CALIFORNIA POWER PLANT SITING STUDY

Appendixes Volume III

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APPENDIX B

ALTERNATIVE REACTOR SYSTEMS

Most of the nuclear steam supply systems installed today in the United States utilize light water reactors (LWR). These systems use a pressurized water (PWR) or a boiling water (BWR) system in the primary loop, the basic difference being that the PWR feeds heated water to a steam generator located outside the reactor vessel and the BWR converts the water to steam inside the reactor vessel. These systems are discussed further, with discussion of the BWR limited only to areas of major difference with the PWR system.

The high temperature gas reactor (HTGR), using gas as the primary heat transfer fluid rather than water, has been developed more recently as a nuclear steam supply system. One of these systems is producing heat for steam generators, one soon will be, and several others are in the engineering phase.

The breeder reactors which are designed to generate more fissionable material than they consume are in various stages of research and development. The liquid metal fast breeder (LMFBR) is discussed because of its basic differences in the primary heat transfer loop and because it is the breeder concept selected by the U. S. Atomic Energy Commission for initial demonstration of commercial feasibility. The light water and gas cooled breeders appear to have principal differences from their predecessors only with respect to the reactor, moderator, and fuel cycle, and are not seen to have much impact on the facility size and other considerations involved in this study.

B.1 LIGHT WATER REACTOR SYSTEMS - LWR

The pressurized water reactor (PWR) concept was first developed for power applications in the Navy program. It is now offered for central station nuclear power plants by three industrial organizations: Babcock and Wilcox, Combustion Engineering, and Westinghouse.

The systems of a PWR nuclear power plant can be grouped into five major categories. These are:

1. Production systems.
2. Engineered safety features.
3. Auxiliary and emergency systems.
4. Radioactive waste and radiation protection.
5. Site and security.

Within each of these categories are several systems or subsystems which determine the space requirements for plant and plant site. The arrangement selected by the plant designer for these systems and system components determines the visual image obtained by an outside observer of the plant. These systems interface with the environment as a source of supply, as a receiver of effluents, or through visual impact of features required for system operation.

Plate B-1 is a flow sheet showing all of the principal systems.

B.1.1 Production Systems

The production systems consist of a source of thermal energy; a means of transferring this energy to steam; a steam turbine to drive an electric generator; a condenser and circulating water system for waste heat rejection; and the electricity producing system including the generator, transformers, switchgear, and transmission lines to deliver the electricity to an existing distribution or transmission system. An integral unit of the production systems is the instrumentation and control system required for start-up, steady-state operation, and shutdown of the production systems.

B.1.1.1 Reactor. The energy source is the nuclear reactor core consisting of fuel elements which must be replaced periodically (cycles vary from 9 to 18 months). New fuel elements must be brought into the plant and spent fuel elements, heavily shielded, must be transported to a fuel reprocessing plant remote from the site.

The core is supported in a heavy walled steel pressure vessel designed for operation up to 2,500 psia at 650 F. This

reactor pressure vessel, shown in Figure B-1, including the vessel head and nozzles is approximately 44 feet long, weighs approximately 500 tons, and requires a space envelope for handling greater than 22 feet in diameter.

B.1.1.2 Nuclear Steam Supply. The other major equipment components which make up the nuclear steam supply (NSS) system are two steam generators (four steam generators are used in some systems), four reactor coolant circulating pumps, and one electrically heated pressurizer. These components are shown in Figures B-2, B-3, and B-4, respectively. The largest component in the entire plant, handled as a single unit during construction, is the steam generator. This unit which weighs more than 550 tons for a 1,000 Mw(e) plant with two steam generators is nearly 66 feet long and requires a space envelope for handling greater than 24 feet in diameter.

The arrangement of the NSS as used by Combustion Engineering is shown in Figure B-5. In operation, it occupies a space envelope approximately 91 feet by 55 feet by 90 feet high, exclusive of the steam outlet piping above the steam generators. This space envelope does not include space for shielding required for personnel protection, insulation of equipment and piping, laydown of reactor components during refueling, or the refueling pool.

The steam line out of the steam generator is 38 inches in diameter (reduced outside the containment to a 30-inch line to the high pressure turbine) and the feedwater line returning to the steam generator is 20 inches in diameter.

Intermittent blowdown from the steam generators is at a normal maximum rate of 75,000 pounds per hour. Some blowdown is continuous during normal operation, due to samples for chemical and radiation monitoring being drained to waste.

Blowdown from all steam generators flows into the steam generator blowdown tank where a portion of the water flashes into steam. The flashed vapor is discharged to the atmosphere, while the remaining condensate normally drains into the circulating water discharge piping.

FIGURE B-1
REACTOR VESSEL

FIGURE B-2
STEAM GENERATOR

FIGURE B-3
REACTOR COOLANT CIRCULATING PUMP

FIGURE B-4

PRESSURIZER

FIGURE B-5

NUCLEAR STEAM SUPPLY SYSTEM

B.1.1.3 Turbine Generator. Steam from the steam generators is fed through 30-inch diameter lines to the high pressure (HP) turbine in a closed loop system consisting of the steam chest of the steam generator, the HP turbine, moisture separators, reheaters, three tandem low pressure turbine units, six-flow condenser, the condensate water box, and six stages of condensate heaters and pumps for return of the condensate to the steam generators.

A steam bypass around the turbine to the condenser and steam dump to the atmosphere (15 percent of full load main steam flow) are provided to dissipate reactor heat prior to reactor shutdown or decreased power level in the event of partial or full loss of external load. Steam operated air ejectors are provided to remove air from the condensate. During low-load conditions high pressure steam is delivered to auxiliary turbines for the steam generator feedwater pumps. These turbines exhaust to the atmosphere.

B.1.1.4 Circulating Water System. The intake water brought in through a large diameter intake line from the ocean passes through a large screen well and pump station structure approximately 110 feet wide and 200 feet long located at the shoreline. Four circulating water pumps, three saltwater pumps for the component cooling water heat exchangers, and two screen wash pumps are located in this structure. Seawater passes through trash racks and then through traveling screens for removal of debris before entering the four pump suction wells. It is estimated that approximately 220 truck loads per year (14 cubic yards/truck) of collected trash will be hauled away from the intake facility for disposal.

B.1.1.5 Power Production. The electric generator, driven by the turbine, is a 22,000 volt (22 kv), three-phase, hydrogen and water cooled unit. Power from the generator is fed through transformers to increase the voltage from 22 kv to 220 kv for transmission. Power from the transformers is delivered to a switchyard which is connected to the system grid by 220 kv transmission lines terminating at substations at the point of intertie with the grid. The area required for the switchyard and the amount of land required for transmission depend upon the number of grids to be supplied and the number of redundant

transmission lines desired. For example, the three generating units planned for San Onofre will supply the Southern California Edison Co. grid by four transmission lines and the San Diego Gas & Electric Company grid by three transmission lines. This requires a switchyard area of approximately 10 acres on terraced terrain. A minimum switchyard for a single unit requires approximately 0.3 acre.

B.1.1.6 Instrumentation and Control. The reactor is controlled by a combination of movable control element assemblies (CEA) and by an adjustable concentration of boric acid dissolved in the reactor coolant.

In addition to the CEA instrumentation and control system, redundant interlocks and automatic protective systems are provided to prevent unsafe operator actions and to initiate reactor shutdown in the event the reactor approaches an unsafe condition.

Because of the large number of parameters monitored for the production systems, the supporting plant processes and the effluent streams, and the redundancy built into the monitoring and control systems, fairly large areas (up to 9,000 square feet) are required for the control room and supporting equipment such as relay cabinets, instrument repair, and computers.

B.1.2 Engineered Safety Features

The engineered safety features are a group of systems designed to localize, mitigate, terminate, and control the consequence in the event of the release of fission products from the reactor core. Their purpose is to protect plant personnel and to assure that off-site consequences are within acceptable limits established by the guidelines of the Code of Federal Regulations.

B.1.2.1 Containment. The reactor containment, shown in Figure B-6, is a monolithic reinforced concrete structure in the shape of a cylinder 138 feet outside diameter with a shallow dome roof and slab foundation. The overall height is approximately 209 feet, with about 35 to 50 feet of the height normally below grade.

The cylindrical and dome portions of the containment structure are prestressed by a post-tensioning system of high strength

FIGURE B-6

PRESTRESSED CONCRETE CONTAINMENT
PWR NSS

cables. The foundation slab is conventionally reinforced with high strength reinforcing steel. The entire interior surface of the containment shell is lined with 1/4-inch steel plate to serve as a leakage barrier. This steel liner is constructed from field-welded segments. A protective layer of concrete covers the portion of the liner over the foundation slab.

Weld inspection procedures employed during construction consist of visual inspection, vacuum-box soap bubble testing, radiography, and dye-penetrant testing. All welds to be inaccessible after construction are vacuum-box soap bubble tested. Approximately 2 percent of welding is spot-examined on a random basis by radiographs.

The containment is designed to contain the pressure (60 psig design pressure) and temperature for the most severe loss-of-collant accident and the most severe environmental conditions conservatively considered credible for the site. The 4-foot thick walls and 3-1/2-foot thick dome of the containment shell provide biological shielding for both normal and accident conditions. The containment structure which completely encloses the reactor and primary coolant system is designed for a leakage rate to the environment of less than 0.3 percent of the 1.92-million cubic foot internal net free volume in 24 hours.

B.1.2.2 Containment Safety Features. The containment safety features include four systems each of which is redundant. These are:

1. Containment Spray System.
2. Containment Emergency Cooling System.
3. Containment Isolation System and Penetration Rooms.
4. Containment Purge Exhaust System.

B.1.2.2.1 Containment Spray System. Two completely independent systems spray 1,750 gpm (each) of borated water mixed with NaOH for iodine removal into the containment atmosphere under the dome to lower temperature and pressure following a loss of coolant accident. Initially, the borated water is supplied from the refueling pool water storage tanks and the NaOH from the chemical storage tank. For long

term cooling following a loss of coolant accident water containing boron and NaOH is obtained from the containment sump through the recirculation lines and shutdown heat exchangers which dump heat to the component cooling water system. Each of the containment spray systems is designed to remove 140×10^6 Btu/hour at the peak containment temperature.

B.1.2.2.2 Containment Emergency Cooling System (CECS). The containment emergency cooling system which provides complete redundancy for the spray cooling system is designed to reduce the containment pressure thus reducing the driving force for leakage from the containment following a loss of coolant accident. The four fan-coil units of the CECS can remove a total of 280×10^6 Btu/hour. The component cooling water system provides the heat sink for the CECS.

B.1.2.2.3 Containment Isolation System and Penetration Rooms. The containment isolation system closes all penetrating lines not required for operation of the engineered safety features to minimize leakage of radioactive materials to the environment in the event of a safety injection initiation due to a loss-of-coolant accident. Isolation is obtained for all lines directly connected to the reactor coolant system or open to the containment atmosphere by two isolation valves in series or an isolation valve and a closed system. Other lines have at least one remotely operated isolation valve.

All electrical and piping penetrations are designed to code requirements and tested for leakage during construction. To provide additional safety and convenience for inspection, all electrical penetrations pass through the containment wall into one of two electrical penetration rooms, and all piping penetrations enter one of two piping penetration rooms at a lower elevation.

Special penetrations, all of which are sealed with valves or gasketed closures, include:

1. An equipment hatch 19 feet in diameter.
2. Two double-door personnel locks.
3. A fuel transfer penetration.
4. Containment supply and exhaust purge ducts.

The fuel transfer penetration is a 30-inch diameter stainless steel pipe installed inside a casing pipe. This provides for transfer of fuel elements between the refueling canal in the containment and the spent fuel pool in the auxiliary building.

B.1.2.2.4 Containment Purge Exhaust System. All air is exhausted from the containment by the purge exhaust system and then passed through prefilters, high efficiency particulate filters (HEPA), and activated charcoal filters for iodine removal before discharge from the vent stack. In emergency situations, the ventilation rate is one-half air change per hour. Accumulation of hydrogen in the containment is controlled to a maximum limit of 3 percent by using the purge system.

B.1.2.3 Safety Injection System. The purpose of the safety injection system or emergency core cooling system (ECCS), consisting of three complementary subsystems, is to prevent damage to the fuel or fuel cladding which might interfere with long term core cooling, and limit the reaction between the fuel cladding and water to less than 1 percent in the event of a loss of primary coolant resulting from incidents up to the maximum hypothetical accident (MHA).

The safety injection system consists of high pressure and low pressure injection subsystems utilizing centrifugal pumps, and a pressure injection subsystem which maintains a reservoir of borated water under nitrogen pressure (200 psig) in four safety injection tanks located inside the containment. Redundant components are provided in each subsystem such that excess capacity is available. Valved interconnections between the subsystems and with the containment spray system provide a high degree of flexibility for short term and long term core cooling. The design criteria can be met for a loss-of-coolant accident with operation of only one of the following:

1. Three out of four safety injection tanks.
2. One out of three high pressure safety injection pumps.
3. One out of two low pressure safety injection pumps.

Pumped safety injection is initiated by either a low pressurizer pressure signal or a high containment pressure signal. The sequence of operation is dependent on the severity of the break causing the loss of coolant.

Immediately following a large pipe break when reactor pressure drops below 200 psig, the safety injection tanks inject 8,200 gallons each through injection nozzles flooding the core in approximately 30 seconds. (Clad melting starts approximately 100 seconds after a loss-of-coolant accident if the core is not cooled.) This action occurs when the reactor coolant system pressure falls below 200 psig even in the event of concurrent loss of outside power.

For less severe pipe ruptures, the safety injection actuation signals start both the high and low pressure pumps and open 12 safety injection line valves which supply an injection nozzle in each of the 4 cold legs of the primary coolant system. Initially, the pumps are supplied borated water from the refueling water storage tank.

For long term core cooling following a loss of coolant accident, a continuous source of borated water is provided by recirculating containment sump water. The low pressure safety injection pumps are automatically shut down and recirculation initiated through the high pressure injection pumps by a signal indicating low water level in the refueling water tank.

The high pressure (1,750 psig) pumps continue to circulate 380 gpm each to provide core cooling water for the complete spectrum of break sizes. During long term cooling, the heat sink is provided by sump water circulated through the shutdown cooling heat exchangers by the containment spray pumps.

Although during recirculation the low pressure (500 psig) pumps are normally secured, they may serve as backup for the containment spray pumps or, if the system pressure permits, may be used to inject 4,000 gpm each directly into the reactor.

Pipe sizes required for the safety injection system are in the range from 4 to 24 inches in diameter, depending on the function and line redundancy.

B.1.2.4 Emergency Electrical Systems. The plant electrical system and the high voltage transmission system are designed to function reliably during normal and emergency conditions. To prevent the concurrent loss of all auxiliary power, the various sources of power are independent of and physically isolated from each other.

All engineered safety features equipment is provided with a minimum of two off-site (preferred) sources and a minimum of two on-site (standby) sources of power. The normal power source for all plant auxiliaries, other than the engineered safety features, is the main turbine generator through two auxiliary transformers. The preferred source is the transmission system network which furnishes power through the reserve auxiliary transformers during start-up, shutdown, or accident conditions. This independent source normally supplies power to the engineered safety feature buses. A second supply available to the preferred source is an intertie to the companion unit of a two-reactor plant.

The standby power source consists of two diesel generators, a third diesel generator that is shared between the two reactor units, and two 125-volt station batteries which are designed to furnish on-site power for reactor shutdown, removal of shutdown heat, and initiation of protection actions. A closed loop cooling water system with heat rejection to the atmosphere by a fan-cooler is provided for each diesel generator unit. Each diesel engine is designed for compressed air start and is supplied with 7 days of fuel supply.

B.1.3 Auxiliary and Emergency Systems

The plant auxiliary systems include:

1. Chemical and Volume Control.
2. Shutdown Cooling.
3. Fuel Pool Cooling.
4. Component Cooling Water.
5. Fluid Sampling and Analysis.
6. Fuel Handling and Storage.
7. Facility Services.
8. Decontamination Processes.

B.1.3.1 Chemical and Volume Control. The major functions of the chemical and volume control system (CVCS) are:

1. To maintain reactor coolant volume, activity level, and chemistry (for corrosion and reactivity control).
2. To provide for filling and testing the reactor coolant system and safety injection of boric acid.

Line sizes used in this system are 3 inches or less in diameter handling the normal letdown flow rate of 40 gpm. Gaseous fission products are released from the coolant stream in the volume control tank and carried to the gaseous waste treatment system.

Periodic laboratory analysis is performed on various streams of the CVCS system to assure proper chemical concentrations.

B.1.3.2 Shutdown Cooling System. The function of the shutdown cooling system is to reduce the temperature of the primary cooling water from 300 F to the refueling temperature in approximately 24 hours and maintain the proper reactor coolant temperature during refueling. The shutdown cooling system is put into service manually after the reactor coolant system temperature has been decreased from the hot shutdown temperature of 545 F to 300 F by bypassing steam to the condenser.

The system utilizes the low pressure safety injection pumps to circulate reactor coolant water through the shutdown heat exchangers and return it to the reactor coolant system through the low pressure safety injection header. The shutdown cooling heat exchangers are cooled by the component cooling water system. Components of the shutdown cooling system are also used for emergency core cooling as described in the discussion of the emergency cooling system. The shutdown cooling system may also be used as a backup for the fuel pool cooling system.

