediate area of the plant. This system is for environmental protection and is not nuclear safety related.

The AFW system consists of two independent divisions (one for each steam generator), each capable of removing 100 percent of the decay heat. Each division has both motor driven and turbine driven pumps which allows the removal of decay heat on a loss of all AC power.

FANR concludes that Chapter 10 of the PSAR, along with supplemental application materials, demonstrates the compliance with relevant regulatory requirements, contained primarily in FANR-REG-03. The AFW has appropriate redundancy, diversity, and capability to perform its function under accident conditions.

No significant issues require review following issuance of the construction licence and before the submission of the OLA.

5.14 Chapter 11 - Radioactive Waste Management

Chapter 11 of the PSAR describes the radioactive waste management system, which is a shared system for Barakah Units 1 and 2. The radioactive waste management system consists of the liquid waste management system (LWMS), the gaseous waste management system (GWMS), and the solid waste management system (SWMS).

The purpose of the LWMS is to protect plant personnel, the general public, and the environment from radioactive liquid waste discharges generated by the operation at Barakah Units 1 and 2. The PSAR describes provisions for collecting, segregating, storing, processing, sampling, and monitoring radioactive liquid wastes. The release points for liquid effluents are identified, and concentration limits of radioactive materials in liquid effluents are specified. An estimate of the annual liquid effluent releases is used to calculate the annual dose to an individual at the exclusion area boundary. The LWMS is comprised of the floor drain subsystem, the equipment waste subsystem, and chemical waste subsystem; and the radioactive laundry subsystem. Separate drain lines route the liquid to tanks dedicated specifically to the individual liquid waste stream.

The purpose of the GWMS is to protect plant personnel, the general public, and the environment from radioactive waste gases generated by the operation at Barakah Units 1 and 2. The GWMS consists of the process gas subsystem and the process vent subsystem. The process gas subsystem is a once-through system using charcoal delay beds. The system includes a collection header in each of the Auxiliary Buildings, the Gas Header Drain Tank. This header provides the input to the Gaseous Radwaste System (GRS) Package, which includes two trains of a Waste Gas Dryer, a charcoal guard bed, and two charcoal delay beds. Discharge is to a common HEPA filter prior to release to the environment through the Compound Building HVAC system.

The purpose of the SSWMS is to protect plant personnel, the general public, and the environment from radioactive materials contained in or on solid wastes. Provisions are described for collecting, segregating, storing, processing, sampling, monitoring, and shipping the solid radioactive waste that is generated; and for processing wet solid active waste and dry active waste. The estimated annual average volume of waste that is processed by the SWMS and the corresponding source terms for each waste type are provided.

Packaged wastes are stored in a shielded storage area in the Compound Building and then transferred to the onsite Low and Medium-Level Radioactive Waste Storage Building. The storage facilities in the Compound Building are designed in accordance with U.S. NRC regulatory guidance and Korean utility requirements. Release pathways are controlled and monitored with design features to contain spills along with area, airborne, and process radiation monitors.

The PSAR addresses the process and effluent radiological monitoring instrumentation and sampling systems. The purposes of the process and effluent radiation monitoring and sampling systems (PERMSS) are to measure, record, and control releases of radioactive materials in plant process systems and effluent streams. Sampling and monitoring equipment that are relied upon, their locations, and capabilities to detect, measure, indicate, record, control, and annunciate radiation releases, component failures, system operational malfunctions, and potential radiological hazards associated with waste processing systems and effluent streams are described in the PSAR.

The PSAR describes the process and effluent radiation monitoring systems. The system provides early warning to personnel of potential system malfunctions and provides continuous monitoring of radioactive releases and process streams.

The PSAR describes the process and effluent radiation sampling program. The radiation sampling program includes provisions for the sampling of all identified radioactive sources and plant environs.

A Radiological Environmental Monitoring Program (REMP) that assesses public exposure resulting from external exposure from sources, discharges, and radioactivity in the environment will be implemented at least two years before initial facility operation.

FANR concludes that Chapter 11 of the PSAR, along with supplemental application materials, demonstrates the compliance with relevant regulatory requirements, contained primarily in FANR-REG-03, FANR-REG-04, and FANR-REG-11. FANR concludes that there is a sufficient basis for establishing that expected doses will be within established dose limits for workers and members of the public, and demonstrating an optimal level of protection in keeping with the principles of As Low As Reasonably Achievable (ALARA).

FANR will conduct further review of source terms, REMP, and the Low and Medium-Level Radioactive Storage Building design during construction.

5.15 Chapter 12 - Radiation Protection

Chapter 12 of the PSAR describes the radiation protection measures that will be taken to ensure that radiation exposure to plant personnel, contractors, and general public is maintained within regulatory limits and will be ALARA. These measures include the policy, design, and operational considerations to be implemented for maintaining radiation exposures at levels considered to be ALARA.

ALARA design considerations include adequate spacing of equipment to facilitate maintenance, segregation of radioactive and non-radioactive systems, use of shielded cubicles, and ventilation systems. Operational considerations include provisions for draining and flushing or decontaminating liquid systems, use of handling tools, use of removable shielding, and features to minimize radiation exposure during in-service inspection and maintenance.

There are ALARA design features used to reduce occupational exposures from high exposure maintenance activities that would occur during a refuelling outage. ENEC identified that the design of the steam generators, the use of low cobalt materials, robust fuel, equipment reliability, and system decontamination will reduce occupational exposures.

The sources of radiation in the plant that were the bases for the design of shielding of radioactive components and for the design of ventilation systems are the contained and airborne (uncontained) sources. The plant shielding design takes into consideration normal plant operation and accident conditions.

