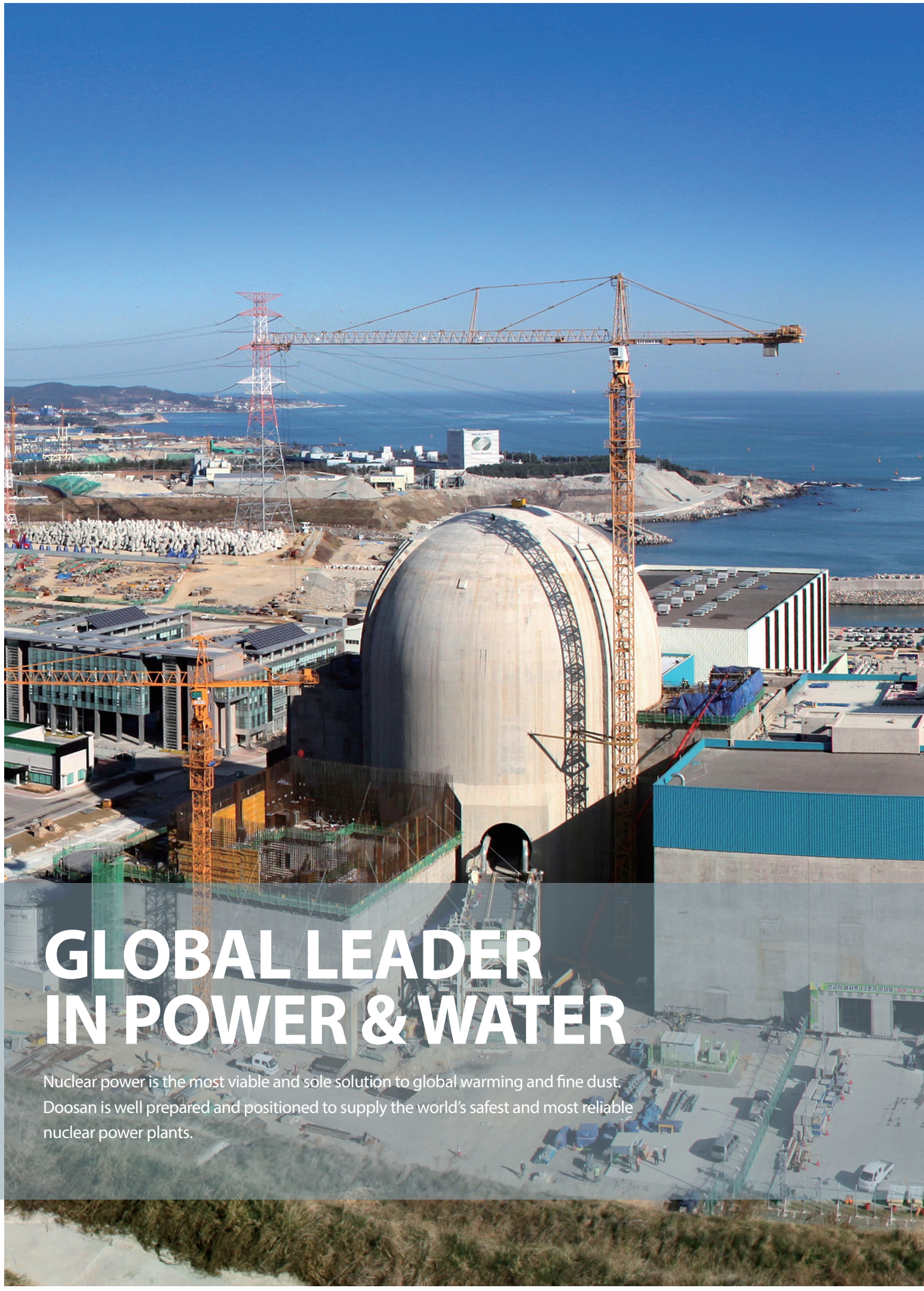
DOOSAN

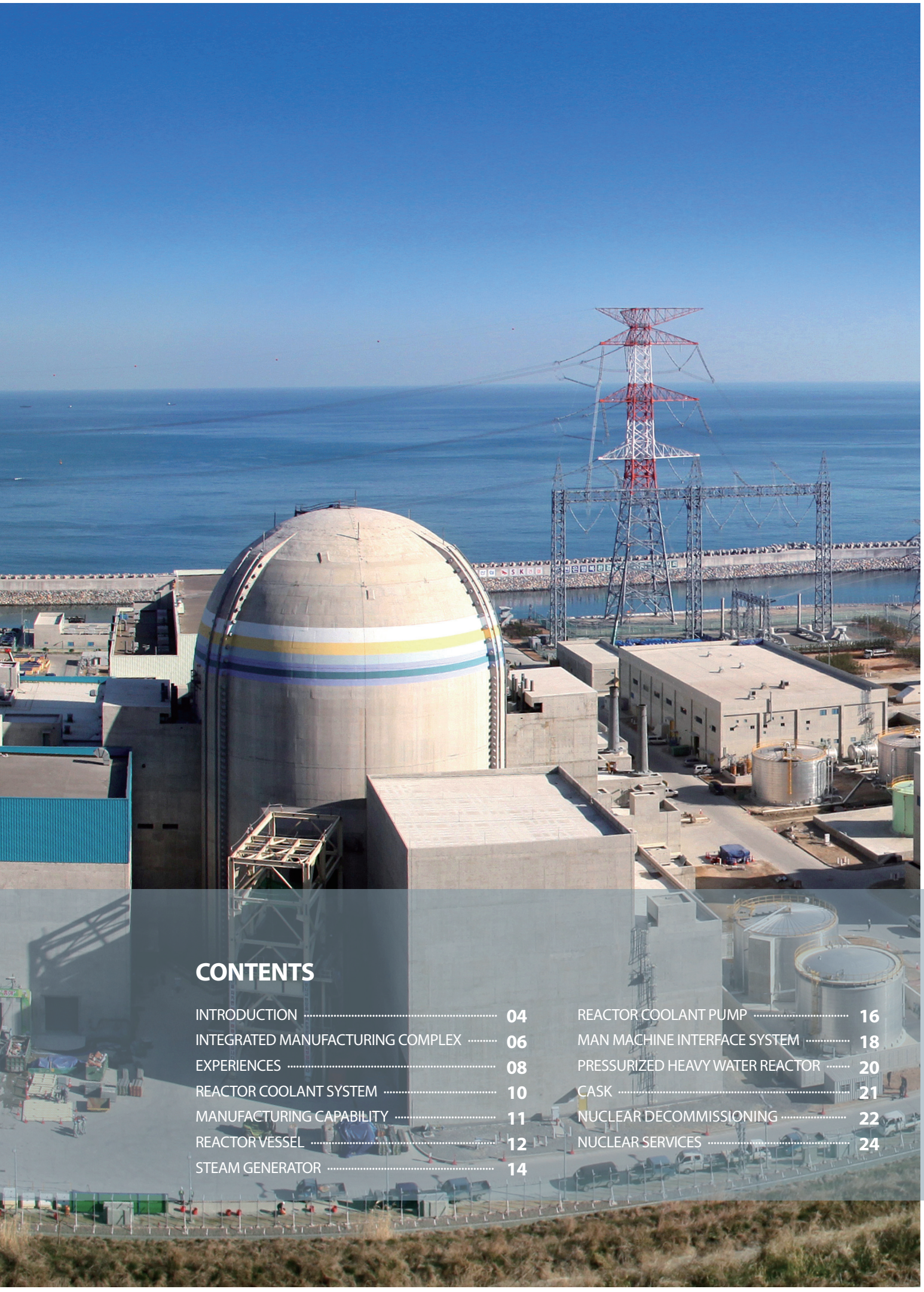
Doosan Enerbility

Integrated solutions for a better life -Nuclear Business



GLOBAL LEADER IN POWER & WATER

Nuclear power is the most viable and sole solution to global warming and fine dust. Doosan is well prepared and positioned to supply the world's safest and most reliable nuclear power plants.



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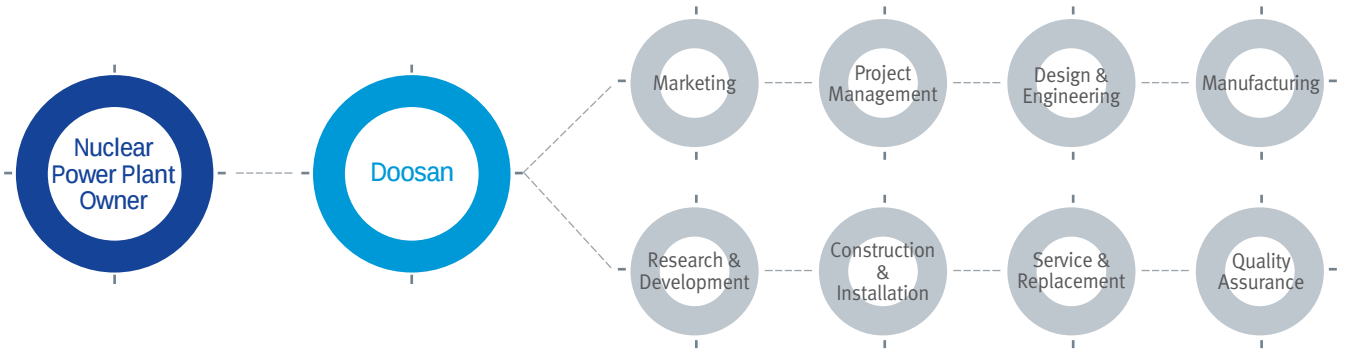
INTRODUCTION

In line with Korea's fast-growing economy, the nation's power demand has surged. As a leading supplier of nuclear equipment, Doosan has taken the responsibility to meet the increasing power demand.



With the groundbreaking of Changwon plant in 1976, Doosan set its foot in the nuclear power business. By 1986, Doosan had supplied power plant system to Hanbit units 1 & 2, which marks 'Technology Implementation Stage' in the company's nuclear business history. During this period, the company adopted new nuclear technologies for th e first time in the industry and laid the foundation for nuclear systems including quality assurance system.

In 1987, Doosan was selected as the main contractor of Nuclear Steam Supply System (NSSS) for Hanbit units 3 & 4. The technology transfer and project implementation enabled the company to accumulate ample and competitive experience in the nuclear project. Building on sufficient production facilities in place to develop the main systems, Doosan brought about a significant advancement in the design and production of materials and systems. With implementation of Hanul units 3 & 4 project, Doosan moved on to 'Technology Advancement Stage' for its nuclear power business. Based on the experience from Hanbit units 3 & 4, Doosan went on to design of Hanul units 3 & 4 by itself. In order to reinforce nuclear technology, engineers were dispatched oversees to take training to supplement its production technology.