B.1.3.3 Fuel Pool Cooling System. The function of the pool cooling system is to remove spent fuel decay heat from the pool water and maintain the desired high purity and clarity of the water.

The cooling loop is a 12-inch diameter line, and the purification loop is 3 inches in diameter.

B.1.3.4 Component Cooling Water System (CCWS). The component cooling water system is designed to remove heat from the various reactor auxiliary and emergency systems carrying radioactive or potentially radioactive fluids. It provides a monitored intermediate barrier between the auxiliary or emergency system fluids and the salt-water coolant system.

The three major functions of the CCWS are:

1. To remove shutdown heat from the reactor coolant system during plant shutdown.
2. Provide for emergency cooling during post-accident conditions.
3. Provide cooling to the following components:
 - a. Component cooling pumps.
 - b. Reactor coolant pumps.
 - c. Component cooling heat exchangers.
 - d. Low pressure safety injection pumps.
 - e. High pressure safety injection pumps.
 - f. Charging pumps.
 - g. Containment spray pumps.
 - h. Shutdown heat exchangers.
 - i. Spent fuel pool heat exchangers.
 - j. Letdown heat exchanger.
 - k. Sample heat exchangers.
 - l. Air compressor jackets and aftercoolers.
 - m. Reactor shield cooling coils.
 - n. Containment coolers (normal operation).
 - o. Containment atmosphere emergency coolers.
 - p. Miscellaneous waste evaporator cooler.
 - q. Boric acid concentrator.

The system consists of two full-capacity loops serving equipment needed for plant shutdown and emergency cooldown, and one loop serving equipment operating during normal plant operation. Lines up to 20 inches in diameter are found in this system to handle the 15,000 gpm flow capacity of each of the three component cooling water pumps.

B.1.3.5 Fluid Sampling and Analysis System. The sampling system provides for collection of samples of the fluids in the reactor coolant and auxiliary systems for analysis by the plant operating staff in the chemical and radiochemical laboratories. The system is operated from the sampling room. Analyses are performed to determine boron concentration, fission and corrosion product activity levels, crud concentration, dissolved gas, corrosion product and chloride concentrations, pH and conductivity levels, and noncondensable gases in the pressurizer steam space.

B.1.3.6 Fuel Handling and Storage. The fuel handling system is an integrated system of equipment, tools, and procedures for refueling the reactor. The major components of the system are the refueling machine, the control element assembly (CEA) change mechanism, the fuel transfer equipment and the spent fuel handling machine.

The refueling machine moves fuel assemblies into and out of the core and between the core and the transfer equipment. The CEA change mechanism moves CEA's from one fuel bundle to another. The fuel transfer equipment tilts fuel assemblies from the vertical position to the horizontal, shuttles them through the containment wall, and returns them to the vertical position. The spent fuel handling machine handles fuel between the transfer equipment and the fuel storage racks in the fuel pool.

Special tools and lifting rigs are also used for disassembly of reactor components and are included in the refueling system.

B.1.3.7 Facility Services Systems. This group of systems includes:

1. Heating, ventilating, and air conditioning system.
2. Turbine plant cooling water system.
3. Fire protection system.
4. Compressed air system.

B.1.3.7.1 Heating, Ventilating, and Air Conditioning System. All inlet airstreams are cleaned and conditioned appropriate to the requirements of the area being served.

During normal plant operation, the total heat losses from equipment inside the containment building are removed by the component cooling water circulating through six coil-fan units in the cooling and recirculation system. For emergency and post-accident containment cooling, four additional units (on a separate system also dumping heat to the component cooling water system) supplement the normal cooling system.

After power operation, the containment is purged to permit personnel occupancy. All air is taken from the outside, cleaned, heated or cooled, and delivered through the purge supply system. All air supplied is exhausted to the vent stack by the purge exhaust system through prefilters, high efficiency particulate filters, and activated charcoal filters. Dilution air from the outside atmosphere can be added to the stack if required.

The control and computer room area is provided with two independent air conditioning systems: one for normal operation and the other for emergency operation.

The engineered safety equipment rooms are provided with redundant sources of cleaned and conditioned air. All other areas are provided with single sources of cleaned and conditioned outside air. Hoods in sampling areas and laboratories have a separate air supply.

Exhaust air from all areas which may contain radioactive materials passes through filter banks before being exhausted through the plant vent stack. Exhaust streams which cannot become radioactive are dumped to the atmosphere at various points of convenience.

The turbine-generator area is usually an open deck requiring no mechanical ventilation. This area, as well as the transformer and switchyard areas, would need to be ventilated if they are enclosed.

B.1.3.7.2 Turbine Plant Cooling Water. The turbine plant cooling water system removes waste heat from the following turbine plant equipment through heat exchangers dumping to the condenser cooling water circulating system:

1. Generator isolated phase bus duct coolers.
2. Exciter air coolers.
3. Generator H₂ coolers.
4. Lube oil coolers for steam generator feed pumps.
5. Heater drains, pumps, seals, bearings, and stuffing box.
6. Circulating water pump bearings.
7. Turbine lube oil coolers.
8. Generator seal oil coolers.
9. Vacuum pumps and other miscellaneous bearing cooling.

B.1.3.7.2 Fire Protection System. Fire protection is provided by means of fog nozzles, hydrants, hose reels, portable extinguishers, carriage-mounted dry chemical and mechanical foam units, and a piped CO₂ system for the diesel generators. Water is provided for the fire protection system by two 1,000 gpm pumps drawing water from the 3-million gallon service water reservoir. As backup to the freshwater supply, the screen-wash pumps in the circulating water intake structure can be diverted into the fire protection water header for a continuous supply of saltwater.

B.1.3.7.3 Compressed Air System. The compressed air system provides compressed air for pneumatic instruments and valve operation and to outlets throughout the plant for pneumatic tool or other requirements.

B.1.3.8 Decontamination Processes. Decontamination capability is provided for cleaning and decontamination of three item categories:

1. Equipment and tools prior to use, shipment, storage, or repair.
2. Shipping casks and large equipment prior to shipping.

3. Personnel who may have become contaminated during normal or emergency operations.

Decontamination facilities are located in a controlled access area.

B.1.4 Radioactive Waste Handling and Radiation Protection

The radioactive waste systems provide controlled handling and disposal of liquid, gaseous, and solid wastes generated during operation of the reactor and other plant facilities. The systems minimize station personnel exposure to radiation and minimize or preclude discharge of radioactive wastes to the surrounding environment.

Liquids normally are held for reuse or for shipment to off-site AEC licensed disposal facilities. Optional capability for discharge, within the limits of federal regulations, to the circulating water outfall also is provided. Gases are stored to provide time for decay before controlled release to the plant vent. Solid wastes, packaged in approved containers, are shipped off-site by an AEC licensed disposal contractor.

B.1.4.1 Coolant Radwaste System. The major quantity (over 99 percent) of liquid waste is produced as the result of changes in boric acid concentration in the reactor coolant during reactor operation, for reactor shutdowns, as a result of thermal expansion on reactor start-up, and to compensate for xenon build-up and decay during plant load changes. The estimated volume of liquid entering the radwaste system is 4.23 million gallons per year.

Waste can be fed to the coolant radwaste system from the chemical and volume control system (CVCS) or by pumping from the reactor coolant system drain tank. In either case, the waste passes through high efficiency corrosion product removal equipment prior to entering the radwaste system, thus maintaining the radwaste system essentially free from particulate activity.

The system consists of ion exchangers to remove ionic fission products and a gas stripper to remove fission product gases. The treated radwaste is held in diaphragm equipped tanks (to prevent loss of tritium) to provide feed for the boric acid concentrator for further processing, or for disposal to the circulating water outfall or by tank truck.

B.1.4.2 Coolant and Boric Acid Recycle System. Coolant and boric acid are recycled by separation in a steam heated boric acid concentrator from which the concentrated boric acid is fed to the boric acid storage tank while the vapor stream is condensed and deborated by ion exchange prior to storage in the primary plant make-up storage tank.

B.1.4.3 Miscellaneous Liquid Wastes System. The primary sources of miscellaneous wastes are drains, sinks, and blowdown steam generator tube leaks. Wastes with high chemical content are collected and treated separately from low chemical content wastes. Interconnections between units of the system provide flexibility to accommodate the appropriate processing which consists of filtration, oil absorption, evaporation, and/or ion exchange. Effluents from this system can be pumped to a tank truck for off-site disposal, drummed if necessary for off-site disposal, recycled for further processing, discharged to the circulating water outfall, or returned to the primary plant make-up water storage tank.

B.1.4.4 Gaseous Waste Processing. Gaseous wastes from the gas stripper condenser, radwaste evaporator condenser, and reactor coolant drain tank are routinely fed into the gaseous wastes surge tank. During the degasification operation associated with reactor cold shutdown or refueling, other gaseous wastes enter the surge tank from the volume control tank or reactor pressurizer. The reactor vents are also manifolded to the surge tank.

Gases collected in the surge tank can be bled directly to the high efficiency filters (99.97 percent removal down to 0.3 micron) and stacked when activity is sufficiently low, or they can be compressed into tanks and held to allow radioactive decay prior to release through the filters and stack. In addition, gaseous wastes of low concentration from chemical waste tanks, miscellaneous waste tanks, concentrated miscellaneous waste storage tanks, and miscellaneous waste evaporator condensate storage tanks are collected in a vent header and discharged through high efficiency filters to the plant vent stack.

B.1.4.5 Solid Waste. All radioactive solid wastes are packaged in approved containers, stored for radioactive decay, and shipped off-site by an AEC licensed disposal contractor. Solid wastes consist of spent ion exchange resins, crud from the primary water system, disposable filter elements, contaminated paper, plastic, clothing, shoe covers, tools, fittings, and other miscellaneous. Items to be laundered are processed off-site by an AEC licensed contractor.

B.1.4.6 Radiation Protection. Radiation protection adds to the space requirement for some areas of the plant to provide for radiation shielding as protection for the plant operating personnel and to prevent undue hazard to the general public during normal operation or in the event of a power plant accident. Systems or areas requiring shielding are:

1. Nuclear Steam Supply.
2. Control Room.
3. Radwaste.
4. Chemical and Volume Control.
5. Sampling.
6. Spent Fuel Transfer and Storage.

B.1.4.6.1 Nuclear Steam Supply System. This system contains the highest levels of radiation found in the plant, both during normal operation and in the event of the maximum hypothetical accident. Three shielding barriers are provided for this system.

The primary shield is a reinforced concrete mass approximately 5 feet thick surrounding the reactor vessel from the containment floor up to the reactor vessel flange, where it is reduced to 4.5 feet to form the upper walls of the refueling pool and fuel transfer canal. This shield permits limited access to the reactor coolant system equipment after shutdown and limits the neutron flux activation of component and structural materials.

The secondary shield is a reinforced concrete structure, approximately 4 feet thick, surrounding the reactor coolant system equipment including piping, pumps, steam generators, and pressurizer. This shield allows limited access to the containment during full power operation by protecting personnel from the direct gamma radiation of the activation products and fission products carried by the reactor coolant, and by attenuating neutron and gamma radiation escaping from the primary shield.

The containment shield is reinforced, prestressed concrete 4 feet thick up to the spring line and 3.5 feet thick in the dome. It completely encloses the nuclear steam supply system and attenuates radiation escaping from the primary-secondary shield complex to a

level less than 1 mrem/hour outside the containment building when the reactor is at full power operation. In addition, the containment shielding attenuates radiation from sources inside the building, following a maximum hypothetical accident, to provide reasonable time for evacuation of the immediate vicinity.

B.1.4.6.2 Control Room. The control room is shielded to allow continuous occupancy for essential control room personnel for more than 90 days following an MHA.

B.1.4.6.3 Auxiliary Systems. The auxiliary systems requiring shielding of some or all components are the radwaste system, the chemical and volume control system, and the sampling system.

Concrete walls, covers, and removable blocks are used to shield typical components such as the gas stripper, boric acid concentrator, waste evaporator, volume control tanks, gas decay tanks, ion exchangers, charging pumps, and concentrated waste storage areas.

B.1.4.6.4 Spent Fuel Transfer and Storage. Shielding is required during all handling and storage of spent fuel due to the inventory of fission products in the fuel. The upper portion of the primary reactor shield and at least 10 feet of borated water provide shielding inside the containment during reloading operations. The fuel transfer canal, transfer tube, refueling cavity, and spent fuel pit are similarly shielded for all operations including loading of spent fuel into shielded shipping casks prior to transportation from the site for fuel reprocessing.

B.1.5 Site and Security

Other features which are characteristic of nuclear power plant sites during normal operation or construction are:

1. Road and railroad access.
2. Parking for plant personnel.
3. Administration building.
4. Shops and warehouses.
5. Security system.
6. Communication systems (telephone, radio).

7. Radiological and meteorological monitoring system.
8. Freshwater reservoir.
9. Visitor center.
10. Temporary requirement for construction.
 - a. Parking
 - b. Equipment and materials laydown
 - c. Shops and subassembly areas

B.1.5.1 Road and Railroad Access. Road access is provided to the plant personnel parking lot, visitor center, administration, shop and warehouse areas, the switchyard, reservoir, equipment access to the containment and other points in the plant for convenient pickup or drop-off of personnel or equipment.

Railroad access is provided to the hatch entrance to the auxiliary building and the laydown area adjacent to the turbine generator. Although it is possible to transport turbine generator parts and the spent fuel shipping cask by special truck, rail transportation is preferred and provided, if feasible. Railroad or barge transport during construction is also preferred for the major components such as the pressure vessel and steam generators.

B.1.5.2 Parking for Plant Personnel. The largest number of personnel are found at the plant during the day shift when the full complement of maintenance and administrative personnel are present. Parking for 30 cars would require about 10,000 square feet.

B.1.5.3 Administration, Shops and Warehouse. This area requires 50,000 to 100,000 square feet depending on the extent of the functions being performed and the particular layout arrangement adopted.

B.1.5.4 Security System. The entire plant site is surrounded by an 8-foot chain link fence with normal access through a single entry gate controlled by a security guard. An additional 8-foot chain link fence surrounds the controlled area which includes the containment, reactor auxiliary building, and spent and new fuel storage building. Access to this area is through clearly marked control points.

B.1.5.5 Communication Systems. The impact of communication systems on the site is the existence of telephone poles and a radio tower if this form of communication is used.

B.1.5.6 Radiological and Meteorological Monitoring. A micro-meteorological tower for measuring wind speeds and directions at various elevations is often provided. Radiological measurements are also taken at established stations and may include a station on the meteorology tower.

B.1.5.7 Freshwater Reservoir. A 3-million gallon freshwater reservoir, about 250 feet in diameter by 20 feet deep, is provided as a source of fire protection water and as reserve make-up for the nuclear steam supply system. (Many plants have much larger reservoirs, particularly if they are to provide emergency cooling water for shut-down heat removal.)

B.1.5.8 Visitor Center. A visitor center including parking requires 50,000 to 60,000 square feet.

B.1.5.9 Temporary Construction Requirements. Parking for the peak construction force of more than 1,000 personnel requires about 8 acres (350,000 square feet) of temporary parking. Another 3 acres are occupied by carpenter, electric and pipe shops, construction power, compressor house, tool room and warehouses, and supervisor portable buildings. Equipment and material laydown and storage areas occupy more than 3 additional acres. Thus, approximately 14 acres of temporary space are required during construction of the plant.

B.2 LIGHT WATER REACTOR SYSTEMS - BWR

The boiling water reactor (BWR) steam supply system has undergone several modifications and advancements in over 15 years of development. The sixth and latest version of this basic concept is designated the BWR/6 by the General Electric Company, the sole supplier in the United States of this type light water reactor system. The BWR/6 incorporates major design improvements in the nuclear steam supply system and provides the basis for cooperative development with plant designers of a new pressure suppression containment configuration and a new turbine building layout to achieve a slightly smaller plant volume requirement.

The same five basic system groups are found in the BWR as in the PWR. The major difference between the BWR and PWR concepts is in the production systems, specifically the nuclear reactor and the

nuclear steam supply. The steam generator, as a separate unit, is eliminated by reduction of the pressure in the reactor pressure vessel, thus allowing steam to form in the reactor core. The steam/water mixture leaving the reactor core is separated in separators and dryers located inside the reactor vessel. Also located inside the pressure vessel are 20 to 24 jet pumps to circulate water through the core. These additional internal components require the pressure vessel to be somewhat larger than a PWR pressure vessel. The BWR vessel measuring about 74 feet high and requiring a 24-foot space envelope is slightly larger than the PWR steam generator which is 66 feet high. Significant space and equipment cost is saved over the PWR system, however, since the BWR pressure vessel provides the functions of the pressure vessel (44 feet by 22 feet), two steam generators (66 feet by 24 feet each), and the pressurizer (37 feet by 10 feet).

Dry steam from the pressure vessel flows directly to the high pressure turbine as shown in Figure B-7. The remainder of the steam, condensate, and feedwater systems is identical in concept to that of the PWR system.

In Figure B-8 the BWR Mark III containment concept is compared in size to the ice condenser pressure suppression system proposed by Westinghouse for the PWR. The BWR concept uses an annular pool of water as a pressure relief path and steam condenser in the event of a line or vessel rupture inside the primary concrete housing. This suppression system allows the design pressure of the containment building to be reduced to only 15 psig rather than the 60 psig normally used for dry PWR containments.

All other systems of a BWR power plant are essentially the same as a PWR plant with difference in detail to suit the preference of the designer.