The design of the Barakah Units 1 and 2 ventilation systems to minimize the potential for spread of airborne contamination is described in the application. In addition, the radiation monitoring systems used for area radiation and airborne radioactivity are described, including design bases and type of radiation monitors and their applications.

The estimated occupational dose, annual dose at the site exclusion boundary, and dose to construction workers have been evaluated.

The occupational exposures for employees at the facility were estimated based on operating experience at reference plant and other similar plants. The expected collective occupational dose is consistent with currently similar operating facilities throughout the world. The estimated annual direct radiation dose at the exclusion area boundary is based on the highest source of direct radiation exposure which is the outside storage tanks. The PSAR states that construction workers receive exposure from direct radiation and as a result of gaseous effluent pathways.

The Health Physics Program is described in the PSAR. The objectives of the Health Physics Program are to ensure plant personnel exposures meet FANR regulatory requirements and are maintained ALARA, and to provide administrative control over radioactive waste releases. The Health Physics Program itself is comprised of rules, practices, and procedures designed to meet these program objectives.

The facilities and equipment include counting rooms, a personnel decontamination facility, an instrument hot shop, and an access control station, as well as the various types of radiation monitoring instrumentation. This includes the laboratory, portable, air, individual and emergency radiation monitoring equipment that will be available at the Barakah facility.

FANR concludes that Chapter 12 of the PSAR, along with supplemental application materials, demonstrates the compliance with relevant regulatory requirements, contained primarily in FANR-REG-03, FANR-REG-04, and FANR-REG-11. FANR concludes that there is a sufficient basis for establishing that expected doses will be within established dose limits for workers and members of the public, and for demonstrating that the plant design is ALARA.

FANR will conduct further review of source terms used in shielding and the contamination control and minimization of waste program during construction.

5.16 Chapter 13 - Conduct of Operations

Chapter 13 of the PSAR describes the proposed conduct of operations which includes management and support organizational structure, staffing levels, qualification requirements, contractor relationships, training and procedures programs for plant staff, and internal review and audit processes, including auditing of the quality assurance and emergency planning.

The PSAR describes corporate functions, including executive management involvement with the project; the division of responsibility between ENEC and the prime contractor; ENEC's organizational definitions, management controls, and responsibilities of key management personnel; and the personnel qualification requirements to support design, construction, and initial testing for Barakah Units 1 and 2.

The PSAR describes plant staff training plans and programs and procedure development plans that facilitate qualification of personnel and help to guide safe, reliable, and efficient plant operation. In addition to plant operation, the training and procedure plans and programs reviewed are applicable to administrative controls, plant maintenance, emergency preparedness, testing, security, and radiation protection.

The purpose of the ENEC's internal review and audit program is to confirm that internal audits and independent reviews of the management system, including the quality assurance program, across all levels of the organization are adequately planned, scheduled, and conducted.

The PSAR states that ENEC's emergency planning and preparation include planning and design process, and the organizational capability to adequately execute the plan in response to emergency situations.

FANR concludes that Chapter 13 of the PSAR, along with supplemental application materials, demonstrates the compliance with relevant regulatory requirements, contained primarily in FANR-REG-01, FANR-REG-02, FANR-REG-03, FANR-REG-06, FANR-REG-12, and FANR-REG-17.

FANR will conduct further review of the development of the elements of emergency planning for operation, during construction.

5.17 Chapter 14 - Initial Test Program

Chapter 14 of the PSAR describes the initial test program which encompasses the operability and functional testing of the plant structures, systems, and components (SSCs) from pre-operational testing through power ascension to ready the plant for full power operation. The start-up organization, staffing plans, preparation of test procedures, and the qualification of personnel to conduct initial testing are described.

The purpose of the pre-operational testing is to verify that the plant is constructed in accordance with design and to demonstrate operability and functionality of systems and components. The hot functional tests are performed to ensure that systems and components will safely perform their intended functions; hot functional tests also provide baseline performance data and allow plant operators to become familiar with operating procedures. Low power physics tests are performed to compare actual measured core parameters against design, and power ascension testing verifies that the plant operates safely within its defined range of design operating parameters.

ENEC's Construction Inspection and Test Plan (CITP) included tables for Stages I and II and committed to providing similar tables for Stages III and IV within one year of issuance of the construction licence. The CITP tables identify specific design parameters that will be validated during the initial test program including testing and inspection. The tables identify the acceptance criteria or the source of acceptance criteria for plant SSCs.

FANR concludes that Chapter 14 of the PSAR along with supplemental application materials demonstrates the compliance with relevant regulatory requirements, contained primarily in FANR-REG-03 and FANR-REG-06. FANR concludes that there is reasonable assurance that the implementation of the initial testing program will demonstrate that plant SSCs will meet their design objectives.

FANR will conduct further review of Stage III and IV CITP tables during construction prior to ENEC implementing those stages of inspection and testing.

5.18 Chapter 15 - Accident Analyses

Chapter 15 of the PSAR describes the design basis accident analyses performed for Barakah Units 1 and 2. The PSAR addresses multiple accident categories: Increase in Heat Removal by the Secondary System, Decrease in Heat Removal by the Secondary System, Decrease in Reactor Coolant Flow Rate, Reactivity and Power Distribution Anomalies, Increase in RCS Inventory, Decrease in Reactor Coolant System Inventory, Radioactive Material Release from a Subsystem or Component, and Anticipated Transient without Scram (ATWS).

The PSAR describes the accident sequence, methods of evaluating accident behaviour and consequences, and the evaluation for each of the accidents. This includes identification of the computer codes and analysis methods utilized to perform the accident analyses, the initial conditions and key input parameters for the various events, assumptions, and the identification of the most limiting single failure applied to the accident being evaluated. The PSAR states that that computer codes and methods of analysis identified by ENEC for conducting the Barakah Units 1 and 2 transient and accident analysis have been approved for use by the USNRC in the design certification of the Combustion Engineering System 80+ plant design.