After successful completion of Hanul units 3 & 4, Doosan achieved its own technological prowess to design and manufacture main nuclear power systems. Along with this, Doosan also signed a steam generator supply contract for China's Qinshan units 1 & 2 (phase III) in 1997. The track record of supplying main nuclear power systems to China and then to the US put the company's technological prowess on the global nuclear map. This marked the beginning of Doosan's technological independence. During Korea's Nu-tech 2012 project, the company proceed to develop RCP and MMIS technology.

As a member of 'Team Korea', a consortium formed by the nation's leading nuclear business entities, Doosan will continue to play a key role in exporting Korean advanced nuclear power system to Europe and Middle East while committed to subsequent nuclear power plants in Korea. Furthermore, most countries wishing to import nuclear power systems believe local contents will serve as their KSF (Key Success Factor) for building more nuclear power plants. Doosan will help these countries develop their own technology, thereby being poised to become an industry leader in the nuclear business.

Doosan Enerbility Co.,Ltd.
INTEGRATED MANUFACURING COMPLEX : Changwon Plant

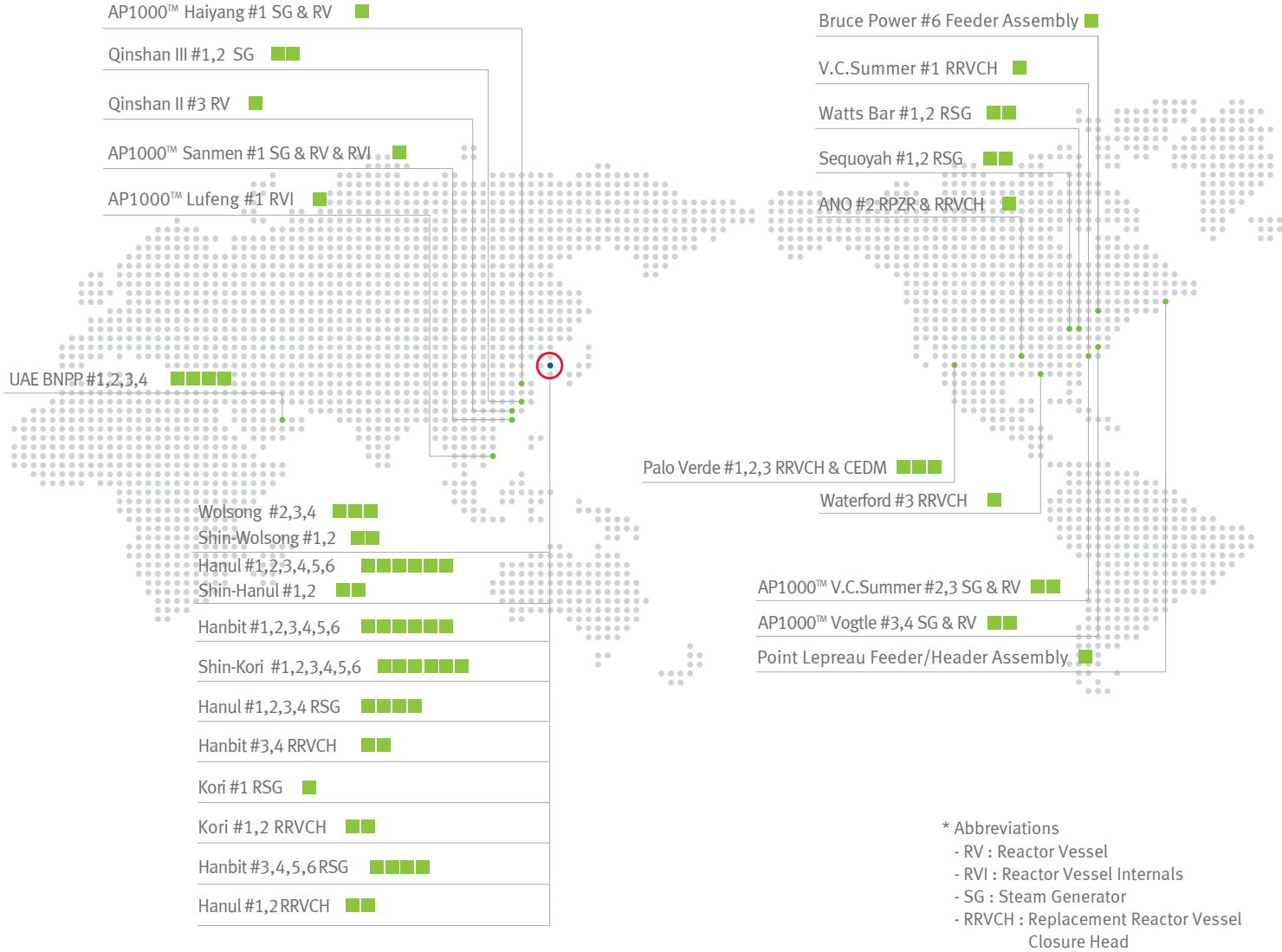
At Doosan, we've consistently brought excellence in engineering, procurement, manufacturing, construction and service to clients around the world since 1962. We've helped utilities build over 680 thermal, combined-cycle and nuclear power units representing almost 200GW of installed capacity to date in over 30 countries. And along the way, our technical innovations and commitment to total client satisfaction have made us a global leader in power and water.

Global HQ & Changwon plant, KOREA
- Ground Area : 4,429,000m^2
- Roofed Area : 425,000m^2

EXPERIENCES

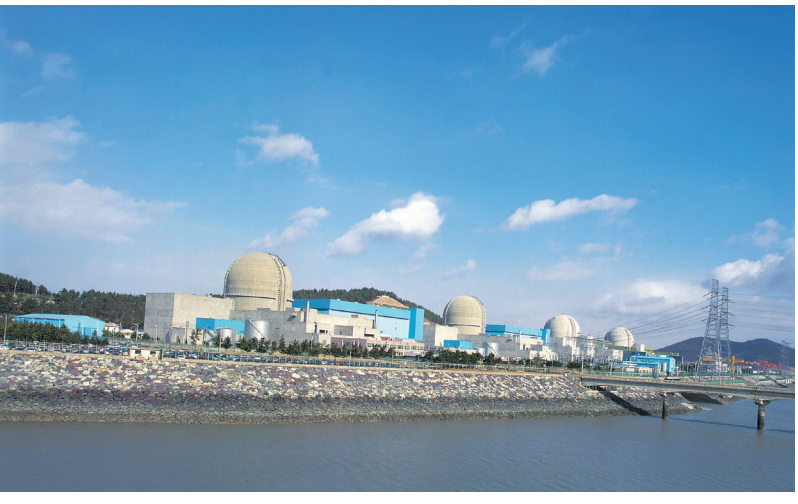
Doosan is Korea's only company that specializes in NSSS (Nuclear Steam Supply System) for nuclear power plants and possesses the highest level of technology. With its NSSS production lines and management systems for design, material, manufacturing, construction, testing, services, maintenance and repair. Doosan is strengthening its position as a leading provider of NPPs in both domestic and overseas markets. Since Hanbit units 1&2, Doosan has so far supplied equipment to total of 25 domestic nuclear power plants.

Worldwide Experiences



* Abbreviations
- RV : Reactor Vessel
- RVI : Reactor Vessel Internals
- SG : Steam Generator
- RRVCH : Replacement Reactor Vessel Closure Head
- RSG : Replacement Steam Generator

Domestic Experiences



Hanbit Nuclear Power Plants (HBN #1,2,3,4,5,6)

Hanul Nuclear Power Plants (HUN #1,2,3,4,5,6)
Shin-Hanul Nuclear Power Plants (SHN #1,2)

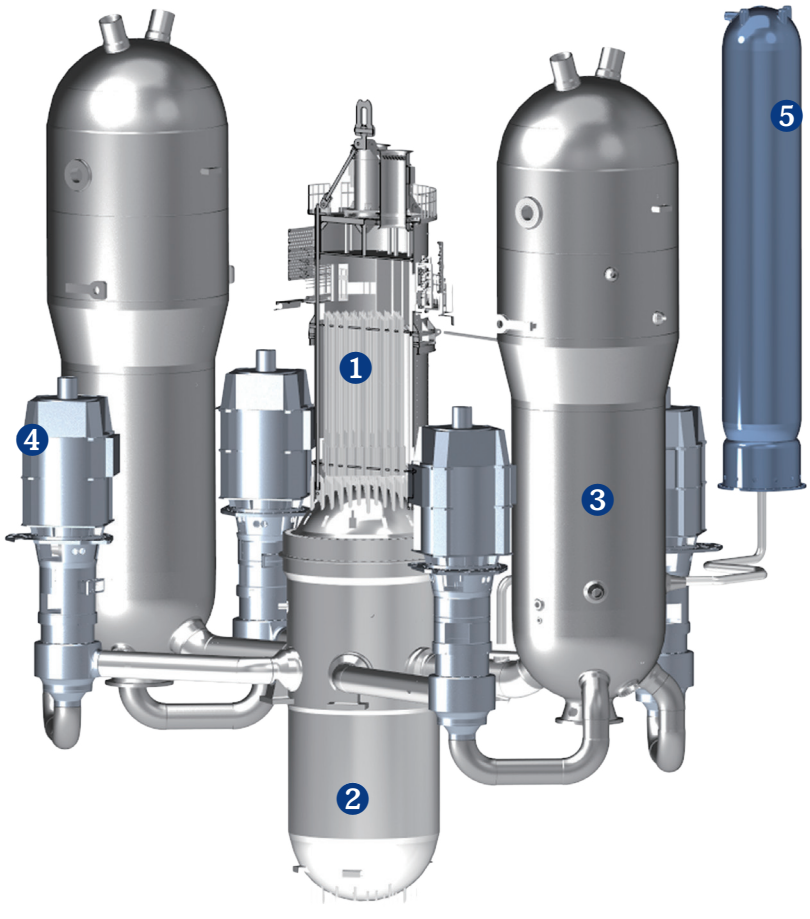
Wolsong Nuclear Power Plants (WSN #2,3,4)
Shin-Wolsong Nuclear Power Plants (SWN #1,2)

Shin-Kori Nuclear Power Plants (SKN #1,2,3,4,5,6)

FEATURES OF APR1400

REACTOR COOLANT SYSTEM

The Reactor Coolant System (RCS) is designed to remove heat from the reactor core. RCS of APR1400 consists of one reactor vessel, two Steam Generators, four Reactor Coolant Pumps and one Pressurizer connected to a hot leg. These major components are designed to have a lifetime of 60 years and the seismic design basis of 0.3g SSE is applied to strengthen the resistance to earthquake.