B.3 HTGR POWER PLANT SYSTEMS

Nuclear power plants based on the high temperature gas-cooled reactor (HTGR) are well along in development and demonstration of economic feasibility. The 40 Mw (e) Peach Bottom Power Station has operated on-line for several years and the 330 Mw(e) Fort St. Vrain Station is scheduled for criticality during 1972. Both of these stations were developed by Gulf General Atomic, the only supplier of the gas-cooled nuclear steam system in the United States. Commercial acceptance of this concept, based on about 15 years of research and development in the United States and Europe, is evidenced by recent letters of intent for six gas-cooled nuclear steam systems in the range of 700 to 1,200 Mw(e).

FIGURE B-7

BWR DIRECT CYCLE REACTOR SYSTEM

FIGURE B-8
BWR-PWR CONTAINMENT COMPARISON

Because the HTGR produces steam at high temperature and pressure, equivalent to modern fossil fuel plants, it will operate with a higher thermal efficiency (more than 39 percent) than water-cooled reactor plants (less than 33 percent). Another feature of the HTGR being developed in the United States is that it employs a U-235/thorium fuel cycle. Development of this fuel cycle will make available the vast energy resource of the thorium reserves unused by other present reactor concepts.

The same major categories of systems

1. Production
2. Engineered Safety
3. Auxiliary and Emergency
4. Radioactive Waste and Radiation Protection
5. Site and Security

found in the PWR power plant also are characteristic of an HTGR plant.

To date, all HTGR plants in advanced stages of hardware development use the conventional steam cycle to drive a turbine generator of the same class used in modern fossil fueled plants. The essential difference between the HTGR and the PWR is the replacement of the high pressure primary water loop by a high temperature gas loop to transport heat from the reactor core to the steam generator. Because of the higher temperatures of the HTGR, it is practical to produce superheated steam (above the boiling temperature for the system pressure) suitable for use with modern high temperature steam turbines. These turbines extract more work per unit of heat input than do the lower temperature turbines designed for use with the saturated steam (at the boiling point for the system pressure) produced by a PWR.

Differences in the engineered safety systems, auxiliary and emergency systems, and radioactive waste systems of the PWR plant and the HTGR plant are the direct result of this replacement of a radioactive, high pressure water primary cooling loop by a gas loop.

B. 3.1 Production Systems

The same production systems are found in the HTGR as in the PWR, specifically a nuclear core to produce heat; a transport loop to carry the heat from the core to a steam generator; a steam turbine to

drive an electric generator; a condenser and circulating water system to reject waste heat; and the electricity producing system consisting of the generator, transformers, switchgear, and transmission lines. An instrumentation and control system comparable to that of the PWR is also required for the HTGR.

B.3.1.1 Reactor. The nuclear core of the HTGR is made up of many hexagonal graphite blocks stacked in vertical columns arranged into a cylinder supported by a graphite support structure. The fuel elements are perforated longitudinally by many small passages, some for coolant flow and others to hold a matrix of graphite binder containing very small uranium and thorium particles. The uranium and thorium oxide or carbide particles are coated with layers of pyrolytic carbon to provide the primary barrier against the escape of gaseous fission products. The uranium fuel particles also have a silicon carbide coating to provide additional retention of metallic fission products.

Many years of operating experience with this high temperature fuel have proven it to have excellent ability for retention of fission products. The contamination of the primary coolant system is significantly lower than that of other conventional reactor systems.

As in the case of the PWR, new fuel elements must be shipped to the plant periodically and spent fuel elements, heavily shielded, must be shipped off-site for reprocessing.

B.3.1.2 Nuclear Steam Supply. The nuclear steam supply (NSS) of the HTGR consists of the reactor core and six helium circulating loops and steam generators each located in separate cavities in a large 90-foot diameter and 90-foot high prestressed concrete reactor vessel (PCRv) shown in Figure B-9. In addition to the NSS, the PCRv which is located inside a secondary containment building contains three auxiliary heat exchangers to provide an independent means of removing reactor decay heat during shutdown or emergency conditions, access penetrations for control rod drives and refueling, and helium purification wells.

All cavities and flow channels in the PCRv are steel lined and sealed to reduce leakage. The PCRv, because of its large size and materials, must be field fabricated and prestressed in place.

The components located in the PCRv are major equipment items installed as prefabricated units. For example, the steam generators are approximately 70 feet high and 14 feet in diameter; the helium circulators are about 42 feet high and 15 feet in diameter; and the auxiliary heat exchangers, including their circulators, are nearly 55 feet high and 10 feet in diameter.

FIGURE B-9

HTGR PRESTRESSED CONCRETE REACTOR VESSEL

The steam generator unit is a very compact, multipurpose system including reheater, superheater, evaporator, and economizer heat transfer surfaces. These integrated heat transfer coils replace several individual heat exchanger units and connecting piping of the PWR plant. Placement of heat transfer surfaces and related circulators in common cavities of the PCRV and elimination or shortening of pipe runs have produced an extremely compact arrangement for the HTGR power plant, as shown in Plates B-2, B-3, and B-4.

B. 3.1.3 Turbine Generator. The steam from the evaporator coils of the steam generators in the PCRV is piped through the wall of the reactor containment building to the high pressure turbine located with the intermediate and low pressures turbine units in the turbine generator building. A simplified flow diagram of the steam/water system is shown in Figure B-10. After leaving the high pressure turbine, the steam passes through the steam turbine drive of the helium compressor circulator and then through the reheater section of the steam generator. The reheated, superheated steam then passes in series through the intermediate pressure and low pressure turbines. Some steam is bled to the feedwater heaters (economizers), but the main flow is to the condensers. The condenser and condensate (feed-water) return system is very similar to the PWR system.

To provide improved plant availability, some concepts for large HTGR plants include two half-size turbine generators for each reactor unit, rather than the one-for-one found in PWR plants. All principal steam and water systems connect to headers at the reactor end of the plant. This lessens the impact of the twin turbines on the reactor plant operation.

B. 3.1.4 Circulating Water System. For a once-through water system, removing heat from the condenser with the same (about 20 F) temperature rise as in the case of a PWR, the circulating water rate would be about 75 percent of that for the PWR, or about 600,000 gpm.

Except for the smaller line (about 16 feet in diameter rather than 18 feet), the circulating water system and pump sizes would be identical to that for the PWR plant.

B. 3.1.5 Power Production. If twin half-size turbine generators are used for the HTGR plant, somewhat more space will be required for the larger number of smaller size turbine units, condensers, pumps, feedwater heaters, generators, transformers, and switchyard gear, than if a single full-size turbine generator is used. If the single unit is used, the power production system from the generator to the transmission lines for the HTGR would be identical to that for a PWR system designed for the same service.

FIGURE B-10
HTGR STEAM AND WATER SYSTEMS

B. 3. 1. 6 Instrumentation and Control. The HTGR core is normally controlled by electrically powered winch-driven control rods raised and lowered by means of flexible steel cables. A reserve system, designed exclusively for performing an "emergency scram," consists of boron-carbide spheres held in hoppers in the refueling penetrations. These neutron absorbing particles can be released into the core by pressurizing the hoppers with gas from an external source.

The HTGR does not use boric acid as a burnable poison or for emergency shutdown thus eliminating the space requirement of the PWR plant for the tanks, pumps, heat exchangers, and ion exchangers of the chemical and volume control system and the coolant and boric acid recycle system.

B. 3. 2 Engineered Safety Features. The high heat capacity of the large mass of core graphite ensures that any core temperature transients will take place over a relatively long time period, thus eliminating the need for rapid injection cooling systems.

Since the entire primary coolant system is within the PCRV, the possibility of a pipe rupture suddenly releasing high pressure, radioactive, primary coolant into the containment building is eliminated.

B. 3. 2. 1 Containment. Containment of fission products is provided in the HTGR concept by three levels of barrier. The fuel particle coatings have been demonstrated to provide excellent retention of fission products resulting in very low activity levels in the primary coolant. The prestressed concrete pressure vessel shown in Figure B-9 is designed to provide a high degree of reliability for containment of the primary coolant and the integrity of the PCRV structure precludes a sudden loss of primary coolant. Flow restriction devices are provided to limit leakage from the vessel through any failed penetration closure to a low value.

The third containment barrier is provided by the reactor building which is a steel lines reinforced concrete structure essentially identical in concept to the dry containment concept used for the PWR. The major differences are a slightly lower design pressure, the addition of a tendon anchor gallery below the foundation mat, and the absence of all the internal concrete cubicle walls which are found in a PWR containment. This building is designed to accommodate and dissipate the pressure associated with the maximum design leakage rate of the primary coolant system. The inside dimensions of a typical containment for a large HTGR are 126 feet in diameter and 228 feet in height.

B. 3. 2. 2 Containment Safety Features. The containment safety systems are those associated with:

1. Shutting off sources of pressure build-up in the PCR.V.
2. Cooling the PCR.V.

A tube rupture in a steam generator module would be the main source of overpressure in the PCR.V. A steam/water detection and dump system is provided to minimize the amount of water that could leak into the primary coolant. Moisture in the primary coolant helium leaving the steam generator is detected resulting in isolation of the unit and dumping the steam/water inventory of the unit to a dump tank. Overpressures in the PCR.V are relieved by safety relief valves vented through filters to the top of the containment building.

The core auxiliary cooling system provides an independent means of cooling the reactor and primary coolant system and removing reactor shutdown heat. Three auxiliary cooling safety loops, completely independent of the main coolant loops, are provided. Each loop consists of a heat exchanger, helium circulator, and helium shutoff valve located in a PCR.V penetration. A cooling water system external to the PCR.V supplies pressurized cooling water to the heat exchangers.

The containment building and ventilation system form the confinement structure. The system is in continuous operation and has standby blowers and filters.

Other containment safety features such as the spray system, the cooling system, and the purge exhaust system required for the PWR containment are not found in the HTGR concept.

B. 3. 2. 3 Safety Injection System. Because of the high heat capacity of the HTGR core, the heat-up rate is about 20 times slower than that of the PWR core. This provides much greater time margins in which to start core cooling in the event of loss of primary coolant. This margin allows time for manual operations and for repair of equipment located outside the PCR.V. Therefore, no quick acting safety injection systems are required.

B. 3. 2. 4 Emergency Electrical Systems. The emergency electrical systems for an HTGR plant are identical in principle and concept to those of a typical PWR plant.

B.3.3 Auxiliary and Emergency Systems. The auxiliary systems in an HTGR plant accomplish the same functions as those in the PWR plant. However, due to replacement of the primary cooling waters by an inert, low activity gas, many of the auxiliary systems are less complex and require less space than their counterpart in the PWR plant.

B.3.3.1 Chemical and Volume Control. The chemical and volume control system of the PWR is replaced by the helium purification system (HPS) of the HTGR. The HPS maintains the impurity levels, particularly those containing oxygen, in the primary coolant to acceptable values during normal operation. It also:

1. Reduces primary coolant radioactivity.
2. Provides a flow of purified helium for purging helium circulator seals, control rod drives, instruments, and PCRV penetrations.
3. Purifies helium which is pumped to storage during depressurization of the primary coolant system for maintenance or refueling.

The HPS consists of redundant purification trains each having the following components:

1. A high temperature charcoal filter absorber to remove dust, fission produced isotopes other than noble gases, and tritium.
2. A water cooled helium cooler.
3. A helium purification dryer to remove carbon dioxide and water by absorption on molecular sieves.
4. A low temperature gas-to-gas exchanger to cool the gas to about -300 F against returning cold purified helium.
5. A liquid nitrogen cooled, low temperature absorber using charcoal at about -300 F as the absorbent to remove krypton, xenon, carbon monoxide, methane, and residual hydrogen and tritium.
6. A purified helium dust filter to protect the purified helium compressors.

7. A helium compressor cross connected with both purification trains.

The HPS is located in several wells embedded in the top head of the PCR/V as shown in Figure B-9.

B. 3. 3. 2 Shutdown Cooling System. Shutdown cooling in preparation for refueling is provided for the HTGR primary coolant and reactor core initially by the primary coolant system loops and/or the core auxiliary cooling system. As the temperature is lowered and for maintaining the upper plenum temperature below 250 F during refueling, cooling is provided by the core auxiliary cooling system discussed as a containment safety feature.

B. 3. 3. 3 Fuel Storage Cooling System. The fuel storage facility, used to store new fuel and reflector elements prior to a refueling shutdown and spent fuel and reflector elements during decay and waiting for shipment, consists of tubular steel storage wells in the fuel storage building.

The walls of the storage wells are water cooled by two independent, full capacity coils attached to the steel liners forming the wells. Decay heat is transferred from the fuel elements to the walls by radiation and natural convection circulation of helium through and around the elements. The controlled helium atmosphere in the well is slightly below ambient pressure and is vented to the gas waste system.

B. 3. 3. 4 Component Cooling Water System. A component cooling water system is required to transport heat from the various water cooled components such as the fuel storage wells, core auxiliary cooling heat exchangers, PCR/V cavity wall cooling coils, water cooled pumps, water cooled helium coolers, and air compressor jackets and aftercoolers, to a circulating water system serving as the heat sink.

B. 3. 3. 5 Sampling and Analysis System. A means is provided for sampling and analysis of fluid streams such as the primary helium coolant and the steam/water to determine fission and corrosion product levels and to determine the presence of water in the primary helium indicating a leak in steam generator heat transfer surfaces.

B. 3. 3. 6 Fuel Handling and Storage. Due to the high temperature characteristics and high burn-ups attainable with the HTGR fuel, refueling operations based on a 4-year core life replace one-quarter of the reactor core each year. No fuel relocation within the core is performed.

The principal differences of the HTGR refueling operations and those of the PWR are due to the fact that the fuel and reflector blocks are handled dry in shielded containers rather than under water as in the case of the PWR. This results in the need for more complex handling and transfer apparatus but eliminates the space requirements and purification system associated with the pool concept.

Before a refueling cycle begins, the primary coolant temperature is reduced to less than 250 F, the pressure is reduced to slightly below one atmosphere, and the circulating helium is purified. These conditions are maintained throughout the cycle.

B. 3. 3. 7 Facility Service Systems. The facility service systems are essentially the same as found in a PWR plant and consist of:

1. Heating, ventilating, and air conditioning.
2. Turbine plant cooling water.
3. Fire protection.
4. Compressed air.

B. 3. 3. 8 Decontamination Processes. Due to the lower level of contamination of the HTGR primary coolant and the confinement of the primary coolant systems including the purification loops within the PCRV, there is less opportunity for contamination of materials equipment and personnel in an HTGR plant than in a PWR plant.

Facilities are provided for decontamination of equipment being repaired or readied for shipment and for personnel cleanliness.

B. 3. 4 Radioactive Waste and Radiation Protection

The HTGR is designed to have very limited quantities of radioactive production resulting in small size of facilities to manage these wastes.

B. 3. 4. 1 Liquid Wastes Processing. The possibility exists that tritium produced in the primary helium coolant may diffuse through the steam generator tube walls into the secondary steam/water coolant and eventually be released in leakage from the secondary coolant system. Since this liquid waste would contain only tritium and not fission products, it would be handled separately from other liquid wastes.

Based on operating experiences for the Peach Bottom reactor, and assuming a secondary coolant leak rate of 70 gpm, as much as 34×10^6 gallons per year of low activity (5×10^{-3} Ci/ml)

waste could be produced. If this were disposed of by discharge (within the requirements of Federal regulations) to cooling tower blowdown or once-through circulating water, there would be between 200 and 650 curies per year of tritium discharged to the environment.

Other sources and quantities of radioactive liquid wastes are:

<u>Source</u>	<u>Quantity (gal/yr)</u>	<u>Activity (Ci/yr)</u>
Decontamination of Fuel Handling Equipment and Control Rod Drives	4,000	70.0
Personnel Showers and Miscellaneous Equipment Drains	75,000	0.1
Accidental Steam Generator Tube Rupture	3,000	19.0

The radioactive liquid waste system consists of a 1,000-gallon sump to receive liquids normally not radioactive but which might contain radioactivity. Liquids collected in the sump are pumped through filters to one of two 3,000-gallon receivers for monitoring. If activity levels are low enough, the liquid is pumped at controlled rates into the cooling tower blowdown or circulating water system. Liquid with activity too high for discharge is pumped through one of two demineralizers and collected in a 3,000-gallon tank for monitoring. This is repeated until the activity level is low enough for discharge.

B.3.4.2 Gaseous Waste Processing. Three potential sources of radioactive waste gas during normal operation of the HTGR are:

1. Instrument effluent.
2. Gas evacuated from fuel handling equipment during annual refueling.
3. Gas resulting from regeneration of absorption beds in the helium purification system.

In addition, the helium circulator handling cask used for nonroutine maintenance might be a source and there are various sources of waste gas, such as air evacuated from fuel handling equipment and various vents, which might be radioactive and must, therefore, be monitored before release to the atmosphere.

These sources and the quantities of gas and radioactivity are summarized below:

<u>Source</u>	<u>Quantity (SCF/yr)</u>	<u>Activity (Ci/yr)</u>
Annual Refueling		
Equipment Purge - Helium	9,000	400
Equipment Purge - Air	9,000	0
Fuel Storage Will Purge	6,000	250
Instrument Effluent	16,000	520
Helium Purification System		
Regeneration	15,000	18,400
Helium Circulator		
Handling Cask (nonroutine)	2,000	140

Potentially radioactive gas enters a system inlet header which is continuously monitored for iodine, particulates, and noble gas activity. If the activity exceeds the normal setpoint, the gas is automatically diverted to the radioactive gas handling system. Otherwise, it is released to the atmosphere through the ventilation system exhaust filters and vent.