FANR concludes ENEC has sufficiently demonstrated the ability to mitigate design basis transients and accidents. FANR concludes that it was appropriate to apply the computer codes approved for use by the USNRC for evaluating Combustion Engineering System 80+

plant designs for evaluating the Barakah Units 1 and 2 plant design and that these codes and methods of analysis are sufficiently conservative.

FANR concludes that Chapter 15 of the PSAR, along with supplemental application materials, demonstrates the compliance with relevant regulatory requirements, contained primarily in FANR-REG-03.

5.19 Chapter 16 - Technical Specifications

Chapter 16 of the PSAR describes the Technical Specifications for Barakah Units 1 and 2. Technical Specifications provide detailed operating conditions which the plant must conform to during operation. The PSAR describes the criteria to determine which structures, systems, and components (SSCs) must be included into the Technical Specifications. In addition, the PSAR describes the Definitions used to implement TS requirements, the rules of reading and complying with the Limiting Conditions for Operation (LCO), Actions, Logical Connectors, and Surveillance Requirements, and the Safety Limits, the system LCOs, and Design Features. There are also requirements for the Radiation and Environmental Monitoring of the Nuclear Facility and the requirements for the facility's Administrative Controls.

FANR concludes that Chapter 16 of the PSAR, along with supplemental application materials, demonstrates the compliance with relevant regulatory requirements, contained primarily in FANR-REG-03 and FANR-REG-06.

5.20 Chapter 17 - Management of Safety and Quality Assurance Program

Chapter 17 of the PSAR describes the ENEC quality assurance program and describes the management systems used to continually improve nuclear safety, security, and quality for the Barakah facility and site. ENEC's management system encompasses the processes used to manage the company's business and technical functions, and provides the framework for the development of policies, procedures, and a strong nuclear safety culture. The ENEC Management System is described in a program document and conforms to IAEA standards.

ENEC's quality assurance program is documented in ENEC Quality Assurance Manual (EQAM). The EQAM is identified as the top-tier QA document that provides ENEC's overall philosophy for quality and safety. The EQAM complies with the Quality Assurance standards of ASME and KEPIC. The PSAR states that the EQAM establishes the QA requirements, and that they are applied in a graded manner in order to address certain equipment and activities that are not safety-related. Management system, safety, and security culture, and quality assurance for commissioning and operations are not described in the PSAR but will be described in the FSAR.

FANR concludes that Chapter 17 of the PSAR, along with supplemental application materials, demonstrates the compliance with relevant regulatory requirements, contained primarily in FANR-REG-01 and FANR-REG-06.

There are no significant issues requiring further assessment following the issuance of the construction licence and before the submission of the OLA.

5.21 Chapter 18 - Human Factors Engineering

Chapter 18 of the PSAR describes the Human Factors Engineering (HFE) program which applies knowledge about human capabilities and limitations to the design of the Barakah Units 1 and 2 facility, systems, and equipment. Human factors engineering ensures that the facility, system, or equipment design, human tasks, and work environment are compatible with the sensory, perceptual, cognitive, and physical attributes of the personnel who operate, maintain, and support the plant.

The PSAR describes the elements of HFE program management and implementation and design of the Main Control Room (MCR) and Remote Shutdown Room (RSR). ENEC states that the HFE program is modelled after U.S. NRC guidance and is consistent with the program used for the reference plant.

The results of preliminary HFE activities were used to form the design bases for the MCR and RSR. ENEC states that the ENEC HFE design guideline is based on applicable industry design guidance which will be used throughout the design process. ENEC's HFE analyses to support detailed design (including HFE verification and validation) will be conducted after the commencement of construction.

FANR concludes that Chapter 18 of the PSAR, along with supplemental application materials, demonstrates the compliance with relevant regulatory requirements, contained primarily in FANR-REG-03.

FANR will conduct further review of HFE tasks analysis and operating experience review during construction.

5.22 Chapter 19 – Probabilistic Risk Assessment, Severe Accident and Aircraft Impact Assessment

Probabilistic Risk Assessment. Chapter 19 of the PSAR provides a summary of the preliminary probabilistic risk assessment (PRA) for Barakah Units 1 and 2. The application includes a Level 1 and a Level 2 PRA for internal events initiated at full power. The Level 1 PRA is performed primarily to quantify the accident sequences and arrive at a total core damage frequency (CDF) for all accidents that result in core damage. The Level 2 PRA is performed to determine the likelihood, magnitude, and timing of containment failure and consequential radiological release. The PSAR briefly addresses external events, including seismic events, internal fire, and internal flooding as initiating events. Other external events such as sand storm, hot weather, channel diversion, meteorite, tsunami, typhoon, and high winds are also addressed.

Level 1 and 2 PRA provide insights to the design and operation of the plant to ensure that adequate measures have been taken to improve the safety of the design and operation. The Barakah PRA model for internal events is an update of the PRA for the reference plant. The Barakah Units 1 and 2 PRA relies on the Korean generic data until the Barakah plant-specific information become available. The Barakah Units 1 and 2 plant-specific conditions need to be addressed, and the data needs to be justified appropriately. The submittals of site-specific information and full scope PRA including external events and low power operating states are deferred to the FSAR stage, and will be reviewed when the full PRA documentation and the electronic model are available at the Operating Licence Application stage.