Design Characteristics

Parameters	Design Value
Hot leg diameter (in)	42
Cold leg diameter (in)	30
Operating pressure (psia)	2,250
Reactor inlet temperature (°F)	555
Reactor outlet temperature (°F)	615
Design Pressure (psia)	2,500
Design temperature (°F)	650
Hydrostatic test pressure (psia)	3,125
Total reactor coolant volume (ft^3)	16,020
Total RCS minimum design flow (gal/min)	446,300

1. Control Element Drive Mechanism
2. Reactor Vessel
3. Steam Generator
4. Reactor Coolant Pump
5. Pressurizer

MANUFACTURING CAPABILITY

As the main contractor for Korea's NSSS (Nuclear Steam Supply System), Doosan maintains the highest level of technology meeting all international standards for manufacturing and quality. Doosan has established its position as a leading supplier of nuclear power components for the international markets and is applying its know-how and experience in a "one-stop" service to cover NSSS production lines of design, raw material, manufacturing, testing, construction and services.

Made in Doosan - From Forging Material to Services

1 Forging

2 Manufacturing

3 Assembly

4 Testing

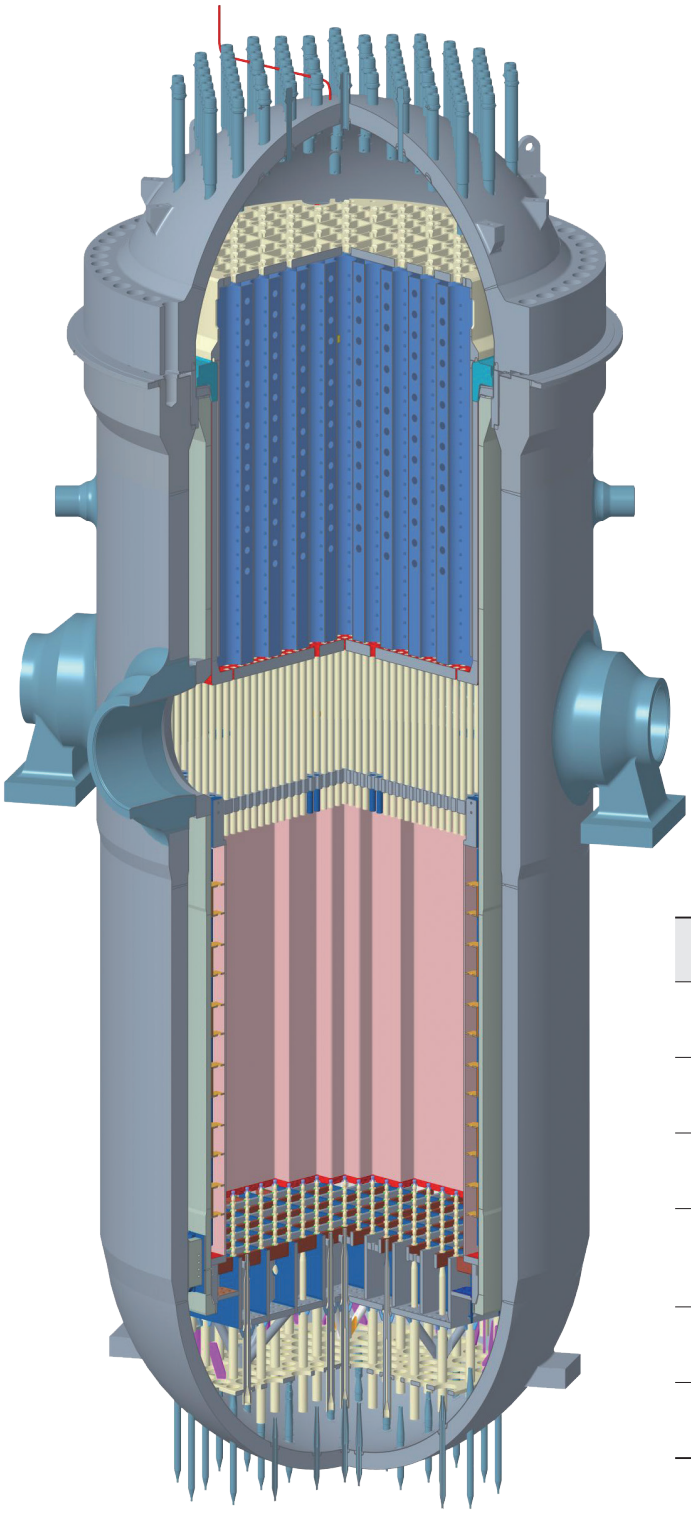
5 Shipping

6 Installation

FEATURES OF APR1400

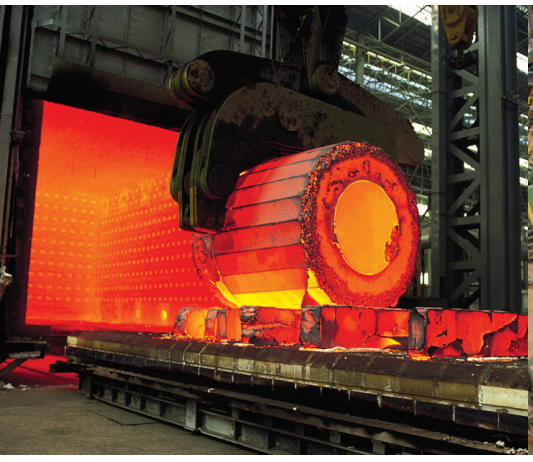
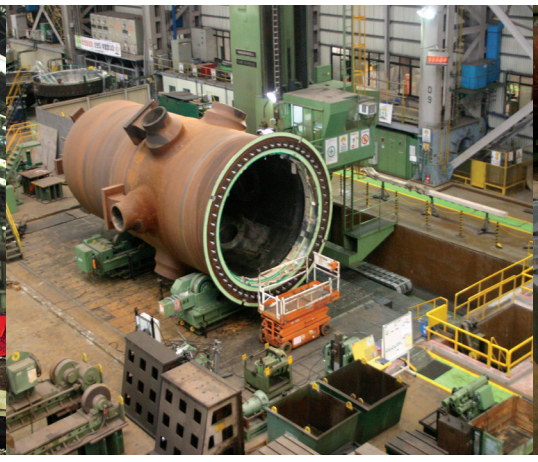
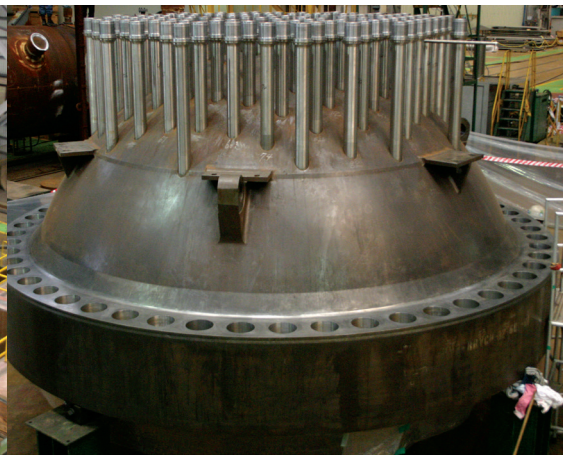
REACTOR VESSEL

The Reactor Vessel designed to withstand high pressure and temperature contains nuclear internals and fuel. The Closure Head is removable to reload the fuel, while the Reactor Vessel is fabricated from ring-forged shells. To enhance safety, APR1400 adopts 4 Direct Vessel Injection Nozzles, which inject the coolant water of Safety Injection Tank into the core directly.



Design Characteristics

Parameters	Design Value
Design pressure (psia)	2,500
Design temperature (°F)	650
Inside diameter at shell (in)	182-1/4
Overall height of vessel and enclosure head (ft-in)	48 7-7/8
Minimum cladding thickness (in)	1/8
Weight (kips)	1,630

Forged Shell Manufacturing

The major part of Reactor Vessel is fabricated from forged material. These ring-forged shells eliminate the need for longitudinal welds thereby reducing production and inspection time. Materials of the Reactor Vessel are carefully selected to withstand high pressure, temperature, and radiation.

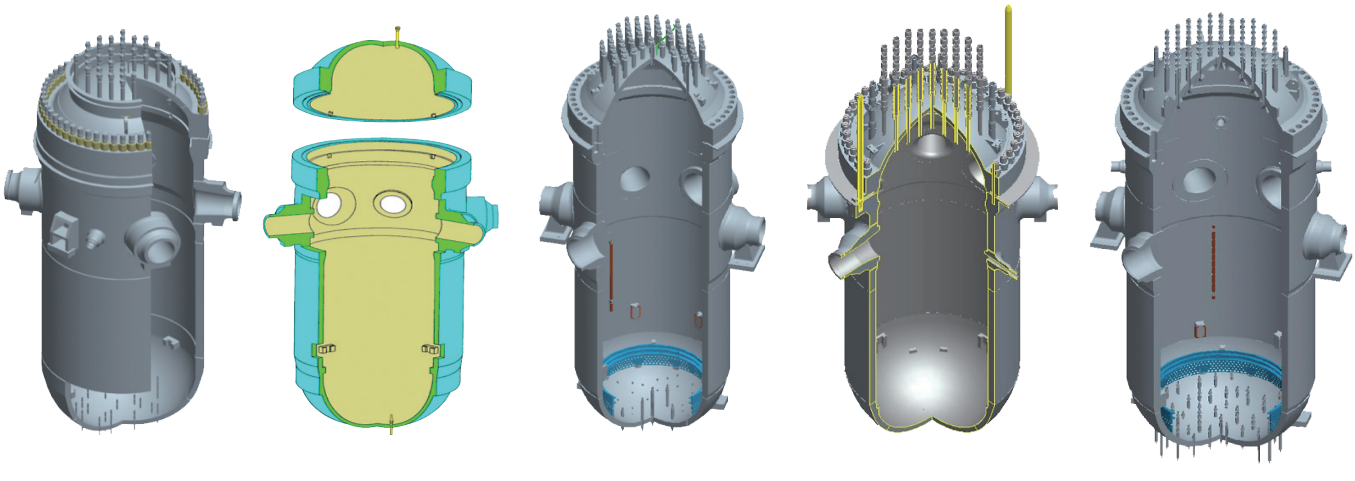
Shell & Nozzle, Bottom Head Welding

The Reactor Vessel is composed of shells, nozzles and domes. The shells are first welded together.
Then holes are machined to the shell for the assembly of nozzles.
Finally, the shell and bottom head dome are welded to form the complete assembly.

