Ministry of Science and ICT

COUNTRY REPORT

of the Republic of Korea

: Focusing on Nuclear Policy & Cancer Radiotherapy

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Contents

PART 1

New Government's Nuclear Power Policy & Progress

Ministry of Science and ICT

01 Increasing the Share of Nuclear Power Plants

Nuclear Power Plants in Korea

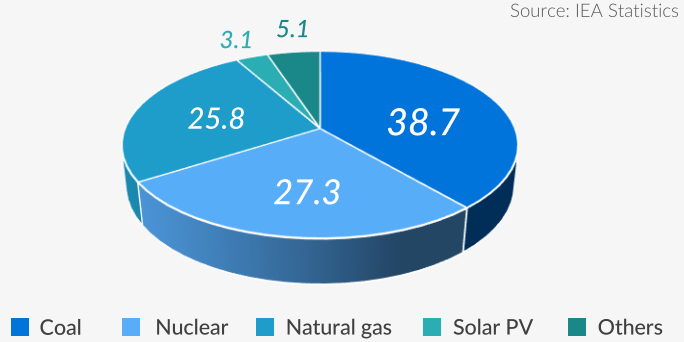
- **(In operation)** 24 units (23,250 MW)
- **(Under construction)** 4 units (5,600 MW)

Increasing Nuclear Power's Share in the Energy Mix

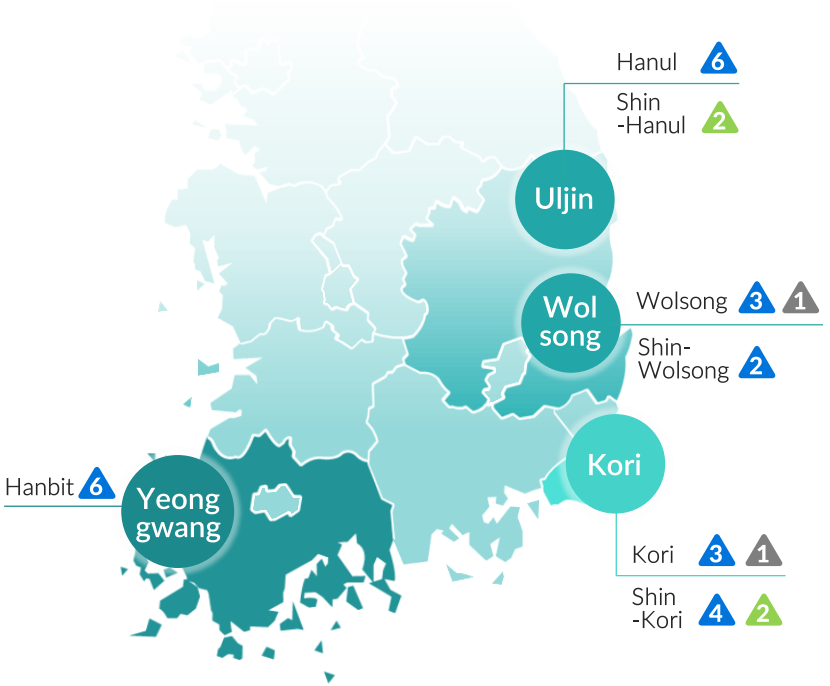
- **(2021)** 27.4% ➞ **(2030)** 30% or higher

<Electricity Generation by Source (2020)>

Source: IEA Statistics



Nuclear Power Plants in Korea

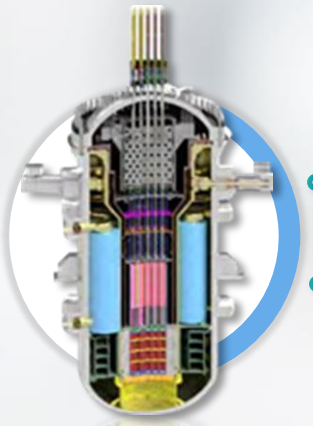


Strengthening Nuclear Power Ecosystem

- Providing a comprehensive support system, encompassing finance, R&D funding, fostering professionals and support for international nuclear bidding

※ Establishment of 'Nuclear Power Company Help-desk', etc.