Severe Accidents. The PSAR provides a description of the plant design features for prevention and mitigation of severe accidents. The severe accident management system employed by ENEC is further supported by Severe Accident Analysis Report, Revision 0 and its Appendices A through F. The PSAR describes design features for prevention of severe accidents that include, but not limited to, anticipated transients without scram (ATWS), mid-loop operation events, station blackout (SBO), fire, and intersystem loss-of-coolant accident (ISLOCA). Examples of the documented design features include, but are not limited to, a diverse protection system for initiation of reactor trip and auxiliary feedwater during an ATWS, redundant shutdown cooling system (SCS) trains and redundant instrumentation to monitor water inventory for prevention of mid-loop operation events, and two emergency diesel generators and an alternate AC (AAC) diesel generator, as well as battery backup capable of supporting essential safety system loads for eight hours.

The PSAR documents plant mitigation features that include containment design, cavity flooding system, hydrogen mitigation system, safety depressurization and vent system, cavity design and emergency containment spray backup system. In addition, ENEC provides severe accident analyses in support of the adopted severe accident management strategy. The CLA materials identify a design departure from the reference plant design in relation to a change of the concrete material considered for the containment structure. This resulted in changes to the analysis of containment performance.

The review by FANR staff was centered on the following elements of the applicant's accident management approaches:

- Strategy to control and mitigate molten core-concrete interaction and core debris coolability
- Strategy to withstand loads from fuel-coolant interaction and hydrogen management
- Methods to prevent high pressure melt ejection into containment accompanied by direct containment heating
- Strategy to demonstrate containment performance and equipment survivability

During the review, FANR staff identified a number of deficiencies in relevant subsections of the submitted PSAR and severe accident analysis results that include incomplete demonstration of validation and verification of the computer code(s) used, inconsistent data and missing information with respect to the parameters of interest for the event, and incomplete technical justifications for assumptions applied in some of the analyses. In the course of the review, the applicant notified FANR of a design departure from the reference plant design in relation to a change of the concrete material considered for the containment structure; this resulted in changes to the analysis of containment performance with incomplete supporting evidence for such changes.

The applicant has committed to address these deficiencies by revising the Severe Accident Analysis Report in a schedule agreed to by FANR. Meanwhile, with the preliminary information supplied on these issues by the applicant, there is no identified issue that would prevent the commencement of the construction activities.

Aircraft Impact Assessment. The PSAR describes an aircraft impact assessment, including identifying imminent threat procedure to cope with an aircraft attack, as well as the loss of large areas of the plant due to fires or explosions. The design requirements in this area are beyond those required for the reference plant and have resulted in certain changes to plant structures, systems, and components. It should be noted that the PSAR description of the aircraft impact assessment has been determined to contain sensitive information and is not available for the general public.

ENEC states that the methods for assessing the adequacy of the design of the Barakah facility to withstand an aircraft impact and to assess the capability of the design to mitigate the consequences of loss of large area of the plant due to fires or explosions is consistent with methodologies developed by the Nuclear Energy Institute and endorsed by the U.S. NRC for these type of assessments.

ENEC developed a number of supplemental classified reports in support of the PSAR intended to demonstrate that (1) structural configurations of the Barakah Units 1 and 2 Reactor Containment Building and spent fuel pool are sufficient to resist the impact of an aircraft and prevent the release of radioactive material, and (2) the Barakah Units 1 and 2 design is sufficiently robust that continued core and spent fuel pool cooling is assured for aircraft strikes, and that the Barakah facility is capable of withstanding the loss of large areas of the plant due to fires or explosions. FANR concludes that these features represent an additional level of defense-in-depth with respect to aircraft impact and effectively reduce the uncertainties associated with aircraft characteristics and aircraft impact results.

Conclusion. FANR concludes that Chapter 19 of the PSAR, along with supplemental application materials, demonstrates the compliance with relevant regulatory requirements, contained primarily in FANR-REG-03.

FANR concludes that aircraft impact assessment indicates that Barakah Units 1 and 2 design can withstand the deliberate impact of a large, commercial aircraft. The assessment also indicates that enough equipment will survive the shock associated with such impact to bring the plant to safe shutdown conditions. FANR further concludes that either the reactor core will remain cooled or the containment will remain intact, and that the spent fuel pool integrity will remain intact.

FANR will review PRA submittals and documentation during construction. FANR will review severe accident submittals and documentation during construction including the effects of changes in concrete materials.

5.23 Chapter 20 – Physical Protection

Chapter 20 of the PSAR is a summary of the Physical Protection Plan (PPP), which contains classified information not to be disclosed to the general public. The Physical Protection Plan is a separate document that ENEC submitted as part of the CLA. The PPP addresses protection of nuclear materials and the nuclear facility against unauthorized removal of nuclear material and radiological sabotage up to and including the Design Basis Threat (DBT).

The Critical National Infrastructure Authority (CNIA) is the competent authority responsible for the security of the facility according to Abu Dhabi Law No. (14) of 2007. CNIA will define, maintain, and protect against the DBT for the Barakah Nuclear Power Plant and will support ENEC implementation of physical protection in accordance with the Nuclear Law, national standards, and FANR regulations and guidance. The functions and responsibilities of CNIA have been transferred, in accordance with Abu Dhabi Law No. (1) of 2012, to the Critical Infrastructure and Coastal Protection Authority (CICPA), General Headquarter of the UAE Armed Forces.

Revision 1 of the PPP submitted by ENEC as a part of the CLA provides an overview of the entire physical protection program for the three phases defined: Construction Phases 1 and 2 and Operation Phase.

FANR concludes that Chapter 20 of the PSAR, along with supplemental application materials, demonstrates the compliance with relevant regulatory requirements, contained primarily in FANR-REG-08.

5.24 Chapter 21 – Safeguards

Chapter 21 of the PSAR describes Safeguards (nuclear non-proliferation) arrangements for Barakah Units 1 and 2. Chapter 21 of the PSAR has been determined to contain sensitive information and is not available for the general public. This chapter provides an overview of a separate document (Preliminary Safeguards Plan) that contains the detail of the Safeguards-related submission. The Preliminary Safeguards Plan (PSP) is organised into two main sections: a general overview of safeguards-related plans and intentions, and a completed Design Information Questionnaire (DIQ), as specified by the International Atomic Energy Agency (IAEA).