Closure Head Assembly

The Reactor Vessel can sustain pressure by tensioning of studs at closure head. At the Closure Head, 108 nozzles are installed for the connection with Control Element Drive Mechanisms.
The Closure Head Assembly and the Vessel are sealed by 54 Studs and 2 O-Rings. The Pad & Lug welded over the Closure Head surface are installed for supporting the Integrated Head Assembly.

Various Types Supplied by Doosan

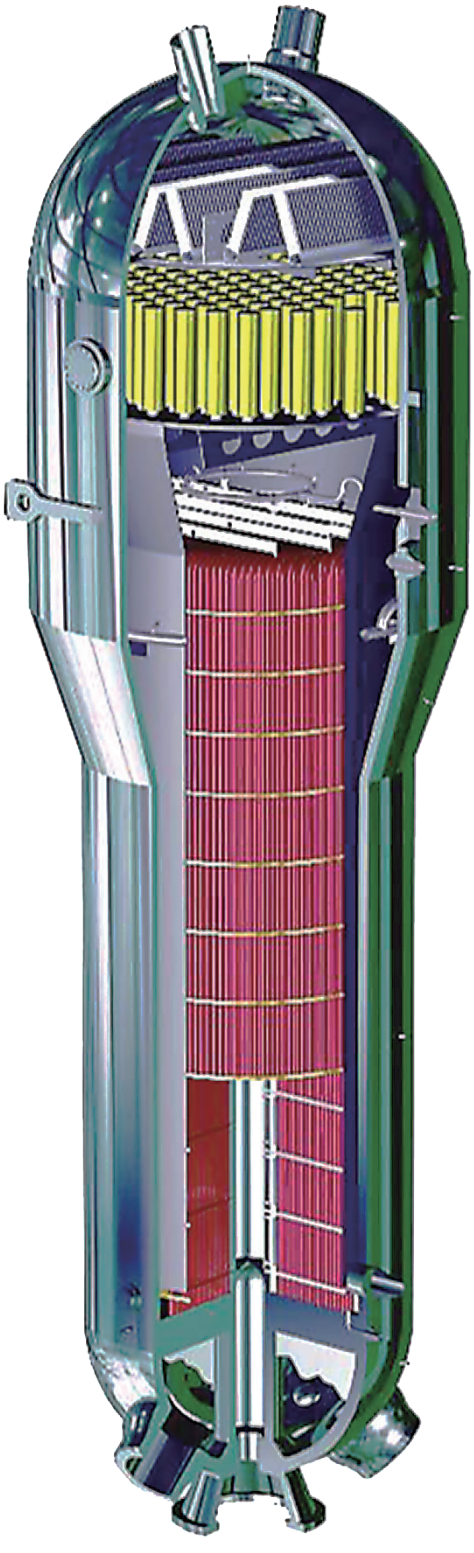


650 MWe (Qinshan/China)	950 MWe (Hanul #1,2/Korea)	1,000 MWe (OPR1000/Korea)	1,000 MWe (AP1000™/USA, China)	1,400 MWe (APR1400™/Korea, UAE)

FEATURES OF APR1400

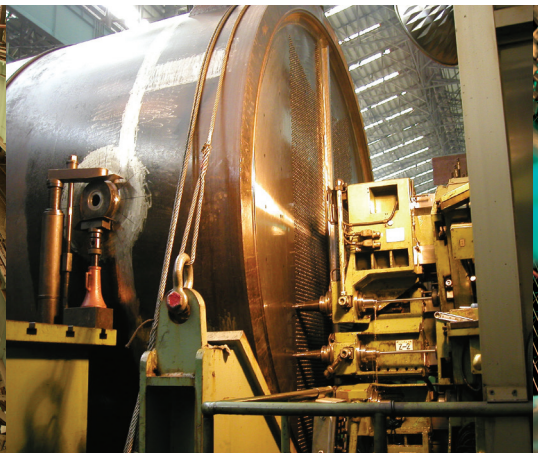
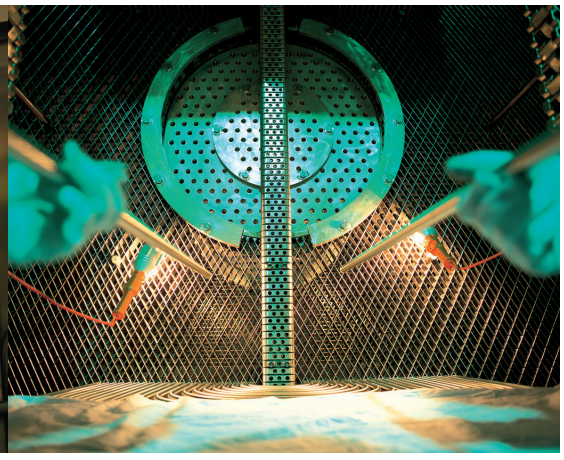
STEAM GENERATOR

The Steam Generator is a type of heat exchanger which provides steam to drive the turbine generator. While heat is exchanged from the Primary Coolant Loop to the Secondary Coolant Loop within the Steam Generator, the coolant within each loop is isolated from the other



Design Characteristics

Parameters	Design Value
Number of SGs	2
Number of tube per SG	13,102
Tube material	Alloy 690
Heat transfer area (ft^2)	163.67
Tube side operating pressure (psia)	2,250
Shell side maximum operating pressure (psia)	1,100
Steam pressure at full power (psia)	1,000
Steam temperature at full power (^oF)	545
Steam flow per SG at full power (lb/hr)	8.975×10^6
Maximum moisture at outlet at full power (w/o)	0.25
Weight (kips)	1,722

Material

The Steam Generator is fabricated from ring forged shells and from close die forged heads. These forgings eliminate the need for longitudinal welds thereby reducing production and inspection time. Materials of Steam Generator are carefully selected to withstand high pressure, temperature and radiation.

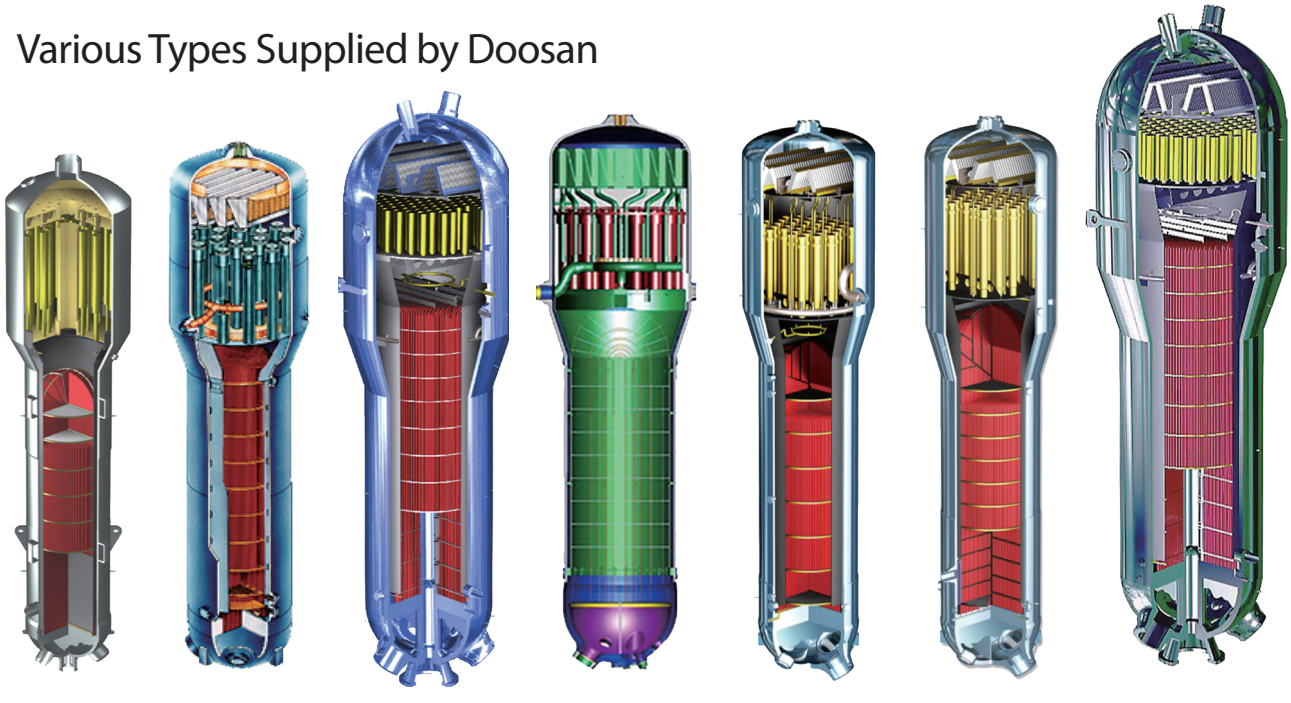
Tube Sheet Drilling

The tubesheet has drilled holes for Installation of U-bend tube using 3-spindle deep hole drilling machine.

Tube Installation

The U-bend tubes are installed, then carefully expanded to the inner face of tubesheet hole. The expansion process shall be carefully controlled so as to produce as low as residual stress in the tubes as is reasonably achievable.