02 Strengthening Technological Innovation & Industrial Competitiveness of Korean SMR



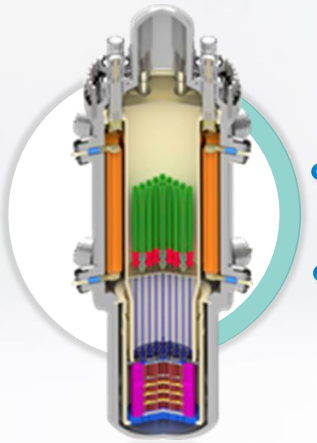
Supporting the Export of SMART (System-integrated Modular Advanced ReacTor)

Korea's representative SMR
Commenced development in 1997 and approved for Standard Design Approval (SDA) in 2012 for the first time in the world

R&D
Applying seven innovative core technologies* to further improve its safety

* ① printed circuit steam generator, ② modularization of multi-units, ③ autonomous operation technology, ④ vessel embedded isolation valve, ⑤ optimization of passive safety system, ⑥ in-vessel control rod drive mechanism and ⑦ safety-grade electric generation system

Current Status
Discussing the construction and export of the first unit to overseas industrial fields where small-scale power generation is needed



Promoting R&D of i-SMR (Innovative SMR)

Korea's brand-new SMR
Next-generation reactor design for export built based on the country's experience in the development of SMART, combined with the expertise gained from the construction and operation of APR-1400

Plan
Commencing concept design and basic design in 2021
Aiming at acquiring standard design approval (SDA) by 2028
Entering the global SMR market by 2030

Characteristics
Applying ten innovative core technologies* to improve safety, economics and flexibility

* **For safety** Infinite cooling, in-vessel control rod drive mechanism and innovative nuclear fuel
For economics Modularization of devices and structures, innovative manufacturing technologies, digital twin, autonomous driving, integrated control of multiple mother-in-law
For flexibility Boric acid-free operation and flexible operation

02 Strengthening Technological Innovation & Industrial Competitiveness of Korean SMR

Comparison between SMART and i-SMR

Division	SMART	Innovative SMR (i-SMR)
Electrical Output (Total output)	110 Mwe (220 MWe)	170 Mwe (680 MWe)
Core Damage Frequency	1.0e-7 /R.·Y or below	1.0e-9 /R.·Y or below
Fuel Assembly	17×17, 2m, 57 units	17×17, 2.4m, 69 units
Boric Acid	With boric acid	Without boric acid
Control Rod Drive Mechanism	External	Built-in
Steam Generator	Cylindrical, helical	Spiral, integrated
Reactor Coolant Pump	4 units (side)	8 units (upper)
Pressurizer	Built-in	Built-in
Reactor Diameter	6 m	4.5 m
Reactor Length	16 m	17 m
Reloading Interval	36 months	24 months
Emergency Core Cooling System	Passive	Passive
Recirculation Valve	-	Available
DC Power	Safety grade	Non-safety grade
Secondary Cooling	Passive auxiliary feedwater system	Passive auxiliary feedwater system
Containment Vessel Cooling	Reloading water tank inside the reactor building + Emergency cooling tank	External reactor vessel cooling + Heat exchanger of the passive containment building's cooling system
Containment Vessel	Concrete	Steel + Concrete

02 Strengthening Technological Innovation & Industrial Competitiveness of Korean SMR

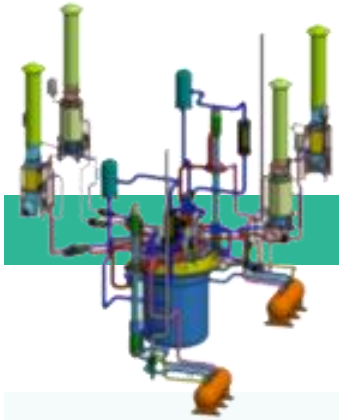
Promoting R&D of Generation Ⅳ Non-light Water SMR

- **Molten Salt Reactor, MSR**
  Suitable for motive nuclear power system and ship propulsion
- **Sodium-cooled Fast Reactor, SFR**
  Available to meet future demands such as dispersed generation

URECA

Ultimate Reactor for Efficient Carbon-free Applications

- **(Overview)** MSR under development by KAERI
- **(Thermal output)** 100 MWth
- **(Neutron spectrum)** High speed
- **(Coolant)** Chlorine molten salt
- **(Outlet temperature)** 650℃
- **(Nuclear fuel)** High-purity low-enriched uranium
- **(Application)** Motive power sources (ship propulsion), offshore plants, distributed power supply, hydrogen production, etc.