The first part of the PSP covers definitions, level of information protection, purpose of the PSP, proliferation resistance of fuel assemblies, compliance with UAE Safeguards Agreement, inspections/designation of responsibility, procedures to support Safeguards, and references to other documents.

The second part of the PSP answers the questions in the IAEA DIQ. The DIQ consists of 58 questions regarding the Nuclear Facility. These questions are arranged into eight main sections that cover: general information, general reactor data, nuclear material description, nuclear material flow, nuclear material handling, coolant data, protection and safety measures, and nuclear material accountancy and control.

ENEC's CLA requested the Construction Licence to cover the import of items controlled under guidelines IAEA INFCIRC/254 Part 1 and Part 2.

FANR concludes that Chapter 21 of the PSAR, along with supplemental application materials, demonstrates the compliance with relevant regulatory requirements, contained primarily in FANR-REG-10 and FANR-REG-06.

5.25 Supplement 1 - Independent Verification Report on Departures/Changes

Supplement 1 of the PSAR provides (1) a description of the design, operational and administrative departures from the reference design (Shin-Kori Units 3 and 4), and (2) a summary of the independent safety verification (ISV) that ENEC conducted on the application to confirm that the application represents a thorough, well documented, and technically sound safety analysis for Barakah Units 1 and 2.

The departure description provided in Appendix S1-A of Supplement 1 of the PSAR identifies those items associated with Barakah Units 1 and 2 that are different from the reference plant, including the reasons for the differences and a description of the differences.

ENEC describes the ISV review of the construction licence application indicating that the preparation was contributed to by ENEC, MPR Associates, Inc., and Maracor Software and Engineering, Inc. The guidelines used in the ISV were those contained in IAEA Safety Standards and Guides. The results of the ISV are described in a supplemental report which identified a number of items that were candidates for improvement. ENEC evaluated each of these items and concluded that no substantial safety issues were identified.

FANR concludes that Supplement 1 of the PSAR, along with supplemental application materials, demonstrates the compliance with relevant regulatory requirements, contained primarily in FANR-REG-03 and FANR-REG-06.

5.26 Supplement 2 - Safety Issues and Use of Operating Experience

Supplement 2 of the PSAR describes safety issues and lessons learned from operating experience applicable to the Barakah Units 1 and 2 design and operation that have been identified subsequent to KINS approval of the APR1400 design in 2002 (the Standard Safety Analysis Report for APR1400 identifies the issues prior to 2001 applicable to Barakah Units 1 and 2). Supplement 2 of the PSAR also summarizes how the issues/lessons learned have been resolved for Barakah Units 1 and 2 and where in the Barakah Units 1 and 2 PSAR their resolution is discussed.

Supplement 2 of the PSAR also identifies those action items resulting from the Three Mile Island (TMI) accident, as well as the U.S. NRC evolutionary and advanced LWR design issues which are applicable to Barakah Units 1 and 2 as discussed in the PSAR. Supplement 2 serves as a roadmap that identifies the safety and operating experience issues applicable to Barakah Units 1 and 2 and where in the PSAR their resolution is discussed.

FANR concludes that Supplement 2 of the PSAR, along with supplemental application materials, demonstrates the compliance with relevant regulatory requirements, contained primarily in FANR-REG-03 and FANR-REG-06. FANR concludes that the scope and process used in preparing Supplement 2 of the PSAR provides reasonable assurance that all significant generic safety issues, operating, and research experiences have been considered in the design.

FANR will conduct further review of emergency core cooling system flow blockage following a loss-of-coolant accident, to demonstrate compliance with FANR-REG-03, Article 56 item, (Generic Safety Issue 191) during construction.

6.0 – FUKUSHIMA LESSONS LEARNED SUMMARY

This section summarizes the review of the implications of the Fukushima event for the proposed Barakah site and facility. The FANR review of the Fukushima event will continue during the construction period including requests for information from ENEC.

6.1 Overview of the Fukushima Event and Subsequent International Analyses

One of the largest earthquakes in recorded history occurred on the east coast of Japan on 11 March 2011.

The nuclear power plants at the Fukushima Daiichi, Fukushima Daini, Higashidori, Onagawa, and Tokai Daini nuclear power stations were affected, and emergency systems were activated. All of these power plants successfully shut down immediately after the earthquake. However, the tsunami generated by the earthquake then struck the east coast of Japan.

Fukushima Daiichi Units 1 through 4 were significantly damaged by the tsunami and by the subsequent accident sequences involving hydrogen evolution from overheated reactor fuel. The subsequent accident sequences resulted in damage to the reactor cores and significant release of radioactive materials beyond the site boundary.

6.2 FANR Regulations Applicable to the Fukushima Review and Initial FANR Actions

FANR-REG-06, Article 6 requires any applicant for a licence to construct a nuclear facility to provide "*a description of how recent lessons learned and experience from other similar facilities, scientific and technical developments, as well as the results of any relevant research on protection and safety have been applied to resolve potential safety issues*."