Various Types Supplied by Doosan

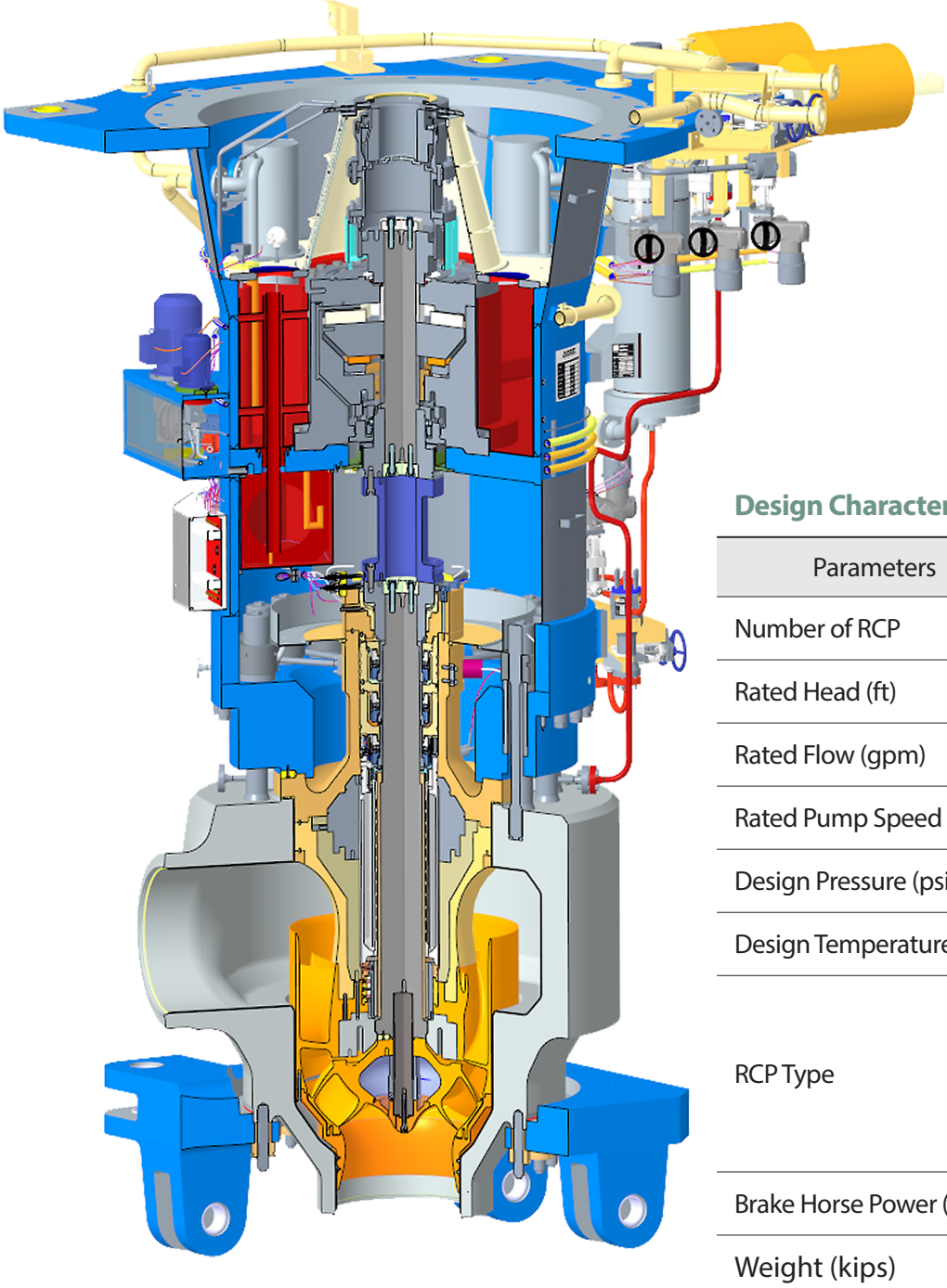


700 MWe (CANDU /China)	950 MWe (Hanul #1,2 RSG/Korea)	1,000 MWe (OPR1000 /Korea)	1,000 MWe (AP1000™ /China,USA)	1,180 MWe (Sequoyah #1,2 RSG/USA)	1,183 MWe (Watts Bar #1,2 RSG/USA)	1,400 MWe (APR1400 /Korea, UAE)

FEATURES OF APR1400

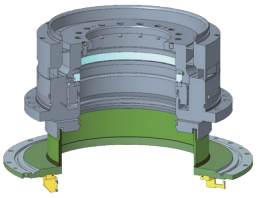
REACTOR COOLANT PUMP

The Reactor Coolant Pump (RCP) is single stage centrifugal pump with cantilevered impeller and vertical shaft with hydrodynamic mechanical seals. The RCP located in Reactor Coolant System circulates reactor coolant from two Steam Generators to the Reactor Vessel and back to the Steam Generators.



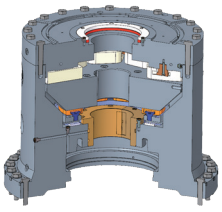
Design Characteristics

Parameters	Design Value
Number of RCP	4
Rated Head (ft)	375
Rated Flow (gpm)	121,600
Rated Pump Speed (rpm)	1,190
Design Pressure (psia)	2,500
Design Temperature (°F)	650
RCP Type	Vertical Single-Stage Centrifugal Pump Horizontal Discharge
Brake Horse Power (HP)	13,900
Weight (kips)	176



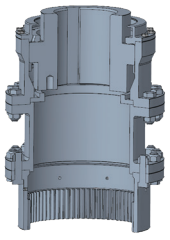
3 Oil Feed Device

- Oil Feed Device is designed to boost circulation of oil in axial & radial bearing by its own blade in the upper bearing housing
- High torque is transferred via special toothed naves and a coupling sleeve.



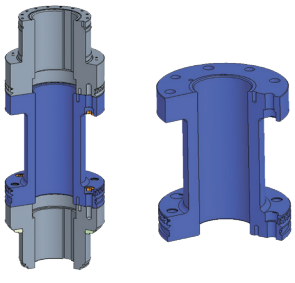
2 Thrust & Radial Oil Bearing

- Axial bearing is a tilting pad bearing, both main and reverse thrust Jacking oil feed in the main thrust pads.



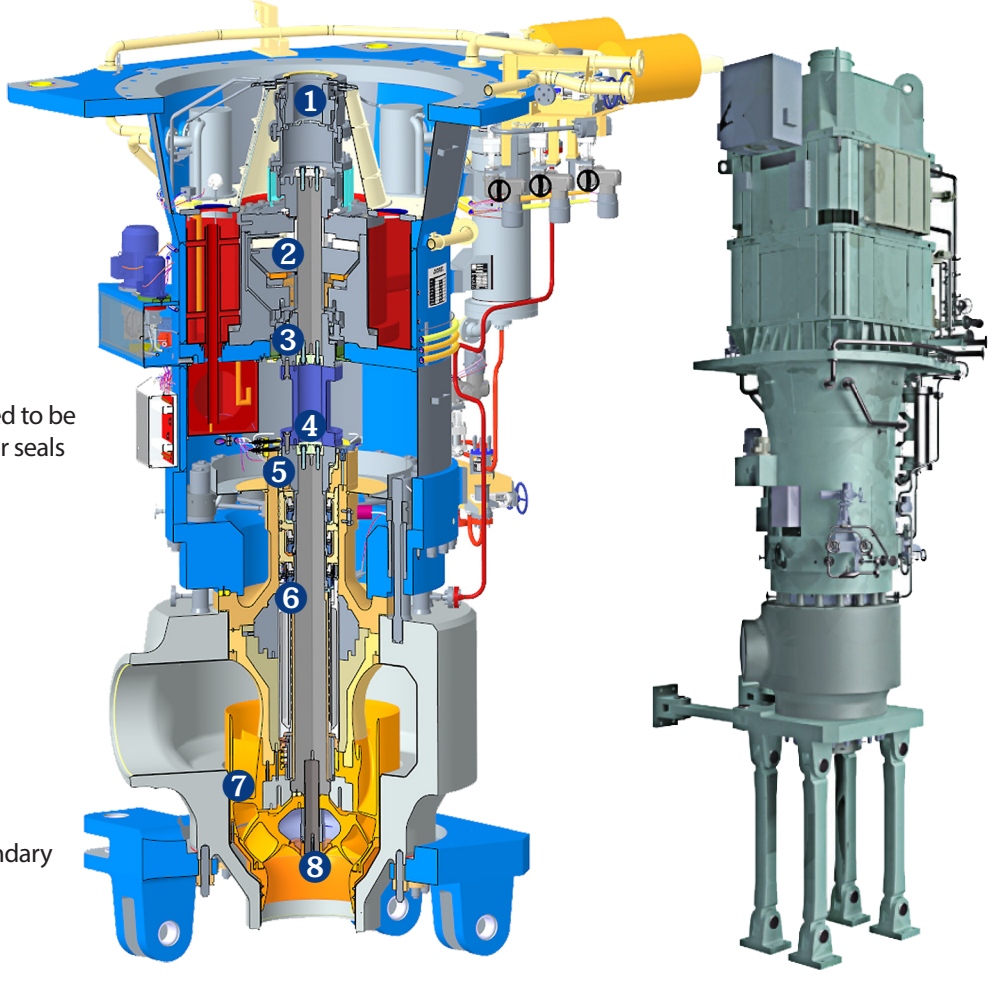
1 Curved Teeth Coupling

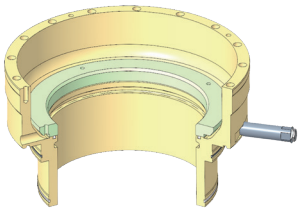
- Designed as flexible coupling, torque is transferred via special toothed naves and a coupling sleeve.



4 Removable Shaft Section

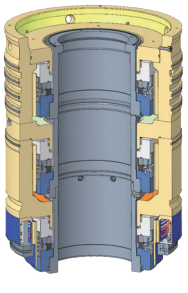
- Removable shaft section is designed to be possible to change upper and lower seals without removing other parts.





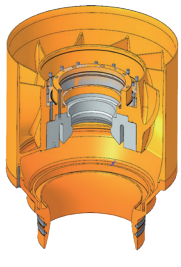
5 Stand Still Seal

- In case of seal failure pressure boundary can be closed by stand still sea.



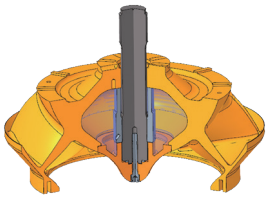
6 3rd Stage Hydrodynamic Seal

- Hydrodynamic effect even at low speed
  No mixed friction at low thermal load
  No thermal deformations due to friction
  Sufficient circulation and cooling.



7 Diffusor

- 11-vane diffusor, other surfaces like water passages between diffusor blades are finished by shot peening.



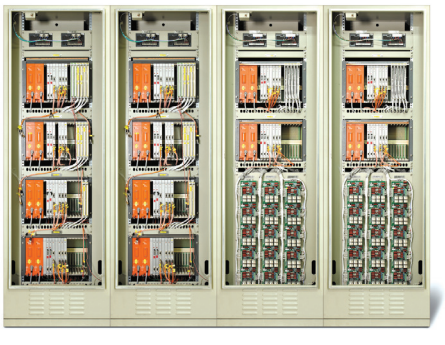
8 Impeller

- Closed semi- axial impeller, 6-blade Back blades are assisting pressure difference for emergency injection water supply.