SALUS-100

Small, Advanced, Long-cycled and Ultimate Safe SFR

- **(Overview)** Pool-type SFR under development by KAERI
- **(Thermal output)** 267 MWth
- **(Neutron spectrum)** High speed
- **(Coolant)** Liquid sodium
- **(Outlet temperature)** 510℃
- **(Nuclear fuel)** Low-enriched uranium metallic fuel
- **(Application)** Small-scale heat sources and power generation

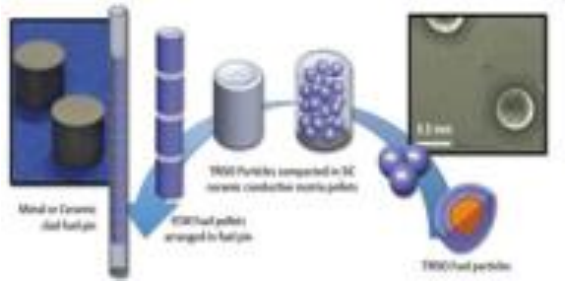
03 Enhancing the Safety of NPPs through Technology Development

Advancing Prediction, Prevention and Responding Capabilities based on ICT Solutions

- Virtual nuclear reactor for multi-physics simulation and safety evaluation programs for combination of external hazards, etc.
- Predicting, preventing, and responding technologies using AI, digital twin, robots, etc.

Physics-based Digital Twin

TRISCO-Sic Pellet



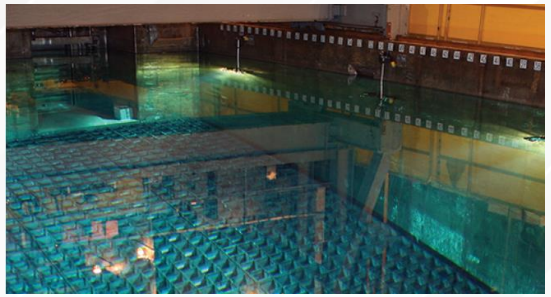
Commercializing the Uses of Accident-Tolerant Fuel (ATF)

- Significantly increasing safety by improving the quality of pellets* and cladding** → Aiming at completing technology development by 2026 and commercialization by 2031
  * (Pellet) UO2 pellets and TRISCO-Sic pellets with improved performance
  ** (Cladding) Surface-coated ODS Zr-alloy cladding and Fe-based alloy cladding

Securing Core Technologies for Safe Management of Radioactive Waste

- Establishing an R&D roadmap for high-level radioactive waste* (2023~2060)
  * Publicly announcing core technologies related to high-level radioactive waste treatment, including transport, storage, site, and disposal, domestic technological level, development schedule and method, and budget

Storage Tank for Spend Nuclear Fuel



04 Advancing the Competitiveness and Support System of the Radiation Industry

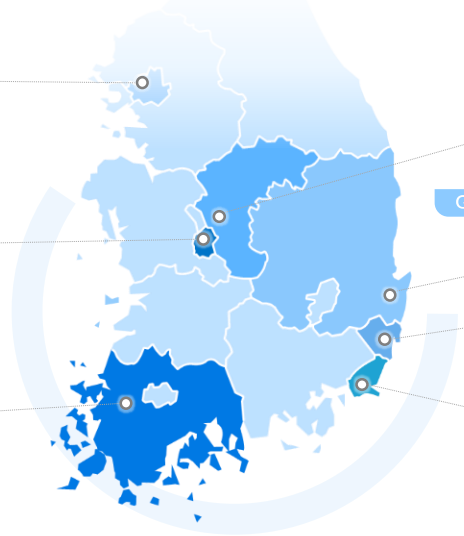
Developing Strategic Radiation Technology