Radioactive gases are collected in a 500-cubic-foot waste gas vacuum tank. The gas is compressed into one of two 700-cubic-foot pressure waste gas surge tanks each with a capacity of about 21,000 standard cubic feet. For minimum activity release the gas is then processed on a batch basis in the radioactive gas recovery system (RGRS).

The RGRS separates the gas into an essentially nonradioactive gas stream which is released to the atmosphere and a radioactive gas stream consisting primarily of Kr-85 which can either be returned to the PCRV for Kr removal in the helium purification system or bottled for off-site shipment.

The RGRS consists of an oil adsorber, water saturator, carbon dioxide absorber, dryer, three gas chromatography absorbers, diaphragm compressor, and vacuum pump. Total operating time of the system is about 1 month per year, and the total activity released from the plant in the 50,000 SCF/year of radioactive gas input to the gas waste system would be less than 0.02 Ci/year.

B.3.4.3 Solid Waste. Sources of solid wastes and the approximate annual quantities are:

<u>Source</u>	<u>Volume (ft³/year)</u>	<u>Activity (Ci/year)</u>
Graphite Reflector Elements	500	75,000
In-Core Instrumentation	6	440
Control Rods	27	5,800
Titanium Sponge	105	4,500
High Temperature Filter Absorber	25	1,500
Various Filters and Demineralizer (Infrequent Replacement)		

All radioactive solid wastes are transported to the hot service facility where they are processed, if required, and placed in appropriately shielded drums or casks for off-site shipment.

B.3.4.4 Radiation Protection - All HTGR systems requiring radiation shielding are either contained in the PCRV or are in vaults in the fuel storage building. The space required for shielding is minimized by this compact arrangement.

The outside walls of the PCRV are approximately 16 feet thick minimum and the top and bottom heads are about 18 feet thick.

B. 3.5 Site and Security

Site features for an HTGR nuclear power plant which would be needed for operation or construction are essentially identical to those for a PWR plant.

B. 4 HTGR GAS TURBINE POWER PLANT SYSTEMS

The HTGR with gas turbine (GT) drive for the electric generator is in the early stages of study by Gulf General Atomic. Their projection for on-line commercial operation of the initial HTGR(GT) power plant is mid-1985 based on an aggressive research and development program.

Although gas turbines have experienced a rapid growth in conventional power plant applications in recent years, much development work remains to extend the technology from these open cycle combustion gas units into the larger size closed cycle helium units required for economical base load plants. In addition, the entire primary system will need to be further developed for operation at pressures 40 percent above those used in the HTGR with steam cycle.

Several advantages are expected from the gas turbine plants in comparison to those using the steam cycle. Perhaps the most important advantage is the possibility of developing an economical dry cooling system for heat rejection to the atmosphere thus providing greater flexibility in site selection. Other advantages are:

1. A gas turbine is more compact than a steam turbine.
2. Heat exchangers and coolers, which are smaller and less expensive, are used rather than steam generators and condensers.
3. Waste heat is rejected over a range of temperatures from about 440 F to 105 F rather than all at about 140 F which is typical of the steam cycle. This makes the waste heat available for other uses such as process heat.
4. Greater density (two orders of magnitude) of the exhaust gas under pressure compared to steam exhausting to a vacuum permits smaller size machinery and associated piping resulting in cost and space savings.

5. Absence of pipes, valves, instruments, and other hardware associated with water treatment, boiler feed pumps, and feed heaters.
6. Elimination of the reactor coolant circulation equipment found in the PWR.

Of the five major categories of systems, only the production system of the HTGR plant is affected in a significant way by substitution of the gas turbine for the steam cycle. The engineered safety features, auxiliary and emergency system, radioactive waste and radiation protection, and site and security system would remain essentially the same as those of the HTGR plant using the steam turbine as prime mover.

B.4.1 Production Systems

The production systems of the HTGR(GT) are:

1. Reactor
2. Nuclear Steam Supply
3. Turbine Generator
4. Circulating Water System
5. Power Production System
6. Instrumentation and Control

By substitution of the gas turbine for the steam turbine, the nuclear steam supply, turbine generator, and circulating water systems are eliminated or drastically changed from those found in the HTGR steam plant.

B.4.1.1 Reactor. The reactor core used in the HTGR(GT) will be essentially the same as that used in the HTGR.

B.4.1.2 Turbine Generator. The gas turbine cycle flow diagram is shown in Figure B-11. All equipment including the power turbine in contact with the helium primary coolant is contained within the PCR.V. The equipment and general plant arrangement is shown in plan view in Plate B-5.

FIGURE B-11

FLOW DIAGRAM
HTGR HELIUM GAS TURBINE CYCLE WITH DRY AIR COOLING

The generators are located outside the PCRV but inside the reactor containment building.

B.4.1.3 Circulating Water System. Since the gas turbine exhaust is at much higher temperature than is practical for the steam cycle, it is economically feasible to use a dry cooling tower for heat rejection rather than an evaporative cooling tower or once-through cooling water. However, it is necessary to provide a circulating high pressure water loop to transport the heat from the precooler inside the PCRV to the cooling tower outside the reactor building.

B.5 LMFBR POWER PLANT SYSTEMS

The liquid metal fast breeder reactor (LMFBR) steam supply system is presently being developed in an intensive AEC sponsored research and development program oriented toward commercial service of sodium-cooled plants by the early or mid-1980's. This program is based on technology developed over a 25-year period including design and operation of several low power, less than 300 Mw(t), liquid-metal-cooled reactors built in the United States and Europe. Three industrial organizations, Atomics International, General Electric, and Westinghouse, have developed reference designs for LMFBR demonstration plants in the 300 to 500 Mw(e) range initially targeted for operation by 1978. Westinghouse has been selected recently as the nuclear system supplier for the initial demonstration plant which is in the design phase. Following successful demonstration of the concept in a commercial environment, one or more designs will be developed in the economically competitive range of 1,000 Mw(e).

The five major categories of systems found in PWR nuclear power plants also are present in LMFBR plants:

1. Production Systems
2. Engineered Safety Features
3. Auxiliary and Emergency Systems
4. Radioactive Waste and Radiation Protection
5. Site and Security

The differences in specific systems of the PWR and LMFBR plants stem from the properties and characteristics of sodium used as the reactor coolant in the LMFBR rather than the water reactor

coolant used in the PWR. The technical problems solved in the development of sodium cooled reactors have required the development of an entirely new technology for the liquid sodium. Some extrapolation from the existing technology to the substantially larger components and higher temperatures characteristic of the commercial plants is required.

B.5.1 Production Systems

The production systems of the LMFBR are identical in principle to those of the PWR: that is, energy released by the fissioning of atomic nuclei is transferred to steam. The steam drives a turbine generator producing electricity which is transmitted to a distribution or transmission grid. A synthesized plant layout concept is shown on Plate B-6.

B.5.1.1 Reactor. The reactor core (energy source) of the LMFBR is geometrically similar to that of the PWR. Both cores are made up of fuel elements or assemblies arranged in the form of a cylinder through which the reactor coolant flows to remove heat.

Two different primary sodium coolant systems are proposed by the developers of the demonstration plant concepts. General Electric bases its approach on the "pot" concept initially used in European liquid metal reactors. This concept places the primary system including the reactor core, primary sodium pumps, and intermediate heat exchangers (IHX), in a large sodium filled vessel or "pot" to assure a sodium environment for the core under all conditions.

Atomics International and Westinghouse each base their concept on a closed "loop" system similar to the conventional piped arrangements used in PWR's. In this concept, the reactor core is contained in a stainless steel vessel designed to assure that the sodium level remains above the top of the core at all times. This vessel is projected to be approximately 30 feet in diameter and 50 feet high for the 1,000 Mw(e) plant.

The core is fueled with a mixture of plutonium dioxide (fissile material) and depleted uranium dioxide (fertile material). Neutrons from the fissioning plutonium convert the U-238 to plutonium with a breeding ratio of approximately 1.2,

thus producing new plutonium at a rate significantly greater than the rate of plutonium consumption. The reactor core will contain substantial quantities of plutonium (more than 2,000 pounds).

B.5.1.2 Nuclear Steam Supply. The nuclear steam supply system consists of three parallel primary pipe loops circulating liquid sodium through the core to transport heat to an intermediate heat exchanger (IHX). The secondary sodium loop carries the heat from the IHX to superheaters, reheaters, and evaporators for production of superheated steam.

Uniform temperature in system components is maintained by following load demand with variable speed pumps to adjust the coolant flow rate to match the power output and maintain a nearly constant temperature of sodium leaving the core.

To assure sodium availability for core cooling in the event of a primary system leak, the reactor vessel, primary circulating pumps, and intermediate heat exchangers are contained in separate guard vessels.

Components of the primary coolant system are large size units. For example, the primary sodium pumps are approximately 8 feet in diameter and 50 feet high including the pump drive motor. Intermediate heat exchangers for the 1,000 Mw(e) plant are projected to be over 60 feet long and about 12 feet in diameter. One concept being developed for a steam generator with integral superheater indicates a vessel approximately 60 feet long weighing over 350 tons and requiring a space envelope 13 feet in diameter.

Plate B-7 is a simplified flow diagram of the LMFBR production systems. The only major difference between the "pot" concept and the "loop" concept is in the primary coolant system. From the intermediate heat exchanger throughout the rest of the system the two concepts are essentially the same.

Because of the high temperatures attainable with the sodium coolant, it is feasible to produce superheated steam (temperature at the boiling point) as produced in a PWR. This results in:

1. Increased plant efficiency (from about 33 percent for PWR to about 42 percent for LMFBR).
2. Decreased steam flow rate for equal electric output.

3. Less heat rejection and thus reduced coolant flow rate for the same temperature rise across the condenser (from about 800,000 gpm to the order of 530,000 gpm).
4. Somewhat smaller line sizes and equipment sizes for steam generators, turbines, heat exchangers, pumps, and condensers.

Partially offsetting the reduced space requirement for the smaller equipment is the fact that superheater units, a high pressure turbine, and a secondary heat transfer system are added to the plant.

B.5.1.3 Turbine Generator. Steam from the superheaters is expanded in a high pressure turbine, reheated in sodium heated reheaters, expanded through an intermediate pressure turbine, and finally expanded through three low pressure turbine units into the condenser. Condensate pumps and boiler feedwater pumps return the condensate to the steam generators through six stages of economizers (feedwater heaters). The condenser and condensate return system is very similar to the PWR system.

B.5.1.4 Circulating Water System. The circulating water system removing waste heat from the condenser is identical to that of the PWR except for the smaller line (about 15 feet in diameter rather than 18 feet) and pump sizes required to circulate about two-thirds the volume of water required for the PWR.

B.5.1.5 Power Production. The power production system for an LMFBR plant, including the generator, transformers, switchyard and transmission lines, is identical to a PWR system designed for the same service.

B.5.1.6 Instrumentation and Control. An LMFBR reactor is controlled by movable control rods similar to those in a PWR. However, the LMFBR does not use boric acid as a supplemental shim control or for emergency shutdown. This eliminates the boric acid make-up concentration control system. Space for the tanks, pumps, heat exchangers, and ion exchangers of the chemical and volume control system and the coolant and boric acid recycle systems is eliminated from the plant space requirements.

The space requirement for the instrumentation and control room and supporting equipment is somewhat less than that required for the PWR systems.

B.5.2 Engineered Safety Features

The engineered safety features of an LMFBR serve the same purpose as those of a PWR, namely to protect plant personnel and assure that off-site consequences of accidents are within acceptable limits.

B.5.2.1 Containment. Since the primary sodium system is not a high pressure system and the potential energy of the system is low, a low-pressure (10 psig) containment is used. One configuration for the primary system containment is shown in Figure B-12. Vaults below the operating floor at grade contain all major equipment with the exception of the refueling equipment in the refueling hot cell and the motor drives for the primary system pumps. Each loop of the primary system is housed in a separate vault containing a nitrogen atmosphere to prevent contact of sodium with oxygen. (The great chemical affinity of sodium for oxygen results in the formation of sodium oxide which interferes with proper flow and proper functioning of mechanical systems. It is sometimes accompanied by fire.) The provisions for vault inerting and for blast and missile protection within the inner barrier provide substantial margins against any potential energy releases for all classes of accidents. The inner barrier provided by the vaults and refueling hot cell is surrounded by a secondary gas-tight steel containment building to provide an added measure of safety assurance.

The refueling hot cell will be air-filled during normal operation (if developments underway are successful) to facilitate maintenance. The dimensions projected for the LMFBR "loop" containment concept indicate a reactor building as large or larger than present concepts for the PWR. Dimensions would be about 170 feet in diameter and 240 feet in overall height for a 1,000 Mw(e) plant.

B.5.2.2 Containment Safety Features. In view of the fact that the primary sodium coolant system operates at essentially atmospheric pressure and will not "flash" to vapor (because of the high boiling point) in the event of a sudden rupture in the confining walls, there is no requirement for the "quenching" action provided by the containment spray system of the PWR.

FIGURE B-12

LMFBR BUILDING CONTAINMENT
"LOOP" PRIMARY SYSTEM

The worst potential design basis accident has been determined to be the complete loss of pumping power followed by reactor shutdown failure. This sequence of events would cause a disruption of the core resulting in rapid vaporization of sodium with moderate release of radioactive sodium containing fission products and plutonium into the refueling cell and possibly some release into the reactor building. The design pressure of 10 psig for both these containment structures is conservative for the resulting temperature and pressure.

The reactor building isolation system would close all openings and divert the exhaust flow of the containment purge system through scrubbers and high efficiency filters to an elevated release point.

B.5.2.3 Safety Injection System. Another simplifying feature resulting from the low vapor pressure of sodium, which prevents flashing and expulsion of the primary coolant from the core in the event of rupture of the confining wall, is the lack of need for a core safety injection system. The elevation of all exits from the reactor vessel assures that the core will remain in a sodium environment under all design basis conditions.

Heat is transferred from the core to the steam generators by means of the primary and secondary sodium systems. For short term emergency conditions, water is injected from a redundant emergency supply into the steam side of the steam generators. The steam generators can be vented to the atmosphere for rejection of the core decay heat. Redundancy of the sodium heat transport circuits assures adequate sodium flow through the core.

B.5.2.4 Emergency Electrical Systems. The emergency electrical systems for an LMFBR plant are identical in principle and concept to those of a typical PWR plant.

B.5.3 Auxiliary and Emergency Systems

The same plant auxiliary systems are found in an LMFBR plant as in a PWR plant except that there is no chemical and volume control system as required for the primary coolant water system of

the PWR. A sodium storage tank connected to the reactor primary tank provides for volumetric changes of the sodium during temperature changes.

B.5.3.1 Shutdown Cooling System. For the "loop" concept, shutdown cooling is provided by the primary and secondary sodium systems driven at 10 percent of rated capacity. The decay heat is transferred across the steam generators to redundant separate decay heat removal loops which discharge through heat exchangers to the atmosphere or to a cooling water heat sink.

B.5.3.2 Fuel Storage Cooling System. Fuel removed from the reactor core is stored in a sodium filled fuel decay tank from which heat is removed by a heat exchanger system. In some concepts, after an initial cooling period, the spent fuel is cleaned to remove residual sodium and stored in a water cooled pool or inert gas cooled vault until shipment to a reprocessing plant.

B.5.3.3 Component Cooling System. The component cooling in an LMFBR plant is provided by oil, cryogenic gas, or water as appropriate to the unit being cooled. Component cooling water is confined to those units of the plant not containing sodium.

B.5.3.4 Sampling and Analysis System. A sampling and analysis system comparable to that in a PWR plant is provided to determine fission and corrosion product levels and other indicators required for process control.

B.5.3.5 Fuel Handling and Storage. As in the case of a PWR, fuel assemblies periodically (annually for the demonstration plant) are added to, removed from, and relocated (blanket assemblies only) within the core. Two different concepts are proposed for the demonstration plants. One concept calls for removal of a large plug from the top of the core tank to provide manipulator access through the liquid sodium to the fuel elements. The other concept has two eccentric rotating plugs which, by proper positioning, provide an access port over any desired fuel position. The initial demonstration plant will be capable of refueling by either method to determine the advantages and disadvantages of each.

Refueling machines are used to transfer the elements within the core or between the core and a fuel storage tank where they are stored under sodium. Boron carbide poisoning and spacer

racks assure noncriticality. The refueling mechanism and storage tanks are within the dry inert gas atmosphere of the refueling hot cell.

B.5.3.6 Facility Service Systems. The facility service systems including heating, ventilating, and air conditioning; turbine plant cooling water; fire protection; and compressed air are essentially the same as found in a PWR plant except that care must be taken to keep water fire protection systems out of sodium containing areas.

B.5.3.7 Decontamination Processes. The systems provided for decontamination processes are essentially the same as for a PWR plant except that provision also must be made for sodium from equipment and tools within the refueling cell and from major equipment components exposed to sodium prior to repair or off-site shipment.