FEATURES OF APR1400

MAN MACHINE INTERFACE SYSTEM

Man Machine Interface System (MMIS) is equivalent to the brain and nerve system of a nuclear power plant.
It monitors and controls the operating conditions to prevent accidents proactively.
Doosan achieved a complete development of MMIS which is core part of nuclear technology that was relied on oversea's companies in the past by an accomplishment of R&D in cooperation with domestic utility, KHNP and research institutions. Doosan will make the highest quality of service for the clients as total provider of the world nuclear power plant equipment who produces safe and reliable nuclear I&C system based on global-top technology.



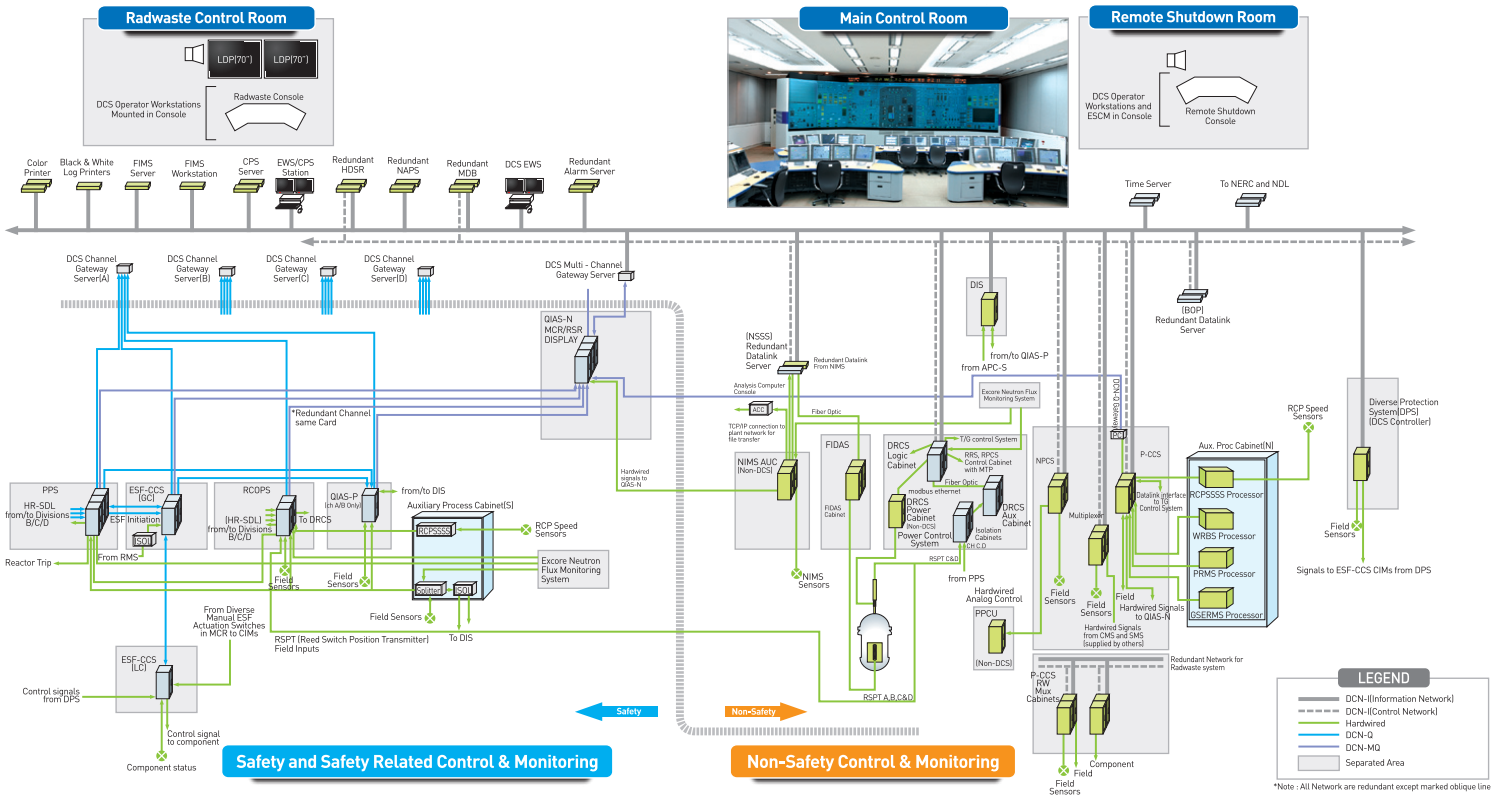
ESF-CCS

P-CCS

Features

System	Technical Features
PPS	Coincidence processor structure (3 Rack with 3 Processor Module)
RCOPS	Improvement of CEA signal checking algorithm to avoid CEA position latching problem
ESF-CCS	Maintenance Feature : MTP/ITP in each safety system
QIAS-P	Application of redundant communication module and path
QIAS-N	Application of separated network with IPS
IPS/CPS	IPS Server and Network configuration based on DCS
PCS NPCS/DPS	Redundant power controller DC Hold Power automatic commitment
NIMS	High performance industrial computer included PCI type data acquisition device
MCR/LDP	Nuclear Steam Supply System & Balance of Plant integrated Control Design

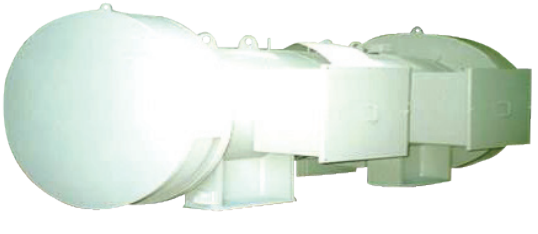
Architecture of DOOSAN MMIS for APR1400



CPS : Computerized Procedure System
DCS : Distributed Control System
DIS : Diverse Indication System
DRCS : Digital Rod Control System
ESF-CCS : Engineered Safety Features-Component Control System
EWS : Engineering Workstation
FIDAS : Fixed In-Core Detector Amplifier System
FIMS : Field Instrument Management System
HDSR : Historical Data Storage and Retrieval
MCR : Main Control Room
MDB : Main Data Base
NDL : Nuclear Data Link

NAPS : Nuclear Application Programs
NIMS : NSSS Integrity Monitoring System
NPCS : NSSS Process Control System
NSSS : Nuclear Steam Supply System
PCCS : Process Component Control System
PPS : Plant Protection System
QIAS-P : Qualified Indication and Alarm System - PAMI
QIAS-N : Qualified Indication and Alarm System - Non Safety
RSR : Remote Shutdown Room
RCOPS : Reactor COre Protection System
RCPSSSS : RCP Shaft Speed Sensing System

CRCS



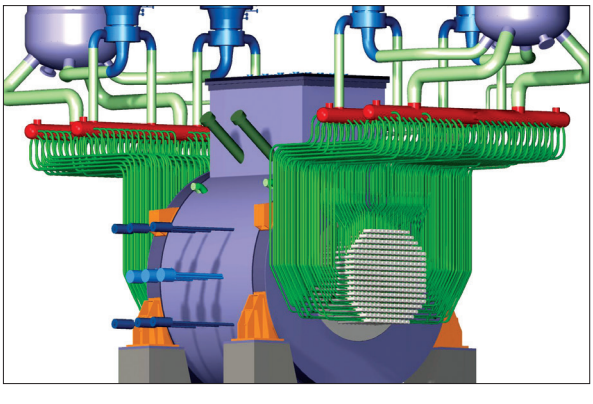
MG-SET

Other Products

- Control Rod Control System (CRCS)
- Control Element Drive Mechanism Control System (CEDMCS)
- Main Control Room (MCR)
- Fuel Handling Equipment (FHE)
- Vital Bus Power Supply System (VBPSS)
- Motor Generator Set (MG-SET)
- Reactor Trip Switchgear System (RTSS)
- Gas Stripper & Boric Acid Concentrator Instrumentation and Control (GS- BAC I&C)

PRESSURIZED HEAVY WATER REACTOR

Doosan also supplied the major components of the PHWR (Pressurized Heavy Water Reactor) plants at Wolsong units 2,3 & 4 and Qinshan CANDU units 1 & 2 in China. PHWR uses natural uranium which is simpler to handle and easier to process into fuel assemblies than enriched uranium.



Steam Generator (PWHR)

Four Steam Generators are installed in the RCS (Reactor Coolant System) of PHWR plant.

Feeder Header Assembly

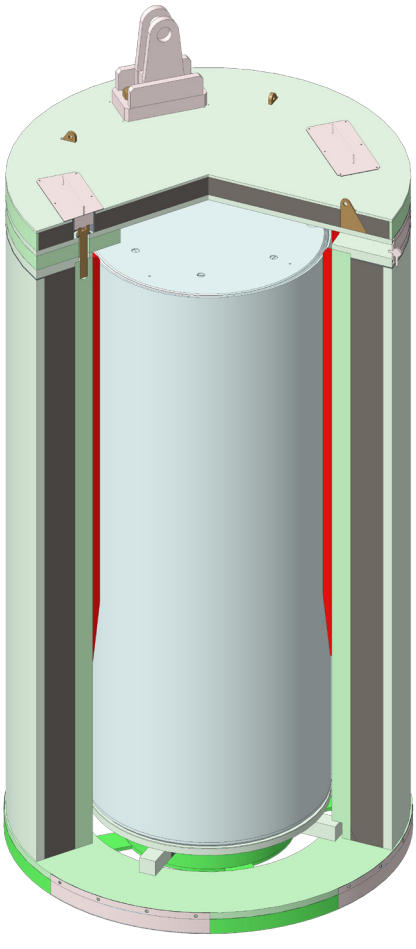
The Feeder consists of several hundred pipes which transmit heated heavy water from Calandria to Steam Generator. The Header merges and distributes the coolant.

CASK

Doosan is one of the best Cask Manufacturing Companies in the world, especially. Doosan entered into Cask business in 1990 and delivered 2 sets of Cask for Kori NPP in 2002 and 1 set of Cask for Hanbit and 2 sets of Cask for Hanul NPP in 2007. In 2014, 12 sets of Cask were supplied for Japanese client and in 2021, 5 set of MAGNASTOR casks has been fabricated and exported to TMI NPP in USA. Since 2015, Doosan has developed the optimized Cask model in Korea. By 2018, Doosan DSS-21 & 24 system has been developed in cooperation with NAC. In 2019, Metal Storage Overpack(MSO-37) Cask models of Doosan has been developed and by 2022, the design license of U.S NRC will be approved.
Doosan is developing various Cask models such as DSS-32 in preparation for the initial dry storage business in Korea continuously.