Pursuant to this Article, FANR issued a letter on 30 March 2011, to ENEC requesting a plan to evaluate and apply any applicable lessons from the event. Subsequently, FANR issued a letter [Letter No FANR/DDGO/ENEC/COR/00081/2011] to ENEC 4 July 2011, providing guidance to ENEC on the requested assessment of how recent experience at Fukushima and lessons learned so far may be applied to address any potential safety issues at the proposed Barakah Nuclear Power Plants. FANR requested:

1. An evaluation of the response of Barakah Units 1 and 2 and the Barakah site when facing a set of extreme situations.

2. A verification of the preventive and mitigation measures selected in accordance with the defence and depth approach: initiating events, consequential loss of safety functions, severe accident management

ENEC submitted a report entitled "Safety Assessment Report for Braka Nuclear Power Plants (Lessons Learned from Fukushima Accident)," through [Letter No. ENA/FANR/11/0356L/LNP] on 30 December 2011, describing proposed design and mitigation measures to improve the robustness of the Barakah facility against extreme events. ENEC also provided a subsequent supplement on 30 January 2012, describing the relation of the proposed

Barakah measures to those of the reference plant. The report addressed the following major topics, in accordance with the FANR guidance:

- Initiating events (including earthquakes, flooding, fire, explosions, sandstorms, oil spills)
- Consequential loss of safety functions (including loss of electrical power, loss of ultimate heat sink, and loss of ultimate heat sink with station blackout)
- Severe accident management (including design features for severe accidents, instrumentation and information systems, provisions for increasing plant robustness, and severe accident management guidelines)

6.3 FANR Safety Review Methodology for the Fukushima Event

The FANR approach to the evaluation of the implications of the Fukushima event for the Barakah site considers the information developed internationally after the event, as well as analyses of the implications for currently operating plants that continues to be evaluated by countries with nuclear power reactors and by international organizations. The guidance provided by FANR to ENEC for the Barakah site Fukushima evaluation considered the Stress Test Specifications developed by the European Nuclear Safety Regulators Group.

The Fukushima event review initiated by FANR is intended to cover the following aspects:

- Operating experience and other nuclear facilities and research programs
- Siting and design considerations in earthquakes, floods, tsunami, and extreme meteorological conditions
- Potential impact of loss of large areas of facilities due to fires and explosions
- Severe accident sequences and risk management actions including emergency preparation review

The specific guidance used by FANR for the evaluation of the ENEC report was provided by FANR Operations Division Review Instruction (RI)-S2.1: "*Assessment of Lessons Learned from Fukushima Event to the Braka Nuclear Facility*," dated 25 January 2012. The review was carried out with respect to potential extreme events and conditions as a supplement to the design-basis reviews conducted for the Barakah Units 1 and 2 PSAR review. FANR also considered the provisions proposed to increase the robustness of reference plant and identified differences that may need to be addressed for Barakah Units 1 and 2. A number of issues were identified during the FANR review for which ENEC provided written responses, including commitments to provide specific additional information as the detailed design of the Barakah Units 1 and 2 progresses.

The FANR review gave priority to those parts of the ENEC report for which a positive finding is needed to support the decision on the issuance of a construction licence. Therefore, a major focus of the review was on the assessment of site characteristics and external initiating events. Specific initiating events included earthquake, flooding, and other extreme natural events (e.g., dust storms, high temperature) and man-made events (excluding aircraft crash, which is already evaluated as part of the PSAR review). The FANR review also evaluated the sensitivity studies performed by ENEC to assess the degree of protection and safety margin and to identify possible weak points and failure modes leading to unsafe plant conditions. In addition, the review included a review of proposed provisions to increase the robustness of the plant through modifications of hardware, modification of procedures, or organisational controls and actions.

The review also identified areas that will be further evaluated by FANR as more detailed information on design and operational procedures are made available by ENEC. For these areas, the review focused on the completeness and sufficiency of the concepts and deferred information commitments provided by ENEC. Areas under this scope included the assessment of loss of safety function, severe accidents, and the implementation plan for safety improvements. The consequential loss of safety functions review included loss of electrical power including onsite back-up electrical power sources, and the loss of the ultimate heat sink for providing cooling to the reactor, plant systems, and fuel storage facility. The review area of severe accident management included the adequacy of the existing accident management measures, including procedural guidance to cope with severe accidents, and the evaluation of potential additional measures.

6.4 Technical Assessment of the ENEC Report by FANR

The following provides a summary of the detailed technical assessment of the ENEC Fukushima report. The assessment includes the identification and evaluation of Fukushima lessons learned issues relevant to Barakah Units 1 and 2 and the Barakah site, evaluation of measures proposed by the applicant to mitigate challenges to reactor safety, even during unlikely but extreme events that may challenge the multiple units planned for the Barakah site, and the need for further studies to be completed by the applicant.

The most significant potential external event challenges are earthquakes, flooding, high temperatures, and sandstorms. These are discussed below, including their implications for consequential loss of offsite power supplies and cooling water and for the mitigation of severe accidents at multiple units.

Earthquakes

The design basis earthquake hazard for the Barakah site has been considered in the context of the review of PSAR Chapter 2. The applicant considers the seismic margin for the Barakah facility structures, systems, and components to be sufficient given the site specific hazard. However, for extreme events beyond the design basis, the FANR staff concluded that further information is needed with regard to the seismic margin or capacity for the Barakah units. This includes situations where non-seismically designed structures, systems, and components could be challenged and have adverse consequences on the operation of structures or equipment that is relied upon for coping with extreme events at the multiple-unit Barakah site. The applicant is performing a seismic probabilistic risk analysis (PRA) as part of the Barakah licensing review, which will address a number of Fukushima-related issues and provide verification that margin exists to accommodate extreme events.

Flooding

The design basis coastal flooding for the Barakah site has been considered in the context of the review of PSAR Chapter 2. The design basis coastal flooding considered a tsunami originating from the Makran Subduction Zone outside of the Arabian Gulf and a cyclone induced storm surge as major sources of this hazard. A combination of these was also considered in the determination of the final plant grade with the objective of assuring a ‘dry site’ in relation to the design basis for coastal flooding. Appropriately, the source of the design basis tsunami was chosen to be outside of the Arabian Gulf, because there are no sources of tsunamigenic faults within the Arabian Gulf itself. The propagation of the tsunami inside the Arabian Gulf from a source outside is the result of conservatively chosen assumptions.