B.5.4 Radioactive Waste and Radiation Protection

The major difference in the radioactive waste systems of the LMFBR plant and the PWR plant is the reduced volume of radioactive coolant to be processed, the less complex processing required, the elimination of tritium containing water discharge, and the elimination of the coolant and boric acid recycle system. The waste processing system provides controlled treatment and preparation for retention or disposal of all liquid, gaseous, and solid wastes thus eliminating any planned routine releases of radioactivity to the environment.

B.5.4.1 Coolant Radwaste System. The primary sodium coolant is processed continually in a bypass-flow cold trap which removes oxides, solid radioactive waste, and other particulate matter.

B.5.4.2 Miscellaneous Liquid Waste System. The only sources of liquid radioactive waste are miscellaneous sources such as drains and sinks. These low-level wastes will be collected and processed by filtration, evaporation, and/or ion exchange as is the case in the PWR plant.

B.5.4.3 Gaseous Waste Processing. All areas containing radioactive sodium systems and the space above the sodium level in the primary system are provided with an inert gas atmosphere to preclude a radioactive sodium fire in the event of a break in the sodium system boundary. These inert gases are circulated for

reuse through cleanup and purification systems resulting in essentially no release of radioactive gas to the environment. The cleanup system consists of a delay bed, a cryogenic fractionator, and a tritium removal subsystem.

B.5.4.4 Solid Waste. As in the case of a PWR plant, all solid wastes are packaged in approved containers, stores for radioactive decay, and shipped off-site by an AEC licensed disposal contractor. The amount of solid waste is expected to be somewhat less for an LMFBR plant than for a PWR.

B.5.4.5 Radiation Protection. The systems of an LMFBR plant requiring radiation shielding are:

1. The reactor core.
2. The primary coolant.
3. Refueling and fuel storage.
4. Primary sodium service systems.

The amount of shielding is minimized by placing these systems in a common area. All system components, except refueling, requiring shielding are placed below the operating floor in low leakage compartments or vaults separated by reinforced concrete shielding walls 4 to 6 feet thick. This permits maintenance access to a service system component without shutdown of other components.

The refueling cell has reinforced concrete walls 5 feet thick for biological protection. The reactor core and primary coolant system are in separate concrete vaults in the "loop" concept. The top shield over the reactor core is approximately 8 feet thick. Only one of the plant concepts proposes radiation shielding for the entire reactor building. The others have partial shielding near ground level.

B.5.5 Site Features

Features of the site for an LMFBR nuclear power plant which would be required for operation or construction are essentially identical to those for a PWR plant.

PLATE B-1

PRESSURIZED WATER
REACTOR FLOW SHEET

GRAPHIC SCALE
0 5 10 20 30 40 50

PLATE B-2
HTGR FACILITIES

PLATE B-3
HTGR FACILITIES

PLATE B-5
HTGR(GT) FACILITIES

PLAN

PLATE B-6
LMFBR FACILITIES

PLATE B-7
LMFBR PRODUCTION FLOW

APPENDIX C

EVALUATION METHODOLOGY

A number of evaluation methodologies have been reviewed for their applicability to this project. Some methodologies were found to be more objective in certain areas being investigated, although not necessarily more accurate nor leading to better judgment. However, their utilization required resources beyond those available in this study. The one selected and presented here provides the quantification foundation for objective ranking purposes and is flexible so that reiteration is possible if modifications in values are encountered.

The term "siting concept" implies broad classes of concepts as well as subcategories of these. Broad classes include aboveground, underground, and offshore. Subcategories include underground in various media, floating platform offshore seabed, etc. Evaluation parameters are the factors on which assessments are made relative to siting concepts. They include cost, feasibility, environmental impact, and risk. The evaluation scheme need not necessarily distinguish between broad classes of concepts, evaluation parameters, or their subcategories. In fact, the scheme is independent of the type and number of siting concepts and the number of evaluation parameters to be considered in the evaluation.

For purposes of discussion, two matrices, A and B, are defined in Figures C-1 and C-2. A is a matrix that contains the values of the evaluation criteria; thus, A_{ij} is the value of evaluation criterion j for concept i. B is a matrix that contains the weights for the evaluation criteria; thus B_{ij} is the weight for criteria j for concept i. One would normally have $B_{ij} = B_{kj}$ for all i and k; i.e., the weight for each criterion is independent of the concept. Thus, the weight factors can be represented by a vector $(b_1, \dots, b_m)$.

The rating for each particular concept i is computed as a number R_i defined from summations by

$$R_i = \sum_{j=1}^m A_{ij} B_{ij}, \quad i = 1, \dots, n \quad (C-1)$$

R_i is the rating given a particular concept. The rank of concepts will be determined by the R_i 's.

<div> <div> Evaluation Criterion Value → </div> <div> Siting Concept ↓ </div> </div>	Criterion 1	Criterion 2	• • •	Criterion m
Concept 1	A_{11}	A_{12}	• • •	A_{1m}
Concept 2	A_{21}	A_{22}		A_{2m}
• • •	• • •	• • •	• • •	
Concept n	A_{n1}	A_{n2}		A_{nm}

A_{ij} is the value that is assigned to siting concept i with respect to evaluation criteria j .

FIGURE C-1
MATRIX A: VALUES ASSIGNED

<div> <div> Evaluation Criterion Weight → </div> <div> Siting Concept ↓ </div> </div>	Criterion 1	Criterion 2	• • •	Criterion m
Concept 1	B_{11}	B_{12}	• • •	B_{1m}
Concept 2	B_{21}	B_{22}		
• • •	• • •	• • •	• • •	
Concept n	B_{n1}	B_{n2}		B_{nm}

B_{ij} is the weight assigned to a siting concept j with respect to siting concept i .

FIGURE C-2
MATRIX B: WEIGHTS ASSIGNED

Data requirements include:

m evaluation criteria

n siting concepts

A set of numbers, A_{ij} ; $i = 1, \dots, n$; $j = 1, \dots, m$

A set of numbers, B_{ij} ; $i = 1, \dots, n$; $j = 1, \dots, m$

In the practical application, this can be seen by referring to the framework of a work sheet, Figure C-3, which was used to evaluate each concept by factor or subfactor. The considerations shown in Column 2 are the bases for assessing each concept. These may be finitely measurable factors such as cost or may be a judgment factor such as interference. Column 3 represents the weighted value of the considerations in Column 2. If there is only one consideration being assessed, or each consideration listed is of the same weight, a value of 1.0 can be assigned. Impact values in Column 4 are the measures of merit, irrespective of consideration weight, and the net impact is the product of Columns 3 and 4, and is logged in Position 5. The net impact for the subfactor is merely the sum of the net impacts of the considerations for that subfactor, and is entered in Row 6 for each concept.

The net impact values computed for all factors or subfactors must be placed on a common base before they are combined or compared with each other. It is convenient to do this by adjusting the impact values in Row 6 so that they extend to 1.0 as the upper limit, representing the most acceptable siting concept(s). Then the other concepts can be rated downwards from 1.0 in proportion to the net values previously derived. Also, in some cases, acceptability or goodness may be measured by high values and, in other cases, by low values. It is, therefore, necessary to normalize the data so that in the process, high values approaching 1.0 are consistently most acceptable. Both processes are accomplished in Row 7 of the work sheet as follows:

Where high values are good, the normalized value J for concept i is given by $J_i/J_{\max}$, where $J_{\max}$ is the highest value of all concepts and J_i is the net value shown in Row 6 for the concept being considered.

Where low values are good, the normalized value J for concept i is given by $J_{\min}/J_i$, where $J_{\min}$ is the lowest value of all concepts and J_i is the net value shown in Row 6 for the concept being considered. In this case, if J_i is zero, the $J_{\min}/J_i$ goes to infinity and is indeterminate. Therefore, to avoid the problem, inapplicability is represented by 0.01 or less instead of 0.

CONCEPT EVALUATION WORKSHEET					
EVALUATION FACTOR _____					
SUBFACTOR _____					
Weight _____					
② Consideration	③ Weighted Value	④ Impact/Net Impact ⑤			
		a	b	Concept c	l d
				④	
				⑤	
⑥ Subfactor Net Impact					
⑦ Relative Rating (J/J)					
⑧ Acceptability					

Denotes Column Number

FIGURE C-3

CONCEPT EVALUATION WORKSHEET

After normalizing, or determining the relative ratings, each factor acceptability (Row 8) can be obtained by multiplying the relative rating in Row 7 by the weight of the factor or subfactor, whichever has been the lowest level used.

The acceptability results are displayed to provide a visual awareness of the importance of contributing factors when reviewing a rating. The relative rating is plotted against criteria using a histogram bar for each criterion that applies to siting concept evaluation. As shown in Figure C-4, the width of the bar corresponds to the weight of the particular evaluation criterion. Initially, factor groups are weighted so that the importance of these larger elements are first reasonably proportioned. Then within each group, the components are proportioned so that their total weight, or width of bars, equals the value allocated to that group. The height of each histogram bar is the relative rating of each component. A visual summary is thus obtained showing the overall acceptability for each siting concept and the contribution by individual factors. The acceptability rating for each concept is obtained by summing the areas of the histogram bars. Then all the concepts can be ranked in order of greatest acceptability.

Although this approach brings together all the factors considered in establishing the rankings, including a judgment of their relative importance, it may be desirable to compare concept acceptability against individual factors or subfactors to delineate their impact on acceptability. For example, the acceptability (rating) of each concept, independent of cost, could be plotted against cost on a chart as shown in Figure C-5. The preferred concepts would be those located in the circled area. The same display can be made for acceptability versus environmental impact or any other evaluation factor. It is important to note that a concept which appears most acceptable when measured against all factors individually is also most acceptable when measured against all the factors together, and, therefore, is most acceptable regardless of the weighted value assigned to evaluation factors.

FIGURE C-4

ACCEPTABILITY BY EVALUATION FACTOR

Acceptability
(Without Cost)

Note: Each point represents a siting concept.

Acceptability
(Without
Environmental
Impact)

Acceptability
(Without Risk)

FIGURE C-5

EVALUATION FACTOR ANALYSIS

APPENDIX D

EVALUATION DATA

This appendix contains summary cost estimates for each concept, estimated construction schedules for each concept, tables showing ranking of concepts based on costs for each of three fixed rate charges, and concept evaluation summaries for each factor or subfactor considered.

D.1 COST TABLES

Costs presented in Tables D-1 through D-17 are in accordance with Federal Power Commission (FPC) electric plant chart of accounts. The detailed content of each account is specified by the FPC. Engineering costs are contained in each account. The basis for each concept estimate is an 1,100 Mw(e) nuclear power plant using a light water reactor system. Rationale for differences in cost are discussed in Section 7.2.1. Estimates for alternatives discussed in Section 7.4 were not developed to the same detail and, therefore, similar cost tables for alternatives are not included.

D.2 SCHEDULES

The schedules presented in Tables D-18 through D-24 are for the period of construction only and do not include land acquisition, site investigation, engineering, or licensing time, all of which are dependent on specific sites. However, the schedules represent minimum differences between concepts and are appropriate to the evaluation. The account numbers shown correspond with account numbers and descriptions.

D.3 COST ANALYSIS RESULTS AND RANKING

Tables D-25, D-26, and D-27 present the ranking of the siting concepts for fixed rate charges of 12, 15, and 18 percent. Ranking was determined by computing estimated bus bar costs for each concept and developing rank in respect to the concept having least cost.

D.4 CONCEPT EVALUATION SUMMARY

The evaluation by each factor, and in some cases subfactor, against each concept is represented individually in Tables D-28 through D-38. The methodology for their development is discussed in Appendix C. The results of the evaluation are presented on the bottom line of each table wherein the contribution of each factor or subfactor to an acceptability

value is indicated for each concept. Figure D-1, located at the end of the appendix is used to convert miles of coastline to rating for inclusion in Table D-37.

TABLE D-1
SUMMARY COST ESTIMATE, ABOVEGROUND - COASTAL

<u>ACCOUNT NO.</u>	<u>DESCRIPTION</u>	<u>COST</u>
CAPITAL		
NUCLEAR PRODUCTION		
320	LAND AND LAND RIGHTS	750000
321	STRUCTURES AND IMPROVEMENTS	63444000
322	REACTOR PLANT EQUIPMENT	126450000
323	TURBOGENERATOR UNITS	93919000
324	ACCESSORY ELECTRIC EQUIPMENT	20065000
325	MISCELLANEOUS POWER PLANT EQUIPMENT	4735000
		<u>309363000</u>
TRANSMISSION PLANT		
350	LAND AND LAND RIGHTS	
351	(RESERVED)	
352	STRUCTURES AND IMPROVEMENTS	715000
353	STATION EQUIPMENT	3965000
354	TOWERS AND FIXTURES	
355	POLES AND FIXTURES	
356	OVERHEAD CONDUCTORS AND DEVICES	
357	UNDERGROUND (UNDERWATER) CONDUIT	
358	UNDERGROUND (UNDERWATER) CONDUCTORS AND DEVICES	
359	ROADS AND TRAILS	
	SUBTOTAL	<u>4680000</u>
	SUBTOTAL CAPITAL	<u>314043000</u>
INTEREST DURING CONSTRUCTION		<u>39567000</u>
	TOTAL INVESTMENT	<u>353610000</u>
OPERATING AND MAINTENANCE		
	FUEL	12000000
	LABOR	1223000
	MATERIALS AND EQUIPMENT	2021000
	SUBTOTAL O & M	<u>15244000</u>

TABLE D-2
SUMMARY COST ESTIMATE, ABOVEGROUND - INLAND

<u>ACCOUNT NO.</u>	<u>DESCRIPTION</u>	<u>COST</u>
CAPITAL		
NUCLEAR PRODUCTION		
320	LAND AND LAND RIGHTS	100000
321	STRUCTURES AND IMPROVEMENTS	60800000
322	REACTOR PLANT EQUIPMENT	140000000
323	TURBOGENERATOR UNITS	85000000
324	ACCESSORY ELECTRIC EQUIPMENT	21065000
325	MISCELLANEOUS POWER PLANT EQUIPMENT	4735000
	SUBTOTAL	311700000
TRANSMISSION PLANT		
350	LAND AND LAND RIGHTS	455000
351	(RESERVED)	
352	STRUCTURES AND IMPROVEMENTS	715000
353	STATION EQUIPMENT	3965000
354	TOWERS AND FIXTURES	6000000
355	POLES AND FIXTURES	
356	OVERHEAD CONDUCTORS AND DEVICES	14000000
357	UNDERGROUND (UNDERWATER) CONDUIT	
358	UNDERGROUND (UNDERWATER) CONDUCTORS AND DEVICES	
359	ROADS AND TRAILS	
	SUBTOTAL	25135000
	SUBTOTAL CAPITAL	336835000
INTEREST DURING CONSTRUCTION		45412000
TOTAL INVESTMENT		382247000
OPERATING AND MAINTENANCE		
	FUEL	132000000
	LABOR	1123000
	MATERIALS AND EQUIPMENT	2753000
	SUBTOTAL O & M	17076000

TABLE D-3
SUMMARY COST ESTIMATE, ABOVEGROUND - HILLSIDE

<u>ACCOUNT NO.</u>	<u>DESCRIPTION</u>	<u>COST</u>
CAPITAL		
NUCLEAR PRODUCTION		
320	LAND AND LAND RIGHTS	100000
321	STRUCTURES AND IMPROVEMENTS	62320000
322	REACTOR PLANT EQUIPMENT	126450000
323	TURBOGENERATOR UNITS	105247000
324	ACCESSORY ELECTRIC EQUIPMENT	21065000
325	MISCELLANEOUS POWER PLANT EQUIPMENT	4735000
	SUBTOTAL	<u>319917000</u>
TRANSMISSION PLANT		
350	LAND AND LAND RIGHTS	
351	(RESERVED)	
352	STRUCTURES AND IMPROVEMENTS	715000
353	STATION EQUIPMENT	3965000
354	TOWERS AND FIXTURES	
355	POLES AND FIXTURES	
356	OVERHEAD CONDUCTORS AND DEVICES	
357	UNDERGROUND (UNDERWATER) CONDUIT	
358	UNDERGROUND (UNDERWATER) CONDUCTORS AND DEVICES	
359	ROADS AND TRAILS	
	SUBTOTAL	<u>4680000</u>
	SUBTOTAL CAPITAL	<u>324597000</u>
INTEREST DURING CONSTRUCTION		<u>40774000</u>
TOTAL INVESTMENT		365371000
OPERATING AND MAINTENANCE		
	FUEL	12000000
	LABOR	1233000
	MATERIALS AND EQUIPMENT	2615000
	SUBTOTAL O & M	<u>15848000</u>

TABLE D-4
SUMMARY COST ESTIMATE, ABOVEGROUND - LOW PROFILE

<u>ACCOUNT NO.</u>	<u>DESCRIPTION</u>	<u>COST</u>
CAPITAL		
NUCLEAR PRODUCTION		
320	LAND AND LAND RIGHTS	1000000
321	STRUCTURES AND IMPROVEMENTS	62620000
322	REACTOR PLANT EQUIPMENT	126450000
323	TURBOGENERATOR UNITS	97593000
324	ACCESSORY ELECTRIC EQUIPMENT	21065000
325	MISCELLANEOUS POWER PLANT EQUIPMENT	4735000
	SUBTOTAL	313463000
TRANSMISSION PLANT		
350	LAND AND LAND RIGHTS	
351	(RESERVED)	
352	STRUCTURES AND IMPROVEMENTS	915000
353	STATION EQUIPMENT	3965000
354	TOWERS AND FIXTURES	
355	POLES AND FIXTURES	
356	OVERHEAD CONDUCTORS AND DEVICES	
357	UNDERGROUND (UNDERWATER) CONDUIT	400000
358	UNDERGROUND (UNDERWATER) CONDUCTORS AND DEVICES	100000
359	ROADS AND TRAILS	
	SUBTOTAL	5380000
	SUBTOTAL CAPITAL	318843000
INTEREST DURING CONSTRUCTION		35483000
TOTAL INVESTMENT		354326000
OPERATING AND MAINTENANCE		
	FUEL	12000000
	LABOR	1233000
	MATERIALS AND EQUIPMENT	2025000
	SUBTOTAL O & M	15258000