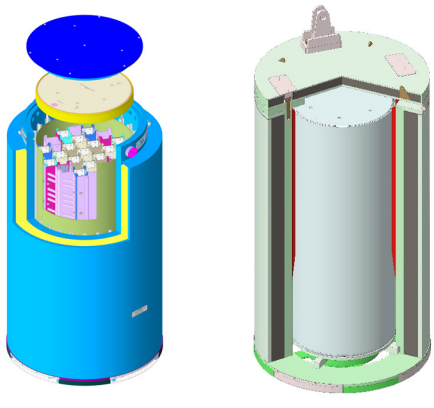
Experience List

Project Name	User	Delivery	Model Name	Capacity	Quantity
KSC-4	KHNP	1990.9	KSC-4	PWR SF 4 Assembly	1 Set
Kori Cask	KHNP	2002.8	CASTOR KN-12	PWR SF 12 Assembly	2 Set
HBN/HUN Cask	KHNP	2007.12	CASTOR KN-12	PWR SF 12 Assembly	3 Set
TEPCOCask	TEPCO	2014. 8	NEO-69	BWR SF 69 Assembly	12 Set
Land & Sea Transport Test	KAERI	2020.12	KORAD-21	PWR SF 21 Assembly	1 Set
TMI#1 Cask	Exelon	2021. 6	MAGNASTOR	PWR SF 37 Assembly	5 Set



DOOSAN DSS-32 System
[MSO-32]

MSO-37 MSO-32 DPC-24



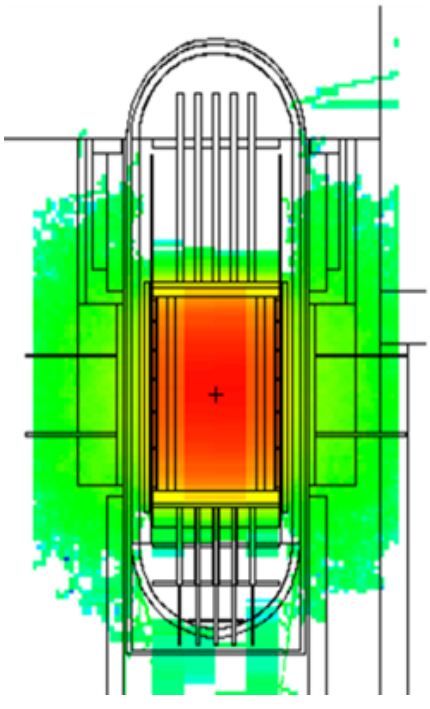
Metal storage Overpack
[Dry Storage System]

Transport & Storage Cask
[Dual Purpose]

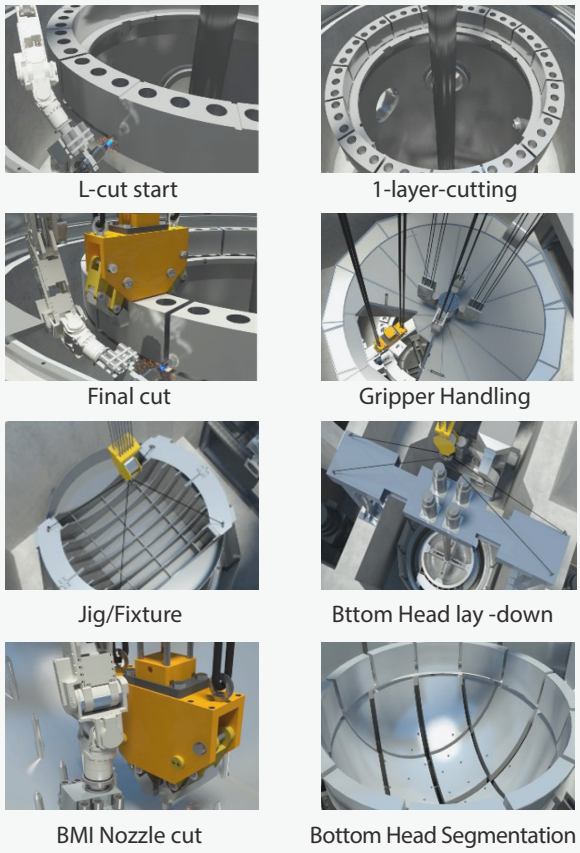
NUCLEAR DECOMMISSIONING

Doosan provides decommissioning engineering services for radioactive structures and large equipment based on its design and manufacturing capabilities for NPP's main equipment. The design of the dismantling process develops the cutting method, dismantling sequence and cutting plan according to the characteristic evaluation results. Doosan also manufactures and supplies major decommissioning equipment and performs dismantling work directly.

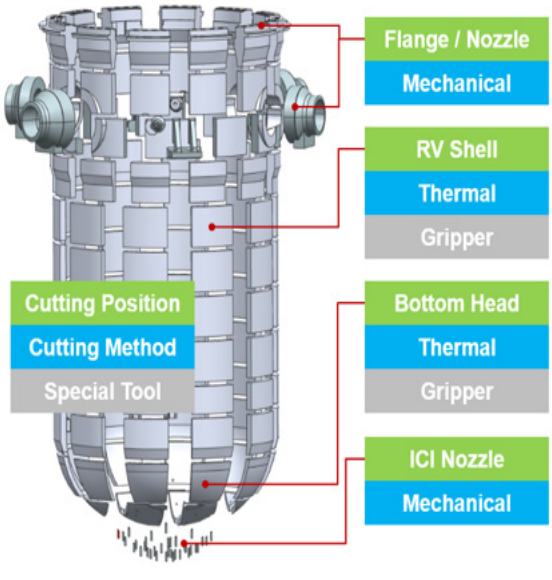
Design of Dismantling Process & Equipment



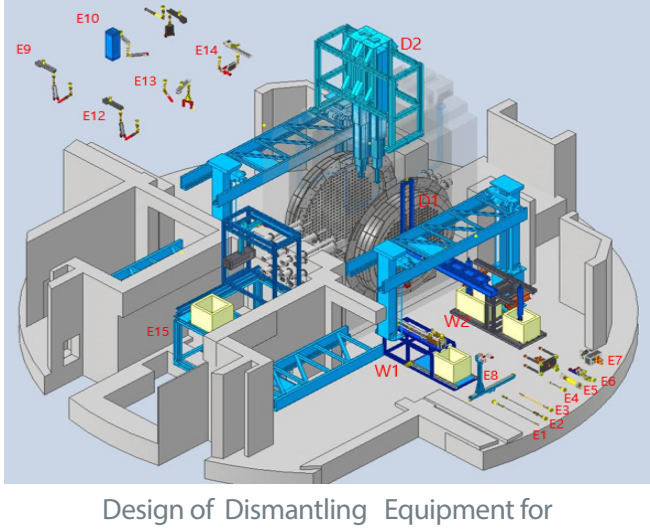
Activation Evaluation



Dismantling Sequence for RPV (PWR)



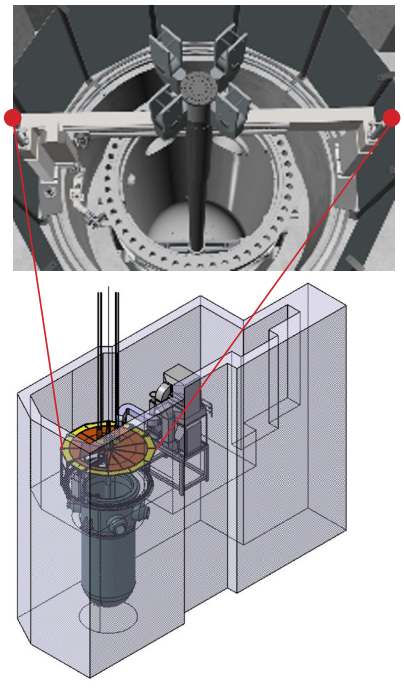
Cutting Plan & Cutting Method for RPV(PWR)

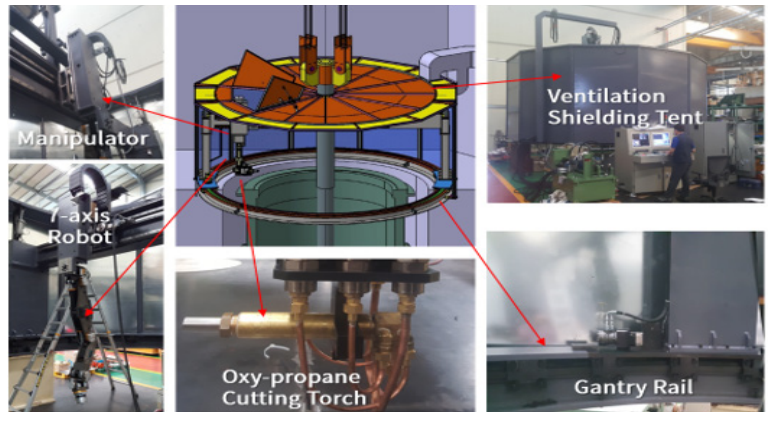


Design of Dismantling Equipment for Radioactive Structures (PHWR)

Dismantling of Reactor Pressure Vessel (PWR)

In-situ Remote Dismantling System



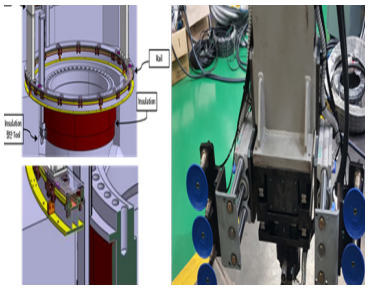


Applied Technology	Advantage
- Cutting method : Oxy-propane - Remote control - 7axe Robot + Gantry Manipulator - Cutting Capability : Max. 600 mm	- Minimization of worker exposure - Prevent the spread of contamination - Multi-function : Cutting, Handling Support etc

Peripheral Dismantling Equipment

Wire Saw for Pre-cutting

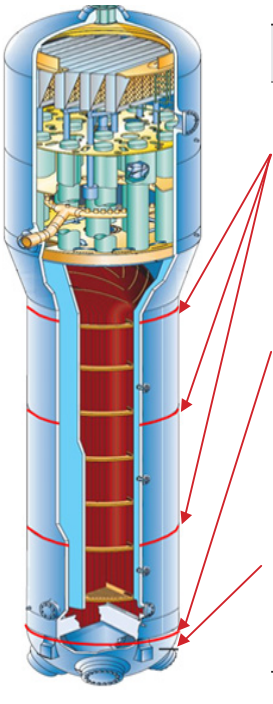
Band/Wire Saw for In/outlet Nozzle



Dismantling and Handling Equipment for RPV Insulation

Applied Technology	Advantage
- Pre-cut / Nozzle Cutting : Wire Saw - Insulation : Hole Saw - Remote control - No coolant oil used or mist oil - Cutting Capability · Pre-cut : Max. 100 mm · Nozzle cutting : 1,400 mm · Hole saw : 15 mm	- Minimization of worker exposure - Minimization of secondary waste