- **(Public health & medicine)** Developing radioisotopes, radiopharmaceuticals, and particle therapy technology for rare and incurable cancers
- **(Industry)** Developing equipment and materials for radiation applications intended for flagship industries, including semiconductors and secondary batteries
- **(Response to social issues)** Developing infectious disease-related technology and radiation technology to reduce plastic waste

Executing Large-scale R&D Projects via Convergence Clusters

- Setting up convergence clusters to support research/industry/human resource development where large-scale radiation facilities are located
- Executing large-scale R&D projects based on the clusters

Hub Cities with Large-scale Radiation Facilities



Korea Radioisotope Center for Pharmaceuticals (KRICP)

Seoul

HANARO

※ Designation as one of IAEA ICERRs in 2019

Daejeon

Advanced Radiation Research Institute (ARTI)

※ Designation as the IAEA Collaborating Centre in 2022 (Three consecutive designation)

Jeongeup

Ochang

Multi-purpose Synchrotron Radiation

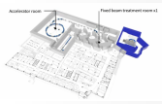
Gyeongju

Proton accelerator

Pohang

Synchrotron Radiation

Busan



New Research Reactor, Heavy Particle Accelerator

PART 2

Current Status of Cancer Radiotherapy in Korea

Ministry of Science and ICT

01 Developing New Drugs and Pharmaceuticals for Cancer Treatment

Establishing & Operating the Korea Radioisotope Center for Pharmaceuticals (KRICP)

- **(Purpose)** Developing radiopharmaceuticals and providing support to the new drug development process by pharmaceuticals*

  * Including the verification process of safety and validity using radioisotopes

- **(Facility)** Ultra-sensitive accelerator mass spectrometers, radioisotope-based nonclinical evaluation rooms, clinical test facilities, radiopharmaceutical production facilities, etc.

  ※ Providing one-stop support, encompassing all stages from pharmaceutical synthesis to imaging evaluation, toxicity evaluation, preclinical trials, and clinical trials, by applying radioisotope-based verification technology in the development process of new drugs

KRICP

GMP Radiopharmaceutical Production Facilities

Developing Disease-specific Radiopharmaceuticals & Transferring to Industry

- Developing radiopharmaceuticals dedicated to the diagnosis and treatment of metastatic breast cancer, radiotherapy enhancers designed for the fluid in the brain and colorectal cancer, etc. → Then, promoting transfer to industry

02 Establishing an Radioisotope Production System for Cancer Treatment

Securing Radioisotope Production Technology using Medical Cyclotrons

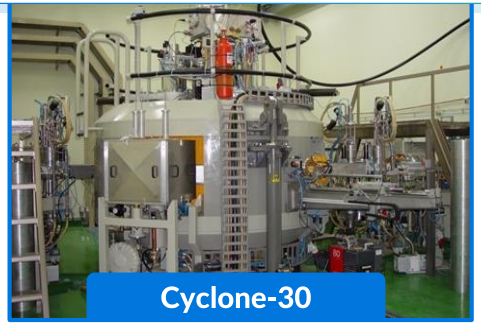
- **(Achievements)** Secured production technology for eight radioisotopes, including Cu-64, I-124, Zr89, Tl-201, and Lu-177 (2017~2022)
  - ➡ Supplying radioisotopes to hospitals and medical research institutes at home and abroad*

    * **(Domestic)** Ten major hub hospitals, including the Seoul National University Hospital and the Samsung Medical Center
    (Overseas) University of Singapore

Medical Cyclotron for Radioisotope Production in Korea

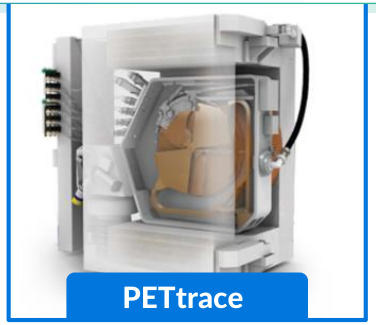
Mc-50 Cyclotron

- **(Energy)** 50 MeV
- **(Beam)** Alpha, Deuteron, Proton
- **(Target Isotopes)** 64Cu (PET), 124I (PET), 89Zr (PET), 18F (PET), 44Sc (PET), 117mSn (beta), 211At (alpha), 67Cu (beta)