TABLE D-5
SUMMARY COST ESTIMATE, ABOVEGROUND - FLOATING LAGOON

<u>ACCOUNT NO.</u>	<u>DESCRIPTION</u>	<u>COST</u>
CAPITAL		
NUCLEAR PRODUCTION		
320	LAND AND LAND RIGHTS	1000000
321	STRUCTURES AND IMPROVEMENTS	97235000
322	REACTOR PLANT EQUIPMENT	132772000
323	TURBOGENERATOR UNITS	93872000
324	ACCESSORY ELECTRIC EQUIPMENT	23315000
325	MISCELLANEOUS POWER PLANT EQUIPMENT	4972000
	SUBTOTAL	<u>353166000</u>
TRANSMISSION PLANT		
350	LAND AND LAND RIGHTS	
351	(RESERVED)	
352	STRUCTURES AND IMPROVEMENTS	715000
353	STATION EQUIPMENT	3965000
354	TOWERS AND FIXTURES	
355	POLES AND FIXTURES	
356	OVERHEAD CONDUCTORS AND DEVICES	100000
357	UNDERGROUND (UNDERWATER) CONDUIT	
358	UNDERGROUND (UNDERWATER) CONDUCTORS AND DEVICES	
359	ROADS AND TRAILS	
	SUBTOTAL	<u>4780000</u>
	SUBTOTAL CAPITAL	<u>357946000</u>
INTEREST DURING CONSTRUCTION		<u>50200000</u>
	TOTAL INVESTMENT	<u>408146000</u>
OPERATING AND MAINTENANCE		
	FUEL	12000000
	LABOR	1163000
	MATERIALS AND EQUIPMENT	2005000
	SUBTOTAL O & M	<u>15168000</u>

TABLE D-6
SUMMARY COST ESTIMATE, UNDERGROUND - MASSIVE IGNEOUS

<u>ACCOUNT NO.</u>	<u>DESCRIPTION</u>	<u>COST</u>
CAPITAL		
NUCLEAR PRODUCTION		
320	LAND AND LAND RIGHTS	100000
321	STRUCTURES AND IMPROVEMENTS	84955000
322	REACTOR PLANT EQUIPMENT	139095000
323	TURBOGENERATOR UNITS	112658000
324	ACCESSORY ELECTRIC EQUIPMENT	25140000
325	MISCELLANEOUS POWER PLANT EQUIPMENT	5200000
	SUBTOTAL	367148000
TRANSMISSION PLANT		
350	LAND AND LAND RIGHTS	
351	(RESERVED)	
352	STRUCTURES AND IMPROVEMENTS	715000
353	STATION EQUIPMENT	3965000
354	TOWERS AND FIXTURES	
355	POLES AND FIXTURES	
356	OVERHEAD CONDUCTORS AND DEVICES	
357	UNDERGROUND (UNDERWATER) CONDUIT	400000
358	UNDERGROUND (UNDERWATER) CONDUCTORS AND DEVICES	100000
359	ROADS AND TRAILS	
	SUBTOTAL	5180000
	SUBTOTAL CAPITAL	372328000
INTEREST DURING CONSTRUCTION		48697000
	TOTAL INVESTMENT	421025000
OPERATING AND MAINTENANCE		
	FUEL	12000000
	LABOR	1283000
	MATERIALS AND EQUIPMENT	2736000
	SUBTOTAL O & M	16019000

TABLE D-7
SUMMARY COST ESTIMATE, UNDERGROUND - MASSIVE SEDIMENTARY

<u>ACCOUNT NO.</u>	<u>DESCRIPTION</u>	<u>COST</u>
CAPITAL		
NUCLEAR PRODUCTION		
320	LAND AND LAND RIGHTS	100000
321	STRUCTURES AND IMPROVEMENTS	84955000
322	REACTOR PLANT EQUIPMENT	139095000
323	TURBOGENERATOR UNITS	112658000
324	ACCESSORY ELECTRIC EQUIPMENT	25140000
325	MISCELLANEOUS POWER PLANT EQUIPMENT	5200000
	SUBTOTAL	367148000
TRANSMISSION PLANT		
350	LAND AND LAND RIGHTS	
351	(RESERVED)	
352	STRUCTURES AND IMPROVEMENTS	715000
353	STATION EQUIPMENT	3965000
354	TOWERS AND FIXTURES	
355	POLES AND FIXTURES	
356	OVERHEAD CONDUCTORS AND DEVICES	
357	UNDERGROUND (UNDERWATER) CONDUIT	400000
358	UNDERGROUND (UNDERWATER) CONDUCTORS AND DEVICES	100000
359	ROADS AND TRAILS	
	SUBTOTAL	5180000
	SUBTOTAL CAPITAL	372328000
INTEREST DURING CONSTRUCTION		48697000
	TOTAL INVESTMENT	421025000
OPERATING AND MAINTENANCE		
	FUEL	12000000
	LABOR	1283000
	MATERIALS AND EQUIPMENT	2736000
	SUBTOTAL O & M	16019000

TABLE D-8
SUMMARY COST ESTIMATE, UNDERGROUND - UNCONSOLIDATED SOILS

<u>ACCOUNT NO.</u>	<u>DESCRIPTION</u>	<u>COST</u>
CAPITAL		
NUCLEAR PRODUCTION		
320	LAND AND LAND RIGHTS	1000000
321	STRUCTURES AND IMPROVEMENTS	203440000
322	REACTOR PLANT EQUIPMENT	139095000
323	TURBOGENERATOR UNITS	112000000
324	ACCESSORY ELECTRIC EQUIPMENT	25140000
325	MISCELLANEOUS POWER PLANT EQUIPMENT	5200000
	SUBTOTAL	485875000
TRANSMISSION PLANT		
350	LAND AND LAND RIGHTS	
351	(RESERVED)	
352	STRUCTURES AND IMPROVEMENTS	715000
353	STATION EQUIPMENT	3965000
354	TOWERS AND FIXTURES	
355	POLES AND FIXTURES	
356	OVERHEAD CONDUCTORS AND DEVICES	
357	UNDERGROUND (UNDERWATER) CONDUIT	400000
358	UNDERGROUND (UNDERWATER) CONDUCTORS AND DEVICES	100000
359	ROADS AND TRAILS	
	SUBTOTAL	5180000
	SUBTOTAL CAPITAL	491055000
INTEREST DURING CONSTRUCTION		72812000
	TOTAL INVESTMENT	563867000
OPERATING AND MAINTENANCE		
	FUEL	12000000
	LABOR	1273000
	MATERIALS AND EQUIPMENT	2030000
	SUBTOTAL O & M	15303000

TABLE D-9
SUMMARY COST ESTIMATE, UNDERGROUND - NONMASSIVE OR PCM

<u>ACCOUNT NO.</u>	<u>DESCRIPTION</u>	<u>COST</u>
CAPITAL		
NUCLEAR PRODUCTION		
320	LAND AND LAND RIGHTS	100000
321	STRUCTURES AND IMPROVEMENTS	88585000
322	REACTOR PLANT EQUIPMENT	139095000
323	TURBOGENERATOR UNITS	112658000
324	ACCESSORY ELECTRIC EQUIPMENT	25140000
325	MISCELLANEOUS POWER PLANT EQUIPMENT	5200000
	SUBTOTAL	370778000
TRANSMISSION PLANT		
350	LAND AND LAND RIGHTS	
351	(RESERVED)	
352	STRUCTURES AND IMPROVEMENTS	715000
353	STATION EQUIPMENT	3965000
354	TOWERS AND FIXTURES	
355	POLES AND FIXTURES	
356	OVERHEAD CONDUCTORS AND DEVICES	
357	UNDERGROUND (UNDERWATER) CONDUIT	400000
358	UNDERGROUND (UNDERWATER) CONDUCTORS AND DEVICES	100000
359	ROADS AND TRAILS	
	SUBTOTAL	5180000
	SUBTOTAL CAPITAL	375958000
INTEREST DURING CONSTRUCTION		50114000
	TOTAL INVESTMENT	426072000
OPERATING AND MAINTENANCE		
	FUEL	12000000
	LABOR	1293000
	MATERIALS AND EQUIPMENT	2740000
	SUBTOTAL O & M	16033000

TABLE D-10
SUMMARY COST ESTIMATE, UNDERGROUND - MASSIVE ROCK FAULT

<u>ACCOUNT NO.</u>	<u>DESCRIPTION</u>	<u>COST</u>
CAPITAL		
NUCLEAR PRODUCTION		
320	LAND AND LAND RIGHTS	100000
321	STRUCTURES AND IMPROVEMENTS	127691000
322	REACTOR PLANT EQUIPMENT	139095000
323	TURBOGENERATOR UNITS	112658000
324	ACCESSORY ELECTRIC EQUIPMENT	25140000
325	MISCELLANEOUS POWER PLANT EQUIPMENT	5200000
	SUBTOTAL	409884000
TRANSMISSION PLANT		
350	LAND AND LAND RIGHTS	
351	(RESERVED)	
352	STRUCTURES AND IMPROVEMENTS	715000
353	STATION EQUIPMENT	3965000
354	TOWERS AND FIXTURES	
355	POLES AND FIXTURES	
356	OVERHEAD CONDUCTORS AND DEVICES	
357	UNDERGROUND (UNDERWATER) CONDUIT	400000
358	UNDERGROUND (UNDERWATER) CONDUCTORS AND DEVICES	100000
359	ROADS AND TRAILS	
	SUBTOTAL	5180000
	SUBTOTAL CAPITAL	415064000
INTEREST DURING CONSTRUCTION		58100000
	TOTAL INVESTMENT	473164000
OPERATING AND MAINTENANCE		
	FUEL	12000000
	LABOR	1283000
	MATERIALS AND EQUIPMENT	2736000
	SUBTOTAL O & M	16019000

TABLE D-11
SUMMARY COST ESTIMATE, OFFSHORE - FLOATING, SHALLOW WATER

<u>ACCOUNT NO.</u>	<u>DESCRIPTION</u>	<u>COST</u>
CAPITAL		
NUCLEAR PRODUCTION		
320	LAND AND LAND RIGHTS	
321	STRUCTURES AND IMPROVEMENTS	186100000
322	REACTOR PLANT EQUIPMENT	132772000
323	TURBOGENERATOR UNITS	93623000
324	ACCESSORY ELECTRIC EQUIPMENT	23315000
325	MISCELLANEOUS POWER PLANT EQUIPMENT	4972000
	SUBTOTAL	440782000
TRANSMISSION PLANT		
350	LAND AND LAND RIGHTS	10000
351	(RESERVED)	
352	STRUCTURES AND IMPROVEMENTS	900000
353	STATION EQUIPMENT	3965000
354	TOWERS AND FIXTURES	
355	POLES AND FIXTURES	
356	OVERHEAD CONDUCTORS AND DEVICES	
357	UNDERGROUND (UNDERWATER) CONDUIT	1333000
358	UNDERGROUND (UNDERWATER) CONDUCTORS AND DEVICES	667000
359	ROADS AND TRAILS	
	SUBTOTAL	6875000
	SUBTOTAL CAPITAL	447657000
INTEREST DURING CONSTRUCTION		67378000
	TOTAL INVESTMENT	515035000
OPERATING AND MAINTENANCE		
	FUEL	12000000
	LABOR	1268000
	MATERIALS AND EQUIPMENT	2067000
	SUBTOTAL O & M	15335000

TABLE D-12
SUMMARY COST ESTIMATE, OFFSHORE - FLOATING DEEPWATER

D-14

<u>ACCOUNT NO.</u>	<u>DESCRIPTION</u>	<u>COST</u>
CAPITAL		
NUCLEAR PRODUCTION		
320	LAND AND LAND RIGHTS	
321	STRUCTURES AND IMPROVEMENTS	122200000
322	REACTOR PLANT EQUIPMENT	132772000
323	TURBOGENERATOR UNITS	88123000
324	ACCESSORY ELECTRIC EQUIPMENT	23315000
325	MISCELLANEOUS POWER PLANT EQUIPMENT	492000
	SUBTOTAL	<u>371382000</u>
TRANSMISSION PLANT		
350	LAND AND LAND RIGHTS	10000
351	(RESERVED)	
352	STRUCTURES AND IMPROVEMENTS	900000
353	STATION EQUIPMENT	3965000
354	TOWERS AND FIXTURES	
355	POLES AND FIXTURES	
356	OVERHEAD CONDUCTORS AND DEVICES	
357	UNDERGROUND (UNDERWATER) CONDUIT	4000000
358	UNDERGROUND (UNDERWATER) CONDUCTORS AND DEVICES	2000000
359	ROADS AND TRAILS	
	SUBTOTAL	<u>10875000</u>
	SUBTOTAL CAPITAL	<u>382257000</u>
INTEREST DURING CONSTRUCTION		<u>54136000</u>
	TOTAL INVESTMENT	<u>436393000</u>
OPERATING AND MAINTENANCE		
	FUEL	12000000
	LABOR	1268000
	MATERIALS AND EQUIPMENT	<u>2067000</u>
	SUBTOTAL O & M	<u>15335000</u>

TABLE D-13
SUMMARY COST ESTIMATE - OFFSHORE - SEABED

<u>ACCOUNT NO.</u>	<u>DESCRIPTION</u>	<u>COST</u>
CAPITAL		
NUCLEAR PRODUCTION		
320	LAND AND LAND RIGHTS	
321	STRUCTURES AND IMPROVEMENTS	143050000
322	REACTOR PLANT EQUIPMENT	132772000
323	TURBOGENERATOR UNITS	88123000
324	ACCESSORY ELECTRIC EQUIPMENT	23315000
325	MISCELLANEOUS POWER PLANT EQUIPMENT	4972000
	SUBTOTAL	<u>392232000</u>
TRANSMISSION PLANT		
350	LAND AND LAND RIGHTS	10000
351	(RESERVED)	
352	STRUCTURES AND IMPROVEMENTS	900000
353	STATION EQUIPMENT	3965000
354	TOWERS AND FIXTURES	
355	POLES AND FIXTURES	
356	OVERHEAD CONDUCTORS AND DEVICES	
357	UNDERGROUND (UNDERWATER) CONDUIT	4000000
358	UNDERGROUND (UNDERWATER) CONDUCTORS AND DEVICES	2000000
359	ROADS AND TRAILS	
	SUBTOTAL	<u>10875000</u>
	SUBTOTAL CAPITAL	<u>403107000</u>
INTEREST DURING CONSTRUCTION		<u>58187000</u>
TOTAL INVESTMENT		<u>461294000</u>
OPERATING AND MAINTENANCE		
	FUEL	12000000
	LABOR	1228000
	MATERIALS AND EQUIPMENT	2065000
	SUBTOTAL O & M	<u>15293000</u>

TABLE D-14
SUMMARY COST ESTIMATE, OFFSHORE - UNDERSEA

<u>ACCOUNT NO.</u>	<u>DESCRIPTION</u>	<u>COST</u>
CAPITAL		
NUCLEAR PRODUCTION		
320	LAND AND LAND RIGHTS	100000
321	STRUCTURES AND IMPROVEMENTS	211388000
322	REACTOR PLANT EQUIPMENT	145418000
323	TURBOGENERATOR UNITS	88636000
324	ACCESSORY ELECTRIC EQUIPMENT	24225000
325	MISCELLANEOUS POWER PLANT EQUIPMENT	5445000
	SUBTOTAL	<u>475212000</u>
TRANSMISSION PLANT		
350	LAND AND LAND RIGHTS	
351	(RESERVED)	
352	STRUCTURES AND IMPROVEMENTS	900000
353	STATION EQUIPMENT	3965000
354	TOWERS AND FIXTURES	
355	POLES AND FIXTURES	
356	OVERHEAD CONDUCTORS AND DEVICES	
357	UNDERGROUND (UNDERWATER) CONDUIT	12000000
358	UNDERGROUND (UNDERWATER) CONDUCTORS AND DEVICES	3800000
359	ROADS AND TRAILS	
	SUBTOTAL	<u>20665000</u>
	SUBTOTAL CAPITAL	<u>495877000</u>
INTEREST DURING CONSTRUCTION		<u>74329000</u>
	TOTAL INVESTMENT	570206000
OPERATING AND MAINTENANCE		
	FUEL	12000000
	LABOR	1400000
	MATERIALS AND EQUIPMENT	2860000
	SUBTOTAL O & M	<u>16260000</u>