The FANR staff concludes that a further evaluation of a beyond design basis tsunami and the combination of storm surge and tsunami is warranted in order to understand the increase that this could cause in run-up at and inundation of the Barakah site. In this context, the applicant will, using appropriately conservative assumptions and a suitable mathematical model, evaluate the flooding caused by a tsunami generated by an earthquake at the Makran subduction zone (outside the Strait of Hormuz) corresponding to a full rupture of this fault.

The applicant has proposed design changes, including water-tight doors and relocated penetrations, which will provide protection against flooding well above the flooding level that would result from a design basis tsunami. The seismic consequences of such a very large but distant earthquake on the Barakah site ground motion and consequently on the facility will also be documented along with the need for any additional site or facility protection or mitigation upgrades.

Other External Initiating Events

The relatively distant location of shipping channels and shallow depths of the Arabian Gulf in the vicinity of the Barakah site provide ample time for plant operators to implement actions to prepare for and mitigate the effects of major oil spills. The applicant’s strategy for addressing extreme toxic gas events, detecting gases, and isolating the control room, is acceptable. Taking appropriate precautions prior to the onset of sand and dust storms will ensure that the plant and plant operators are properly prepared to deal with the potential effects and minimize the consequences of these events. In the limiting case, plant operators who have been properly trained can ensure that the alternate AC diesel generator is preserved for use following the event.

With respect to high temperatures, even at temperatures of 50 °C, the Main Control Room air conditioning system design margins will continue to be maintained. The fire probabilistic risk assessment will include consideration of extreme fire and flood events in order to assess vulnerabilities that may need to be addressed. External explosion hazards were evaluated. An evaluation of margins and a qualitative assessment of the robustness of the building/barriers against explosions will be later provided.

Consequential Loss of Safety Functions

The reference plant has one alternate AC diesel generator (in addition to the emergency diesel generators) for two units. The Barakah design currently proposes one alternate AC generator to be shared among units. FANR has requested the applicant to perform sensitivity analyses with multiple, diverse, alternate AC generators to establish what improvements in risk reduction could be achieved. The applicant has proposed to extend the battery duty life to 16 hours from the design basis value of 8 hours. This provides substantial additional time for operators to take measures to cope with a station blackout condition. The applicant has proposed the addition of cross-tie capabilities to provide AC power for emergency loads from any emergency diesel generator or alternate AC diesel generator on the site, and the capability to connect a mobile diesel generator to each unit. In order to fully assess the effects of sand/dust storms or events on the ultimate heat sink and potential impacts on the various downstream systems being served, further analyses will be performed as part of the detailed design. FANR has requested the applicant to address low power and shutdown events in the applicant’s Fukushima Report, including appropriate procedural measures to cope with the effects of extreme events affecting multiple units, at the operating licence stage.

Severe Accident Mitigation Measures

The Barakah Units 1 and 2 design already incorporates plant features designed for coping with severe accidents. Nevertheless, a number of areas to improve the mitigation of severe accidents will be addressed at the operating licence stage, including operator actions to flood the reactor cavity. Backup power for communications systems will be provided from emergency electrical sources. FANR has requested the applicant to perform feasibility studies to determine whether alternate means should be used to mitigate spent fuel heat-up and oxidation in the event of uncovery of the spent fuel assemblies, including spraying of water on top of fuel, and establishing a capability to measure pool water level below the top of the stored fuel.

Safety Improvements

The safety improvement changes proposed by the applicant to enhance the robustness of the Barakah design include the following:

Safety Improvement Category	Prevention/Mitigation Measures
Earthquake	Improving the Seismic Capacity of Main Control Room Display (Seismic Category I Alarm Window for Earthquake)
	Improving the Seismic Capacity of AAC Diesel Generator Building, AAC DG and Auxiliaries (higher than 0.14g)
Tsunami	Installation of Water-proof Doors/Gates for Auxiliary Building, AAC DG Building, ESW Intake Structure and CCW HX Building
	Preparing Countermeasures for Damage of the Outdoor Tanks
Fires	Improving Fire Protection Facilities and Response Capability of Plant Firefighting Team
Station Blackout	Unit Cross Tie Design of EDGs and AAC DG for Emergency Power Supply
	Installation of Mobile DG Connection on the outside of the Auxiliary Building (location and number of Mobile DG TBD)
	Extension of Fuel Capacity, of AAC DG Fuel Oil Storage Tank, from 8 hr to 24 hr
	Division C & D Battery Duty Extension from 8 hr to 16 hr
	Class 1E Power Backup for Communication System
Severe Accident	External Water Injection for Steam Generators
	External Water Injection for Reactor Coolant System
	External Water Injection for Spent Fuel Pool
	Installation of Passive Autocatalytic Recombiners in the Spent Fuel Pool

	Building
	Spent Fuel Pool Instrumentation Upgrade
	Toxic Gas Monitor in Main Control Room
Procedural	Development of EOPs, SAMG, EP, training, taking into account Lessons Learned from the Fukushima Accident

6.5 Conclusions

The applicable lessons learned from the Fukushima event are being evaluated by ENEC in a systematic and technically detailed manner to ensure that the construction, design, and operation of the multiple-unit Barakah facility will mitigate the type of consequences experienced at the Fukushima facility even when challenged by very unlikely but extreme events.

FANR concludes that the ENEC report on applying the lessons learned from the Fukushima event in Japan, along with supplemental application materials, demonstrates a sufficient safety basis for issuing a construction licence. FANR concludes that sufficient information has been presented to conclude that structures, systems, and components in combination with proposed safety improvements will provide substantial margin above the design basis capabilities to ensure that a multiple-unit plant can be brought to safe shutdown condition or cope with and mitigate the effects of severe but low probability events.