Cyclone-30

- **(Energy)** 50 MeV
- **(Beam)** Alpha, Deuteron, Proton
- **(Target Isotopes)** 64Cu (PET), 124I (PET), 89Zr (PET), 18F (PET), 44Sc (PET), 117mSn (beta), 211At (alpha), 67Cu (beta)



PETtrace

- **(Energy)** 16.5MeV
- **(Beam)** Deuteron, Proton
- **(Target Isotopes)** 18F (PET), 11C (PET)

KIRAMS-30

- **(Energy)** 30MeV
- **(Beam)** Proton
- **(Target Isotopes)** Radioisotopes used for Single-Photon Emission Computed Tomography (SPECT) and Positron Emission Tomography (PET)

02 Establishing an Radioisotope Production System for Cancer Treatment

Securing Domestic Production & Mass-production Technology for Major Radioisotopes using Research Reactors and Accelerators

- **(With the New Research Reactor)** Possible to mass-produce Mo-99, I-131, At-211, Ac-225, etc. at the domestic level

Aerial View of the New Research Reactor

Overview of the New Research Reactor

- **(Construction period)** 2022~2027
- **(Thermal Power)** 15 MW
- **(Fuel/Enrichment/Cladding)** U-7Mo/Al-5Si/19.75wt%/Aluminum
- **(Utilization)** RI production, Neutron Transmutation Doping

※ The target mass-production amount of Mo-99 used for cancer diagnosis has been set to 100,000 curies (Ci), which would account for about 20% of global demand

Major Mo-99 Producers in the World

Netherlands

Belgium

France

South Africa

+

Production to be started in 2027!

03 Developing New Radiation Technologies for Cancer Treatment

Developed the First FLASH Radiotherapy Research System * in Asia

* Providing therapeutic performance for cancer equivalent or superior to existing methods by instantaneously emitting high-intensity radiation within one second, while significantly reducing adverse effects on normal tissues

- **Achievements**
  Developed accelerator and test apparatus capable of FLASH clinical trials for the first time in Asia
- **Plan**
  Establishing a FLASH research accelerator and later making it available for use by research institutes in Korea, applying research results to clinical trials and further using in the development of FLASH Radiotherapy Research System equipment
  ※ As of now, only five US and five European institutes are capable of FLASH clinical research.

FLASH Radiotherapy Research System

Reaching Completion of Development of Boron Neutron Capture Therapy (BNCT) System

- **Concept**
  Injecting Boronophenylalanine (BPA) into the body and then externally irradiating a neutron beam
  → In the process, cancer tissues are selectively destroyed by the injected boron absorbing thermal neutrons and then engaging in nuclear reactions
- **Achievements**
  Verified its effectiveness in suppressing tumor growth through tissue and animal efficacy trials in 2021 and going through clinical trials in 2022

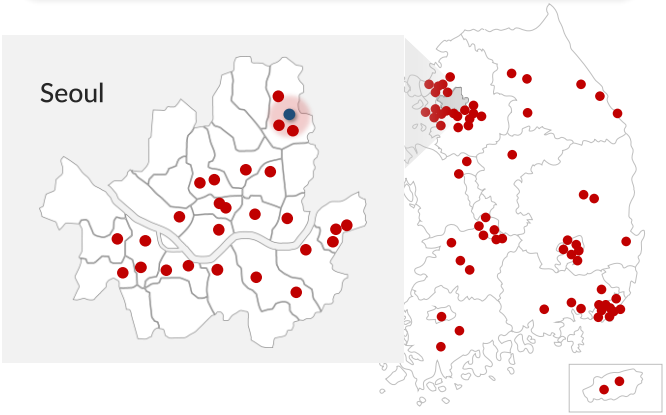
Results of Domestic Animal Efficacy Trials

03 Developing New Radiation Technologies for Cancer Treatment

Current Status of Radiation Oncology Centers & Devices in Korea

- **Radiation Oncology Centers**
  101 centers in operation
- **Devices**
  Using a total of 279 radiation treatment devices of 11 different types* either in use or being established
  * Vero, viewray, proton therapy equipment, heavy particle therapy equipment, MR-LINAC, HALCYON, cyber knife, gamma knife, HDR, tomography, LINAC