TABLE D-15
SUMMARY COST ESTIMATE, OFFSHORE - ARTIFICIAL ISLAND

<u>ACCOUNT NO.</u>	<u>DESCRIPTION</u>	<u>COST</u>
CAPITAL		
NUCLEAR PRODUCTION		
320	LAND AND LAND RIGHTS	
321	STRUCTURES AND IMPROVEMENTS	106894000
322	REACTOR PLANT EQUIPMENT	139095000
323	TURBOGENERATOR UNITS	90283000
324	ACCESSORY ELECTRIC EQUIPMENT	25140000
325	MISCELLANEOUS POWER PLANT EQUIPMENT	4812000
	SUBTOTAL	<u>366224000</u>
TRANSMISSION PLANT		
350	LAND AND LAND RIGHTS	900000
351	(RESERVED)	
352	STRUCTURES AND IMPROVEMENTS	3965000
353	STATION EQUIPMENT	
354	TOWERS AND FIXTURES	
355	POLES AND FIXTURES	
356	OVERHEAD CONDUCTORS AND DEVICES	
357	UNDERGROUND (UNDERWATER) CONDUIT	1333000
358	UNDERGROUND (UNDERWATER) CONDUCTORS AND DEVICES	667000
359	ROADS AND TRAILS	
	SUBTOTAL	<u>6865000</u>
	SUBTOTAL CAPITAL	<u>373089000</u>
INTEREST DURING CONSTRUCTION		<u>56244000</u>
	TOTAL INVESTMENT	<u>429333000</u>
OPERATING AND MAINTENANCE		
	FUEL	12000000
	LABOR	1268000
	MATERIALS AND EQUIPMENT	2067000
	SUBTOTAL O & M	<u>15335000</u>

TABLE D-16
SUMMARY COST ESTIMATE, OFFSHORE - NATURAL ISLAND

<u>ACCOUNT NO.</u>	<u>DESCRIPTION</u>	<u>COST</u>
CAPITAL		
NUCLEAR PRODUCTION		
320	LAND AND LAND RIGHTS	400000
321	STRUCTURES AND IMPROVEMENTS	71058000
322	REACTOR PLANT EQUIPMENT	139095000
323	TURBOGENERATOR UNITS	101110000
324	ACCESSORY ELECTRIC EQUIPMENT	25140000
325	MISCELLANEOUS POWER PLANT EQUIPMENT	4812000
	SUBTOTAL	<u>341615000</u>
TRANSMISSION PLANT		
350	LAND AND LAND RIGHTS	
351	(RESERVED)	
352	STRUCTURES AND IMPROVEMENTS	900000
353	STATION EQUIPMENT	3965000
354	TOWERS AND FIXTURES	
355	POLES AND FIXTURES	
356	OVERHEAD CONDUCTORS AND DEVICES	
357	UNDERGROUND (UNDERWATER) CONDUIT	30000000
358	UNDERGROUND (UNDERWATER) CONDUCTORS AND DEVICES	16000000
359	ROADS AND TRAILS	
	SUBTOTAL	<u>50865000</u>
	SUBTOTAL CAPITAL	392480000
INTEREST DURING CONSTRUCTION		<u>45341000</u>
	TOTAL INVESTMENT	437821000
OPERATING AND MAINTENANCE		
	FUEL	12000000
	LABOR	1268000
	MATERIALS AND EQUIPMENT	2105000
	SUBTOTAL O & M	<u>15373000</u>

TABLE D-17
SUMMARY COST ESTIMATE, OFFSHORE-TUNED SPHERE

<u>ACCOUNT NO.</u>	<u>DESCRIPTION</u>	<u>COST</u>
CAPITAL		
NUCLEAR PRODUCTION		
320	LAND AND LAND RIGHTS	
321	STRUCTURES AND IMPROVEMENTS	175650000
322	REACTOR PLANT EQUIPMENT	139408000
323	TURBOGENERATOR UNITS	92529000
324	ACCESSORY ELECTRIC EQUIPMENT	24480000
325	MISCELLANEOUS POWER PLANT EQUIPMENT	5220000
	SUBTOTAL	<u>437287000</u>
TRANSMISSION PLANT		
350	LAND AND LAND RIGHTS	10000
351	(RESERVED)	
352	STRUCTURES AND IMPROVEMENTS	900000
353	STATION EQUIPMENT	3965000
354	TOWERS AND FIXTURES	
355	POLES AND FIXTURES	
356	OVERHEAD CONDUCTORS AND DEVICES	
357	UNDERGROUND (UNDERWATER) CONDUIT	4000000
358	UNDERGROUND (UNDERWATER) CONDUCTORS AND DEVICES	2000000
359	ROADS AND TRAILS	
	SUBTOTAL	<u>10875000</u>
	SUBTOTAL CAPITAL	<u>448162000</u>
	INTEREST DURING CONSTRUCTION	<u>69643000</u>
	TOTAL INVESTMENT	517805000
OPERATING AND MAINTENANCE		
	FUEL	12000000
	LABOR	1228000
	MATERIALS AND EQUIPMENT	2065000
	SUBTOTAL O & M	<u>15293000</u>

TABLE D-19
CONSTRUCTION SCHEDULE
ABOVEGROUND - INLAND

		YEARS																
ACCOUNT	:	1	:	2	:	3	:	4	:	5	:	6	:	7	:	8	:	9
320		XXX																
321		XX										XXXXXXX						
322						XX												
323						XX												
324						XX												
325						XX												
352						XXXXXXXXXXXXXXXXXXXX												
353						XX												
356						XXXXXXXXXXXXXXXXXXXXXXXXXXXX												

TABLE D-20
CONSTRUCTION SCHEDULE
OFFSHORE - ARTIFICIAL ISLAND

		YEARS																
ACCOUNT	:	1	:	2	:	3	:	4	:	5	:	6	:	7	:	8	:	9
320		XXX																
321		XX															XXXXXXX	
322												XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX						
323												XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX						
324																	XXXXXXXXXXXXXXXXXXXXXXXXXXXX	
325																	XXXXXXXXXXXXXXXXXXXXXXXXXXXX	
352																	XXXXXXXXXXXXXXXXXXXX	
353																	XXXXXXXXXXXXXXXXXXXXXXXXXXXX	
357																	XXXXXXXXXXXXXXXXXXXXXXXXXXXX	
358																	XXXXXXXXXXXXXXXXXXXX	

TABLE D-21
CONSTRUCTION SCHEDULE
OFFSHORE - TUNED SPHERE

YEARS																					
ACCOUNT	:	1	:	2	:	3	:	4	:	5	:	6	:	7	:	8	:	9			
321		XX																			
322										XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX											
323										XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX											
324												XXXXXXXXXXXXXXXXXXXXXXXXXXXX									
325													XXXXXXXXXXXXXXXXXXXX								
350										XXX											
352												XXXXXXXXXXXXXXXXXXXX									
353												XXXXXXXXXXXXXXXXXXXX									
357													XXXXXXXXXXXXXXXXXX								
358																XXXXXXX					

TABLE D-22
CONSTRUCTION SCHEDULE
UNDERGROUND - UNCONSOLIDATED SOILS

		YEARS																
ACCOUNT	:	1	:	2	:	3	:	4	:	5	:	6	:	7	:	8	:	9
320		XXX																
321		XX																
322												XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX						
323												XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX						
324													XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX					
325																XXXXXXXXXXXXXXXXXXXXXXXXXXXX		
352													XXXXXXXXXXXXXXXXXXXX					
353														XXXXXXXXXXXXXXXXXXXXXXXXXXXX				
357																XXXXXXXXXXXXXXXXXXXX		
358																	XXXXXXXXXX	

TABLE D-23
CONSTRUCTION SCHEDULE
ABOVEGROUND-FLOATING LAGOON; OFFSHORE-FLOATING, SHALLOW WATER
OFFSHORE - FLOATING, DEEPWATER; OFFSHORE - SEABED

YEARS																		
ACCOUNT	:	1	:	2	:	3	:	4	:	5	:	6	:	7	:	8	:	9
320(FLT LAG)XXX																		
321		XX															XXXXX	
322						XX												
323						XX												
324								XXXXXXXXXXXXXXXXXXXXXXXXXXXX										
325										XXXXXXXXXXXXXXXXXXXX								
350 (NO FLT LAG)																		
						XXX												
352										XXXXXXXXXXXXXXXXXXXX								
353										XXXXXXXXXXXXXXXXXXXX								
357														XXXXXXXXXXXXXXXXXXXX				
358																XXXXXXXXXXXX		

TABLE D-24
CONSTRUCTION SCHEDULE
OFFSHORE-UNDERSEA, UNDERGROUND MASSIVE FAULTED, UNDERGROUND-IGNEOUS
UNDERGROUND-SEDIMENTARY, UNDERGROUND-NONMASSIVE OR PCM

		YEARS																			
ACCOUNT	:	1	:	2	:	3	:	4	:	5	:	6	:	7	:	8	:	9	:		
320		XXX																			
321		XX															XXXXXXX				
322								XX													
323								XX													
324										XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX											
325												XXXXXXXXXXXXXXXXXXXX									
352												XXXXXXXXXXXXXXXXXXXX									
353												XXXXXXXXXXXXXXXXXXXX									
357												XXXXXXXXXXXXXXXXXXXX									
358																XXXXXXXXXXXX					

TABLE D-25

COST ANALYSIS RESULTS AND RANKING - FIXED RATE CHARGE, 12 PCT.

CONCEPT	SIZE (MW)	TOTAL INVESTMENT (000)	OPERATING EXPENSES (000)	ANNUAL COST (000)	MILS PER KW-HR
ABOVEGROUND-COASTAL	1100	353610	15244	57677	7.48
ABOVEGROUND-LOW PROFILE	1100	354326	15258	57777	7.49
ABOVEGROUND-HILLSIDE	1100	365371	15848	59692	7.73
ABOVEGROUND-INLAND	1100	382247	17076	62946	8.17
ABOVEGROUND-FLOATING LAGOON	1100	408146	15168	64146	8.32
UNDERGROUND-MASSIVE SEDIMENTARY	1100	421025	16019	66542	8.61
UNDERGROUND-MASSIVE IGNEOUS	1100	421025	16019	66542	8.61
OFFSHORE-ARTIFICIAL ISLAND	1100	429333	15335	66855	8.67
UNDERGROUND-NON-MASSIVE OR PCM	1100	426072	16033	67161	8.69
OFFSHORE-FLOATING, DEEP WATER	1100	436393	15335	67702	8.78
OFFSHORE-NATURAL ISLAND	1100	437821	15373	67912	8.81
OFFSHORE-SEABED	1100	461294	15293	70648	9.16
UNDERGROUND-MASSIVE ROCK FAULT	1100	473164	16019	72798	9.42
OFFSHORE-FLOATING, SHALLOW WATER	1100	515035	15335	77139	10.01
OFFSHORE-TUNED SPHERE	1100	517805	15293	77430	10.04
UNDERGROUND-UNCONSOLIDATED SOILS	1100	563867	15303	82967	10.76
OFFSHORE-UNDERSEA	1100	570206	16260	84685	10.99

TABLE D-26

COST ANALYSIS RESULTS AND RANKING - FIXED RATE CHARGE, 15 PCT.

CONCEPT	SIZE (MW)	TOTAL INVESTMENT (000)	OPERATING EXPENSES (000)	ANNUAL COST (000)	MILS PER KW-HR
ABOVEGROUND-COASTAL	1100	353610	15244	68285	8.86
ABOVEGROUND-LOW PROFILE	1100	354326	15258	68407	8.87
ABOVEGROUND-HILLSIDE	1100	365371	15848	70653	9.18
ABOVEGROUND-INLAND	1100	382247	17076	74413	9.65
ABOVEGROUND-FLOATING LAGOON	1100	408146	15168	76390	9.91
UNDERGROUND-MASSIVE SEDIMENTARY	1100	421025	16019	79172	10.25
UNDERGROUND-MASSIVE IGNEOUS	1100	421025	16019	79172	10.25
OFFSHORE-ARTIFICIAL ISLAND	1100	429333	15335	79735	10.35
UNDERGROUND-NON-MASSIVE OR PCM	1100	426072	16033	79943	10.39
OFFSHORE-FLOATING, DEEP WATER	1100	436393	15335	80794	10.48
OFFSHORE-NATURAL ISLAND	1100	437821	15373	81046	10.51
OFFSHORE-SEABED	1100	461294	15293	84487	10.96
UNDERGROUND-MASSIVE ROCK FAULT	1100	473164	16019	86993	11.30
OFFSHORE-FLOATING, SHALLOW WATER	1100	515035	15335	92590	12.01
OFFSHORE-TUNED SPHERE	1100	517805	15293	92964	12.06
UNDERGROUND-UNCONSOLIDATED SOILS	1100	563867	15303	99883	12.96
OFFSHORE-UNDERSEA	1100	570206	16260	101791	13.20

TABLE D-27

COST ANALYSIS RESULTS AND RANKING - FIXED RATE CHARGE, 18 PCT.

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CONCEPT	SIZE (MW)	TOTAL INVESTMENT (000)	OPERATING EXPENSES (000)	ANNUAL COST (000)	MILS PER KW-HR
ABOVEGROUND-COASTAL	1100	353610	15244	78894	10.23
ABOVEGROUND-LOW PROFILE	1100	354326	15258	79037	10.25
ABOVEGROUND-HILLSIDE	1100	365371	15848	81614	10.57
ABOVEGROUND-INLAND	1100	382247	17076	85880	11.14
ABOVEGROUND-FLOATING LAGOON	1100	408146	15168	88634	11.50
UNDERGROUND-MASSIVE SEDIMENTARY	1100	421025	16019	91803	11.89
UNDERGROUND-MASSIVE IGNEOUS	1100	421025	16019	91803	11.89
OFFSHORE-ARTIFICIAL ISLAND	1100	429333	15335	92615	12.01
UNDERGROUND-NON-MASSIVE OR PCM	1100	426072	16033	92725	12.01
OFFSHORE-FLOATING, DEEP WATER	1100	436393	15335	93886	12.18
OFFSHORE-NATURAL ISLAND	1100	437821	15373	94181	12.22
OFFSHORE-SEABED	1100	461294	15293	98326	12.76
UNDERGROUND-MASSIVE ROCK FAULT	1100	473164	16019	101188	13.10
OFFSHORE-FLOATING, SHALLOW WATER	1100	515035	15335	108041	14.02
OFFSHORE-TUNED SPHERE	1100	517805	15293	108498	14.07
UNDERGROUND-UNCONSOLIDATED SOILS	1100	563867	15303	116799	15.15
OFFSHORE-UNDERSEA	1100	570206	16260	118897	15.42

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[illegible]

D-31

CONSIDERATION	WEIGHTED VALUE	IMPACT/NET IMPACT CONCEPT																
		ABOVEGROUND					UNDERGROUND					OFFSHORE						
		Coastal	Inland	Hillside	Low Profile	Floating Lagoon	Igneous	Sedi- mentary	Un- consoli- dated	Poorly Ce- mented	Faulted	Floating Shallow	Floating Deep	Seabed	Under- sea	Arti- ficial	Natural Island	Tuned Sphere
Agriculture	0.06	0.2 0.012	0.9 0.054	0.2 0.012	0.2 0.012	0.5 0.030	0.2 0.012	0.2 0.012	0.5 0.030	0.2 0.012	0.2 0.012	0.01 0.001	0.01 0.001	0.01 0.001	0.01 0.001	0.01 0.001	0.01 0.001	0.01 0.001
Recreational	0.11	1.0 0.110	0.4 0.044	0.6 0.066	0.5 0.055	0.6 0.066	0.5 0.055	0.5 0.055	0.6 0.066	0.5 0.055	0.5 0.055	0.4 0.044	0.2 0.022	0.2 0.022	0.1 0.011	0.4 0.044	0.1 0.011	0.2 0.022
Transportation Systems	0.11	0.1 0.011	0.1 0.011	0.1 0.011	0.1 0.011	0.1 0.011	0.1 0.011	0.1 0.011	0.1 0.011	0.1 0.011	0.1 0.011	0.1 0.011	0.1 0.011	0.1 0.011	0.1 0.011	0.1 0.011	0.1 0.011	0.1 0.011
Industrial	0.18	0.2 0.036	0.2 0.036	0.1 0.018	0.1 0.018	0.1 0.018	0.1 0.002	0.01 0.002	0.1 0.018	0.01 0.002	0.01 0.002	0.1 0.018	0.1 0.018	0.1 0.018	0.1 0.018	0.1 0.018	0.1 0.018	0.1 0.018
Commercial	0.27	0.5 0.135	0.3 0.081	0.1 0.027	0.1 0.027	0.4 0.108	0.1 0.027	0.1 0.027	0.4 0.108	0.1 0.027	0.1 0.027	0.1 0.027	0.1 0.027	0.1 0.027	0.1 0.027	0.1 0.027	0.1 0.027	0.1 0.027
Residential	0.27	0.5 0.135	0.3 0.081	0.1 0.027	0.1 0.027	0.4 0.108	0.1 0.027	0.1 0.027	0.4 0.108	0.1 0.027	0.1 0.027	0.1 0.027	0.1 0.027	0.1 0.027	0.1 0.027	0.1 0.027	0.1 0.027	0.1 0.027
ΣSubfactor Net Impact		0.439	0.307	0.161	0.150	0.341	0.134	0.134	0.341	0.134	0.134	0.128	0.106	0.106	0.095	0.128	0.095	0.106
Relative Rating (J/J)		0.217	0.310	0.590	0.633	0.278	0.708	0.708	0.278	0.708	0.708	0.742	0.895	0.895	1.00	0.742	1.00	0.895
Acceptability		0.011	0.016	0.030	0.032	0.014	0.036	0.036	0.014	0.036	0.036	0.037	0.045	0.045	0.050	0.037	0.050	0.045