FANR will review additional submittals and documentation during construction and during the review of the operating licence application to provide assurance that reasonably practicable measures have been taken to minimize adverse consequences from postulated severe but low probability events. FANR will also review the additional severe accident submittals and documentation for PSAR Section 19.2 to assure that the consideration of extreme events is factored into the severe accident mitigation strategies.

7.0 – OVERALL FINDING AND LICENSING RECOMMENDATION

7.1 Overall Finding and Licensing Recommendation

FANR staff has conducted a thorough review and assessment of ENEC's application for a licence to construct the first two units of a nuclear facility at the Barakah site. The staff finds that the information submitted by ENEC, along with supplemental application materials, demonstrates a sufficient safety basis for issuing a construction licence; is sufficient to demonstrate that the proposed facility complies with relevant regulatory requirements; and satisfies the relevant principles, objectives, and criteria for safety, radiation protection, nuclear security, and non-proliferation.

On this basis, the staff recommends that the FANR Board issue a licence pursuant to Articles 5, 24, 24, 25, 27, 28, and 32 of the Law to authorise ENEC to conduct the activities it requested, namely the manufacture, use, transport, possession, storage, assembling, installation, inspection, and testing of SSCs and carrying out of civil works comprising the Nuclear Facility, including supporting and auxiliary equipment and associated facilities.

The proposed licence would also authorise ENEC to import to the United Arab Emirates equipment and technology exclusively for the construction of the nuclear facility. This includes specially designed or prepared components, equipment, or technology directly associated with the APR1400 nuclear reactor.

The staff at the present time does not have a sufficient basis to recommend authorisation of possession, use, manufacturing, or handling of any Nuclear Material as requested by ENEC. The staff recommends that such activities be subject to further specific authorisations by FANR.

The staff also notes that the authorised activities covered by the proposed licence do not include the operation of the nuclear facility. This regulated activity will be subject to a further authorisation by FANR after receipt and review of the required application.

7.2 Proposed Licence Conditions

FANR proposes to impose on the licence several licence conditions, which provide rules and procedures of a general nature that shall be complied with by the Licensee during the authorised activities for the Barakah Nuclear Facility. A summary follows of the conditions proposed:

1. Compliance with the Law, Regulations, Licence, and the Licensee's submissions

   This licence condition sets the obligation of the Licensee to conduct the activities authorized in the Licence complying with a number of documents.

2. Transfer of licence

   This licence condition sets the obligation of the Licensee not to transfer, assign, or dispose the Licence without the express written approval of the Authority.

3. Modifications

   This licence condition sets the obligation of the Licensee to obtain the prior approval of the Authority prior to implementing any modification having significance on safety to the management systems and organisational arrangements; nuclear security or safeguards; the structures, systems, and components of the Facility; or any of the application documents.

4. Plan of activities

   This licence condition sets the obligation of the Licensee to provide the Authority with schedules of activities to be undertaken under the general authority of the Licence and update this information when significant revisions to the construction schedule are required.

5. Regular reporting

   This licence condition sets the obligation of the Licensee to provide the Authority on a regular basis with a quarterly report on the activities carried out under the Licence.

6. Reporting of unplanned events

   This licence condition sets the obligation of the Licensee for reporting to the Authority unplanned events. The condition identifies the range of violations, accidents, events and deficiencies that shall be reported. The condition sets the notification and reporting time schedules for Licensee compliance.

7. Access to facilities and documents, and assistance

   This licence condition sets the obligation of the Licensee to provide the Authority and its authorized representatives with unfettered access to any place, to any document, record, or report or to any authorized person, and shall provide all assistance necessary to enable the Authority to inspect the licensed activities.

8. Records

   This licence condition sets the obligation of the Licensee to make and retain records of the design and construction of the Barakah Nuclear Facility and to demonstrate compliance with the conditions of the Licence. The retention period is specified.

9. Fulfilment of commitments

   This licence condition sets the obligation of the Licensee to comply with the commitments made in its application materials for the Barakah Nuclear Facility. It specifies that amendments to commitments made in the Licensee application materials shall be subject to the approval of FANR Director General.

10. Update of PSAR

    This licence condition sets the obligation of Licensee to provide a revised version of the Barakah PSAR to the Authority within 180 days of the approval of the Construction Licence. The revised PSAR shall include the proposed revisions to the PSAR in conformance to the application materials and all supplement made to the application material.

11. Construction Inspection and Test Plan

    This licence condition sets the obligation of the Licensee to provide the Authority on a regular basis with information on the status of the execution of the Construction Inspection and Test Plan. The Licensee is also obliged to request the approval from the Authority for specific CITP elements of Stage III (Cold Function Test) and Stage IV (Hydrostatic & Hot Function Test) pre-operational testing, and request authorisation from the Authority for beginning these activities at the site.

12. Addressing extreme events

    This licence condition sets the obligation of the Licensee to provide the Authority with information and request its authorisation on design changes for addressing potentially extreme events like the one that occurred at Fukushima.

7.3 Licensee Commitments

In implementing Licence Condition 9 in Section 7.2 above and consistent with the FANR licensing process, FANR has determined that submittal of certain additional technical and design information not required by FANR regulations for issuance of a Construction Licence can reasonably be deferred for review either before a specific construction activity takes place or at the Operating Licence review phase. Information in this category has been committed to by ENEC in the PSAR, other documents in the CLA, and in written responses to FANR requests for additional design and safety information. Licence Condition 9 above requires ENEC to meet these licensee commitments. The FANR staff is tracking these licensee commitments and due dates to ensure that the commitment is addressed by the licensee by the committed due date or activity and that the action taken or response provided by the licensee is acceptable.