Radiation Oncology Centers in Korea



Major Radiotherapy Devices in Korea

Equipment name	#	Remarks
Heavy particle therapy equipment	2 units	• High cure rates for the three major difficult-to-treat cancers (lung cancer, liver cancer, and pancreatic cancer) • Capable of treating almost all types of cancer, except for blood cancer, from early to late stage
Proton therapy equipment	2 units	• Applicable to non-metastatic solid cancer with limited affected areas • Used to treat cancer in children and adolescents because normal tissues are not damaged
MR-LINAC	3 units	• Linear accelerator combined with MRI
Cyber Knife	8 units	• Capable of emitting radiation from different directions using compact linear accelerators mounted on robot arms • Mainly used to treat lung cancer, prostate cancer, liver cancer, and metastatic spinal cancer


Cyber Knife


Heavy Particle Treatment Center


Proton Therapy Equipment

PART 3

Contribution to the International Society in Cancer Treatment

Ministry of Science and ICT

01 Cooperating with International Organizations to Fight against Cancer

Cooperating with the IAEA to Join the Efforts in Fighting Cancer

- Providing financial support from the Korean government to the IAEA PACT since 2013
- Planning to make an extrabudgetary contribution to the Rays of Hope initiative in 2022
- Contributing financially to the PACT through voluntary fundraising by the general public since 2007
  (Delivered at each year's IAEA General Conference)

66th IAEA General Conference in 2022

Enhancing the Asian-Pacific Region's Cancer Treatment Capabilities by Leading RCA Projects

- Participating in RCA projects in the human health sector as a “Leading Country” over the past ten years
  → Sharing Korea's rich experience and excellent technical expertise in cancer diagnosis and clinical treatment

- **Achievements**
  Strengthening Stereotactic Body Radiation Therapy for Frequent Cancers of the RCA Region (2016~2019)
  - Provided education and training programs for radiotherapy experts to a total of 187 individuals from 16 countries through five regional training sessions
  - Seconded experts four times to provide advisory support for radiotherapy, equipment installation and quality control
  - Established local network platforms and hubs for radiotherapy education and training in seven countries

Education and training activities conducted through RCA projects in the public health and medicine sector

02 Providing Infrastructure for Cancer Control and Treatment to Major Partners

Providing Physical & Human Infrastructure Support for Cancer Control and Treatment to Major Partner Countries

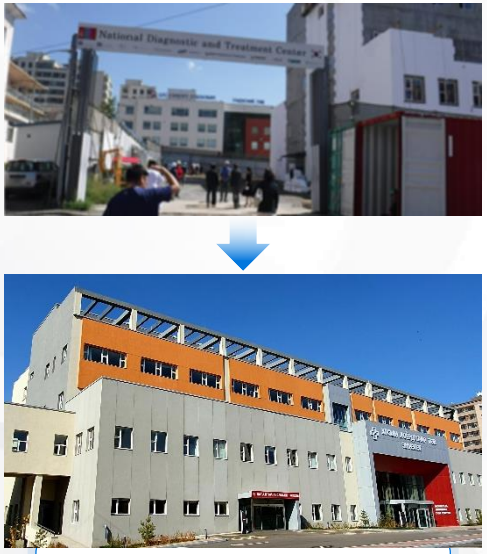
- Promoting medical device facilitation, technology transfer, education & training for professionals in connection with R&D support programs and aid projects of the Ministry of Science and ICT.

PET/CT equipment at the center

Best Practice

Supported in the Construction and Operation of the National Diagnostic and Treatment Center of Mongolia

- **Contents**
  Constructed the center and provided necessary equipment* with education & training
  * Cyclotrons, magnetic resonance imaging (MRI) equipment, computed tomography (CT) equipment, positron emission tomography (PET), etc.
- **Achievements**
  Successfully conducted the first cancer diagnosis imaging* in Mongolia
  * FDG PET/CT imaging for five cancer patients, including breast cancer patients
- **Follow-up Cooperation**
  Signed the international research MOU between Korea-Mongolia for multinational clinical research and conducting Korea-Mongolia joint research for the development of a diagnostic target for PET imaging (KIRAMS)



National Diagnostic and Treatment Center in Mongolia

THANK YOU

Ministry of Science and ICT