Dismantling of Steam Generator



		Applied Technology	Advantage
SG Shell Cutting		- Cutting method : Circular saw - Remote control - Infinite rotation function - No coolant oil used or mist oil - Cutting capability : Max. 170 mm	- Cutting method : Band saw - Remote control - Turn table combination - No coolant oil used or mist oil - Cutting capability : Max. 4,300 mm
SG Lower Head Cutting		- Cutting method : Wire saw - Remote control - Flexible cutting function - No coolant oil used - Cutting capability : Max. 4,300 mm	- Cutting for complex structure - Minimization of worker exposure - Minimize secondary waste - Excellent space utilization
Segmentation Equipment		- Cutting method : Band saw - Remote control - Turn table combination - No coolant oil used or mist oil - Cutting capability : Max. 4,300 mm	- Cutting for complex structure - Minimize secondary waste

NUCLEAR SERVICES

Doosan's technological prowess has been highly recognized based on its track record all across the operating power plant in the aspect of periodic inspection/maintenance, preventive maintenance, troubleshooting, etc.
As a main manufacturer, Doosan engages in full range of operating plant business including manufacturing and installation of major equipment replacements (SG, RVH), Alloy600 maintenance and start-up maintenance.
In addition, it has developed and applied various technologies in terms of keeping track of plant operation (Dome CLP inspection, RV Flange Scanning) and carrying out preventive maintenance (Laser Peening, Thermal Sleeve replacement). With its industry-proven experience and technology, Doosan has made significant contribution to enhancing safety and performance of operating power plants domestic and abroad.

Maintenance

Doosan provides a full range of maintenance services for operating plants from start-up to outage maintenance to retain its capability for improvement, efficiency, and reliability.
- Start-up maintenance : Hanul units 5&6 and Shin-Hanul units 1&2
- Preventive maintenance : Alloy600 mitigation applying up-to-date technology, such as half-nozzle repair, overlay welding, and peening.
- Outage maintenance : Reactor Coolant Pump internal parts, including chemical decontamination and Refueling system

Manufacture of Replacement Equipment

Replacement equipment for all domestic and numerous overseas projects have been supplied by Doosan.

Location	Component	
	RSG	RRVCH
Domestic	20	10
Overseas	15	6

* Abbreviations
- RRVCH : Replacement Reactor Vessel Closure Head
- RSG : Replacement Steam Generator

Installation of Replacement Equipment

SG & RVCH Replacement for domestic nuclear power plant has been successfully performed by Doosan.

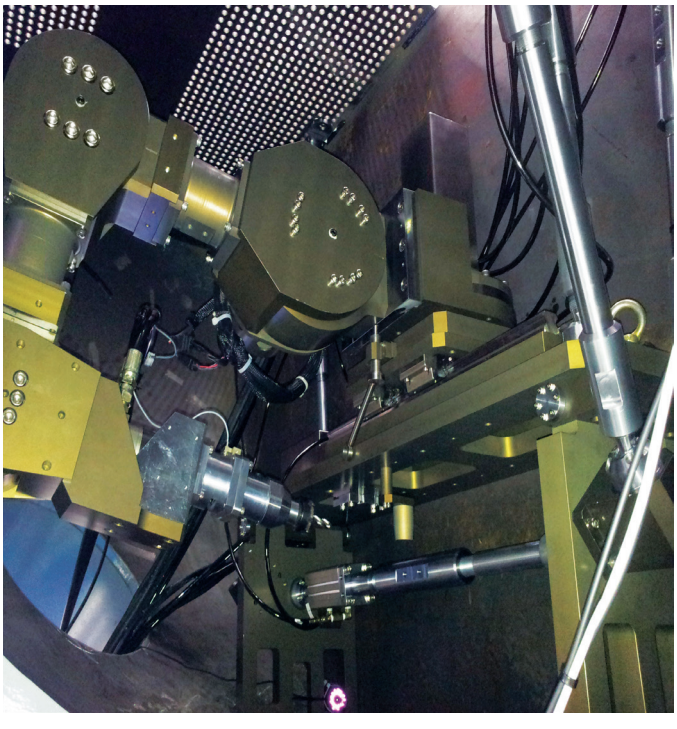
Component	Site
Steam Generator	Hanul #3,4
Reactor Vessel Head	Kori #1,2 / Hanbit #3,4,5,6/ Hanul#1,2,3,4

Repair

Doosan has various facilities and extensive field experiences for Reactor Vessel (RV), Steam Generator (SG), Pressurizer (PZR) & Reactor Coolant Loop (RCL) repair.

Component	Description
Reactor Vessel	Overlay & Seal Weld Repair of Control Element Drive Mechanism Nozzles & Vent Nozzle In-Core Instrumentation Nozzle Repair RV Stud Hole Inspection & Repair Half-nozzle Repair of small diameter penetrations Boat sampling of J-Groove Weld in reactor vessel head
Steam Generator	Tube Plugging Repair of Divider Plate & Nozzles Cleaning of Tube Inside (CANDU type) Replacement of Primary separator Foreign Object Retrieval
Pressurizer	Heater Replacement Overlay of Dissimilar Metal Welds
Reactor Coolant Loop	Thermal/Sleeve Removal in Safety Injection Nozzle Repair of Resistance Temperature Detector Nozzle Half-nozzle Repair of small penetration

* Abbreviations
- CANDU : Canadian Deuterium Uranium Reactor

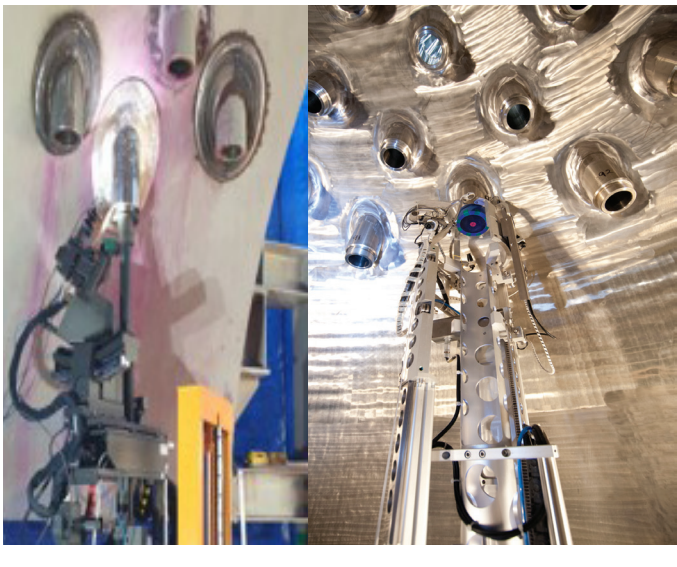


Non Destructive Examination

Doosan retains 10 EPRI Performance Demonstrations and a numerous skilled staffs with NDE expert qualification and conducts Non Destructive Evaluation Inspection on operating Nuclear power plant and Pre service inspection.

- RVCH Penetration Nozzle and Vent Pipe Inspection
- ICI(BMI) Nozzle & Weld Inspection
- Reactor Coolant System Pump Shaft Inspection
- Pressure Vessel Weld Auto and Manual Ultrasonic test
- Steam Generator Tube Eddy current test

* Abbreviations
- EPRI : Electric Power Research Institute

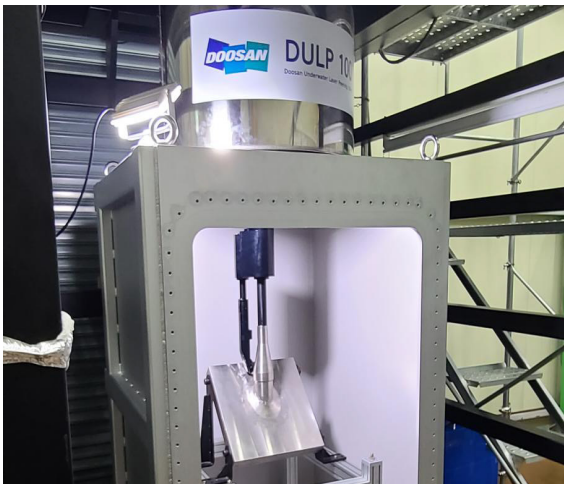


R&D

Ranging from conventional maintenance work to state-of-art technology including primary component replacement and Alloy-600 nozzle/weld repair, mitigation, replacement, Doosan's been continuously upgraded nuclear service technologies and successfully delivered to customers.

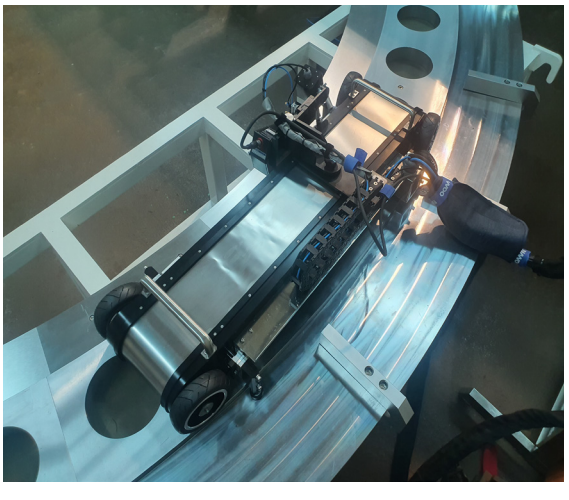
Thermal Sleeve Replacement

Replacement for the thermal sleeve on the Reactor Vessel Head. (for Framatome & WEC)



Laser Peening

Underwater laser peening system to mitigate tensile residual stress of nozzle and J-weld surface for BMI nozzle



RV Flange

Laser scan and eddy current inspection to maintain the RPV mating surface integrity, to prevent seal leak during operation

Dome CLP

Automated inspection system with remoted vehicle & laser tracker for Dome containment liner plate

Others

Supplying Spare Parts
- Pressurizer Heater, Reactor Vessel Studs & Nuts, etc.

Upgrade and Modification
- Fuel Handling System, Integrated Head Assembly, High Density Fuel Rack, etc

Technical Advisory Service
- Installation
- Startup test

Doosan Enerbility

Energy + Sustainability

The name "Enerbility" was newly coined by combining the words "energy" and "sustainability" as a portrayal of the company's aspirations to enable the achievement of sustainability with the company's energy technologies. The intent was to create a name that embodies the company's core business values, one that expresses the company's commitment to enriching people's lives and making Earth a cleaner planet with its energy technologies.

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