D-32

[illegible]

Weight: 0.055

[illegible]

Weight: 0.015

CONSIDERATION	WEIGHTED VALUE	IMPACT/NET IMPACT CONCEPT																
		ABOVEGROUND					UNDERGROUND					OFFSHORE						
		Coastal	Inland	Hillside	Low Profile	Floating Lagoon	Igneous	Sedi- mentary	Un- consoli- dated	Poorly Ce- mented	Faulted	Floating Shallow	Floating Deep	Seabed	Under- sea	Arti- ficial	Natural Island	Tuned Sphere
Traffic	0.20	0.80 0.16	0.60 0.12	0.80 0.16	0.80 0.16	0.40 0.08	0.80 0.16	0.80 0.16	1.00 0.20	0.80 0.16	0.80 0.16	0.20 0.04	0.20 0.04	0.20 0.04	0.80 0.16	0.20 0.04	0.01 0.00	0.20 0.04
Aesthetics	0.16	0.90 0.14	0.80 0.13	0.01 0.00	0.80 0.13	0.40 0.06	0.50 0.08	0.50 0.08	1.00 0.16	0.50 0.08	0.50 0.08	0.20 0.03	0.10 0.02	0.10 0.02	0.01 0.00	0.30 0.05	0.01 0.00	0.10 0.02
Noise	0.12	0.50 0.06	0.50 0.06	0.30 0.04	0.50 0.06	0.40 0.05	0.10 0.01	0.10 0.01	1.00 0.12	0.10 0.01	0.10 0.01	0.01 0.00	0.01 0.00	0.01 0.00	0.01 0.00	0.01 0.00	0.01 0.00	0.01 0.00
Labor Force Support	0.36	0.60 0.22	0.60 0.22	0.80 0.29	0.60 0.22	0.30 0.11	0.80 0.29	0.80 0.29	0.30 0.11	0.80 0.29	0.80 0.29	0.10 0.04	0.10 0.04	0.10 0.04	0.80 0.29	0.10 0.04	0.10 0.04	0.10 0.04
Impact on Biota	0.16	0.60 0.10	0.60 0.10	0.60 0.10	0.60 0.10	0.60 0.10	0.40 0.06	0.40 0.06	0.60 0.10	0.40 0.06	0.40 0.06	0.20 0.03	0.10 0.02	0.10 0.02	0.01 0.00	0.20 0.03	0.80 0.13	0.10 0.02
ΣSubfactor Net Impact		0.68	0.53	0.59	0.67	0.40	0.60	0.60	0.69	0.60	0.60	0.14	0.12	0.12	0.45	0.16	0.17	0.12
Relative Rating (J/J)		0.176	0.227	0.204	0.180	0.300	0.200	0.200	0.174	0.200	0.200	0.857	1.00	1.00	0.267	0.750	0.708	1.00
Acceptability		0.003	0.003	0.003	0.003	0.005	0.003	0.003	0.003	0.003	0.003	0.013	0.015	0.015	0.004	0.011	0.011	0.015

TABLE D-34: CONCEPT EVALUATION SUMMARY
FACTOR: ENVIRONMENTAL IMPACT
SUBFACTOR: MULTIPLE USES - HEAT AND PLANT
Weight: 0.033

CONSIDERATION	WEIGHTED VALUE	IMPACT/NET IMPACT																
		CONCEPT																
		ABOVEGROUND					UNDERGROUND					OFFSHORE						
		Coastal	Inland	Hillside	Low Profile	Floating Lagoon	Igneous	Sedi- mentary	Un- consoli- dated	Poorly Ce- mented	Faulted	Floating Shallow	Floating Deep	Seabed	Under- sea	Arti- ficial	Natural Island	Tuned Sphere
Aquaculture	1.0	1.00 1.00	0.01 0.01	0.60 0.60	1.00 1.00	1.00 1.00	0.60 0.60	0.60 0.60	1.00 1.00	0.60 0.60	0.60 0.60	0.01 0.01	0.01 0.01	0.01 0.01	0.01 0.01	0.01 0.01	1.00 1.00	0.01 0.01
Water Sports	1.0	0.01 0.01	0.80 0.80	0.01 0.01	0.01 0.01	1.00 1.00	0.01 0.01	0.01 0.01	0.01 0.01	0.01 0.01	0.01 0.01	0.01 0.01	0.01 0.01	0.01 0.01	0.01 0.01	0.01 0.01	0.01 0.01	0.01 0.01
Irrigation	1.0	0.01 0.01	0.70 0.70	0.01 0.01	0.01 0.01	0.01 0.01	0.01 0.01	0.01 0.01	0.01 0.01	0.01 0.01	0.01 0.01	0.01 0.01	0.01 0.01	0.01 0.01	0.01 0.01	0.01 0.01	0.01 0.01	0.01 0.01
Population Shelter	1.0	0.01 0.01	0.01 0.01	0.01 0.01	0.01 0.01	0.01 0.01	1.00 1.00	1.00 1.00	1.00 1.00	1.00 1.00	1.00 1.00	0.01 0.01	0.01 0.01	0.01 0.01	1.00 1.00	0.01 0.01	0.01 0.01	0.01 0.01
ΣSubfactor Net Impact		1.03	1.52	0.63	1.03	2.02	1.62	1.62	2.02	1.62	1.62	0.04	0.04	0.04	1.03	0.04	1.03	0.04
Relative Rating (J/J)		0.51	0.75	0.31	0.51	1.00	0.80	0.80	1.00	0.80	0.80	0.02	0.02	0.02	0.51	0.02	0.51	0.02
Acceptability		0.017	0.025	0.010	0.017	0.033	0.026	0.026	0.033	0.026	0.026	0.001	0.001	0.001	0.017	0.001	0.017	0.001

Weight: 0.040

CONSIDERATION	WEIGHTED VALUE	IMPACT/NET IMPACT CONCEPT																
		ABOVEGROUND					UNDERGROUND					OFFSHORE						
		Coastal	Inland	Hillside	Low Profile	Floating Lagoon	Igneous	Sedi- mentary	Un- consoli- dated	Poorly Ce- mented	Faulted	Floating Shallow	Floating Deep	Seabed	Under- sea	Arti- ficial	Natural Island	Tuned Sphere
Bathing	0.25	0.80 0.20	1.00 0.25	0.40 0.10	0.80 0.20	1.00 0.25	0.40 0.10	0.40 0.10	0.80 0.20	0.40 0.10	0.40 0.10	0.10 0.03	0.10 0.03	0.10 0.03	0.10 0.03	0.10 0.03	0.10 0.03	0.10 0.03
Picnicking	0.20	0.80 0.16	1.00 0.20	0.40 0.08	0.80 0.16	1.00 0.20	0.40 0.08	0.40 0.08	0.80 0.16	0.40 0.08	0.40 0.08	0.10 0.02	0.10 0.02	0.10 0.02	0.10 0.02	0.10 0.02	0.10 0.02	0.10 0.02
Camping	0.15	0.80 0.12	1.00 0.15	0.80 0.12	0.80 0.12	1.00 0.15	0.80 0.12	0.80 0.12	0.80 0.12	0.80 0.12	0.80 0.12	0.10 0.01	0.10 0.01	0.10 0.01	0.10 0.01	0.10 0.01	0.10 0.01	0.10 0.01
Fishing	0.15	0.80 0.12	1.00 0.15	0.40 0.06	0.80 0.12	1.00 0.15	0.40 0.06	0.40 0.06	0.80 0.12	0.40 0.06	0.40 0.06	0.10 0.01	0.10 0.01	0.10 0.01	0.10 0.01	0.10 0.01	0.10 0.01	0.10 0.01
Boating	0.10	0.40 0.04	1.00 0.10	0.20 0.02	0.40 0.04	1.00 0.10	0.20 0.02	0.20 0.02	0.40 0.04	0.20 0.02	0.20 0.02	0.10 0.01	0.10 0.01	0.10 0.01	0.10 0.01	0.10 0.01	0.10 0.01	0.10 0.01
Enjoyment - Wildlife	0.10	0.50 0.05	0.50 0.05	1.00 0.10	0.50 0.05	1.00 0.10	1.00 0.10	1.00 0.10	1.00 0.10	1.00 0.10	1.00 0.10	0.10 0.01	0.10 0.01	0.10 0.01	0.10 0.01	0.10 0.01	0.10 0.01	0.10 0.01
Water Skiing	0.05	0.01 0.00	0.50 0.03	0.01 0.00	0.01 0.00	1.00 0.05	0.01 0.00	0.01 0.00	0.01 0.00	0.01 0.00	0.01 0.00	0.01 0.00	0.01 0.00	0.01 0.00	0.01 0.00	0.01 0.00	0.01 0.00	0.01 0.00
ΣSubfactor Net Impact		0.69	0.93	0.48	0.69	1.00	0.48	0.48	0.74	0.48	0.48	0.09	0.09	0.09	0.09	0.09	0.09	0.09
Relative Rating (J/J)		0.69	0.92	0.48	0.69	1.00	0.48	0.48	0.74	0.48	0.48	0.09	0.09	0.09	0.09	0.09	0.09	0.09
Acceptability		0.028	0.037	0.019	0.028	0.040	0.019	0.019	0.030	0.019	0.019	0.004	0.004	0.004	0.004	0.004	0.004	0.004

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CONSIDERATION	WEIGHTED VALUE	IMPACT/NET IMPACT																	
		CONCEPT																	
		ABOVEGROUND						UNDERGROUND						OFFSHORE					
		Coastal	Inland	Hillside	Low Profile	Floating Lagoon	Igneous	Sedi- mentary	Un- consoli- dated	Poorly Ce- mented	Faulted	Floating Shallow	Floating Deep	Seabed	Under- sea	Arti- ficial	Natural Island	Tuned Sphere	
Structure	0.24	1.00 0.24	1.00 0.24	1.00 0.24	1.00 0.24	0.90 0.22	0.50 0.12	0.50 0.12	0.20 0.05	0.50 0.12	0.50 0.12	0.90 0.22	0.50 0.12	0.20 0.05	0.50 0.12	0.90 0.22	1.00 0.24	0.20 0.05	
Production System	0.33	1.00 0.33	1.00 0.33	1.00 0.33	1.00 0.33	0.90 0.30	1.00 0.33	1.00 0.33	1.00 0.33	1.00 0.33	0.90 0.30	0.90 0.30	0.90 0.30	1.00 0.30	1.00 0.33	1.00 0.33	1.00 0.33	0.90 0.30	
Transmission System	0.29	1.00 0.29	1.00 0.29	1.00 0.29	1.00 0.29	0.90 0.26	0.90 0.26	0.90 0.26	0.90 0.26	0.90 0.26	0.50 0.15	0.90 0.26	0.90 0.26	0.90 0.26	0.90 0.26	0.90 0.26	0.50 0.15	0.90 0.26	
Construction Method	0.14	1.00 0.14	1.00 0.14	1.00 0.14	1.00 0.14	0.90 0.13	0.90 0.13	0.90 0.13	0.50 0.07	0.90 0.13	0.90 0.13	0.90 0.13	0.90 0.13	0.20 0.03	0.90 0.13	0.90 0.13	1.00 0.14	0.20 0.03	

TABLE D-37: CONCEPT EVALUATION SUMMARY
FACTOR: FEASIBILITY
SUBFACTOR: POTENTIAL SITES
Weight: 0.153

CONSIDERATION	WEIGHTED VALUE	IMPACT/NET IMPACT																
		CONCEPT																
		ABOVEGROUND					UNDERGROUND					OFFSHORE						
		Coastal	Inland	Hillside	Low Profile	Floating Lagoon	Igneous	Sedi- mentary	Un- consoli- dated	Poorly Ce- mented	Faulted	Floating Shallow	Floating Deep	Seabed	Under- sea	Arti- ficial	Natural Island	Tuned Sphere
Miles of Coastline	See Figure D-1	144 0.53	20,000* 1.00	408 0.83	119 0.48	115 0.47	6 0.02	96 0.43	69 0.38	265 0.70	29 0.20	580 0.93	855 0.98	135 0.50	102 0.45	580 0.93	2 0.01	855 0.98
Σ Subfactor Net Impact		0.53	1.00	0.83	0.48	0.47	0.02	0.43	0.38	0.70	0.20	0.93	0.98	0.50	0.45	0.93	0.01	0.98
Relative Rating (J/J)		0.53	1.00	0.83	0.48	0.47	0.02	0.43	0.38	0.70	0.20	0.93	0.98	0.50	0.45	0.93	0.01	0.98
Acceptability		0.080	0.153	0.125	0.072	0.070	0.003	0.066	0.058	0.107	0.030	0.142	0.152	0.077	0.069	0.142	0.002	0.152

Represents equivalent coastline miles, based on 1-1/2 mile wide coastal zone.

TABLE D-38: CONCEPT EVALUATION SUMMARY

FACTOR: RISK

Weight: 0.140

CONSIDERATION	(1) WEIGHTED VALUE	IMPACT/NET IMPACT CONCEPT																
		ABOVEGROUND					UNDERGROUND					OFFSHORE						
		Coastal	Inland	Hillside	Low Profile	Floating Lagoon	Igneous	Sedi- mentary	Un- consoli- dated	Poorly Ce- mented	Faulted	Floating Shallow	Floating Deep	Seabed	Under- sea	Arti- ficial	Natural Island	Tuned Sphere
Storms and Floods	1x10 ⁻⁴	34.0 ⁽²⁾ 3.4 ⁽³⁾	47.0 4.7	29.0 2.9	32.0 3.2	3.0 .3	1.0 .1	1.0 .1	6.0 .6	49.0 4.9	1.0 .1	12.0 1.2	211.0 21.1	52.0 5.2	35.0 3.5	10.0 1.0	45.0 4.5	165.0 16.5
Earthquake	1x10 ⁻³	122.0 122.0	120.0 120.0	110.0 110.0	116.0 116.0	74.0 74.0	154.0 154.0	154.0 154.0	145.0 145.0	145.0 145.0	320.0 320.0	89.0 89.0	1.0 1.0	400.0 400.0	678.0 678.0	160.0 160.0	155.0 155.0	1.0 1.0
Landslide	1x10 ⁻⁴	19.6 2.0	NA	66.0 6.6	43.0 4.3	5.0 .5	19.5 2.0	19.5 2.0	10.0 1.0	40.0 4.0	19.5 2.0	NA	NA	20.0 2.0	NA	NA	20.0 2.0	NA
Tsunamis and Tides	1x10 ⁻⁵	39.0 .4	NA	19.0 .2	30.0 .3	10.0 .1	19.0 .2	19.0 .2	141.0 1.4	19.0 .2	19.0 .2	20.0 .2	5.0 .05	10.0 .1	10.0 .1	20.0 .2	47.0 .5	5.0 .05
Ship Collision	1x10 ⁻³	NA ⁽⁴⁾	NA	NA	NA	NA	NA	NA	NA	NA	NA	58.0 58.0	223.5 223.5	300.0 300.0	NA	57.9 57.9	NA	148.5 148.5
Accidental Missile	8x10 ⁻⁸	232.0 .02	197.0 .02	197.0 .02	213.0 .02	242.0 .02	10.0 .0	10.0 .0	150.0 .01	25.0 .0	10.0 .0	243.0 .02	240.0 .02	300.0 .02	5.0 .0	240.0 .02	259.0 .02	240.0 .02
Target Missile	1x10 ⁻⁶	408.0 .4	338.0 .3	338.0 .3	380.0 .4	444.0 .4	20.0 .02	20.0 .02	250.0 .2	50.0 .1	20.0 .02	454.0 .5	700.0 .7	700.0 .7	10.0 .01	454.0 .5	440.0 .4	700.0 .7
Sabotage	1x10 ⁻⁷	660.0 .1	600.0 .1	600.0 .1	630.0 .1	680.0 .1	540.0 .1	540.0 .1	520.0 .1	500.0 .1	540.0 .1	680.0 .1	800.0 .1	800.0 .1	540.0 .1	650.0 .1	750.0 .1	800.0 .1
Fire	1x10 ⁻⁶	41.0 .04	37.0 .04	37.0 04	39.0 .04	45.0 .05	70.0 .1	70.0 .1	87.0 .1	70.0 .1	70.0 .1	51.0 .1	51.0 .1	83.0 .1	70.0 .1	51.0 .1	44.0 .04	51.0 .1
Transport Accident	7.5x10 ⁻⁴	1.3 1.0	1.3 1.0	1.3 1.0	1.3 1.0	1.3 1.0	1.3 1.0	1.3 1.0	1.3 1.0	1.3 1.0	1.3 1.0	2.0 1.5	2.0 1.5	2.0 1.5	1.3 1.0	2.0 1.5	2.0 1.5	2.0 1.5
ΣSubfactor Net Impact		129.3	126.1	121.1	125.3	76.4	157.5	157.5	149.4	155.4	323.5	150.6	247.9	709.7	682.8	221.2	164.0	168.5
Relative Rating (J/J)		.58	.60	.63	.61	1.00	.48	.48	.51	.49	.24	.51	.31	.10	.11	.34	.47	.45
Acceptability		.081	.084	.088	.085	.140	.067	.067	.071	.069	.034	.071	.044	.014	.015	.048	.066	.063

(1) Weighted values are frequency of occurrence per year (2) Damage estimate in millions of dollars, (3) Risk in thousands of dollars per year = (1) x weighted value,
 (4) Event not applicable to concept.

FIGURE D-1