2024 Annual Report

National Atomic Research Institute

Published in June, 2025

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Preface

Board Chair's Message

Reflecting on the past year in 2024 brings into focus a defining chapter the emergence of the National Atomic Research Institute (NARI) as a legalized administrative corporation in its first full year. The institution is supervised by a board of directors and supervisors, guiding NARI in its new status as an administrative corporation to leverage its exclusive operational management and pursue greater achievements. For instance, drawing on its comprehensive talent development strategy, NARI leverages the flexible personnel system of an administrative corporation to attract top professionals and cultivate talent. This effort aims to equip its team with solid research and development capabilities, establish systems to enhance operational efficiency, continue advancing research and development across a variety of scientific and technological fields.

Change may come with challenges, but it also ignites momentum, driving us toward greater possibilities. NARI is equipped with the potential and dynamism in atomic energy technology for the research and development of technologies on nuclear safety, radiation application, and new energy laying a stronger foundation for future growth. With the concerted efforts of all colleagues at NARI, we are taking a significant step toward a stable and promising future. NARI is also dedicated to exploring the potential of atomic energy and its related derivative technologies to drive innovation and foster R&D. Moreover, the ongoing development of integrated systems in nuclear medicine, public welfare radiation applications, and innovative energy solutions is making significant strides toward success. To advance our nation's progress, it is vital to forge partnerships with leading global institutes. These strategic collaborations will allow us to access cutting-edge medical materials and innovative new energy technologies in the field of atomic energy, ensuring a brighter, more prosperous future.

Given the broad scope of atomic energy technology research, coupled with the continuous evolution of science and technology, the applications of atomic energy technology in energy, medicine, and environmental protection are poised to become increasingly indispensable. In response to global trends, it is imperative to consolidate NARI's R&D capabilities, expand into emerging applications, proactively invest in cutting-edge and competitive technological development, and nurture professional talent all to strengthen domestic collaboration across industry, government, academia, and research sectors. Ultimately, NARI is destined to become an indispensable pillar in driving the nation's scientific and technological development.

Looking ahead, our aim is to achieve numerous accomplishments and breakthroughs year after year, fostering growth, creativity, and innovation in the field of atomic energy science and technology. This will be driven by every colleague at NARI, united in a shared pursuit of excellence. With its growing capabilities, NARI aspires to drive sustainable development and expand its global influence, including making contributions in Taiwan. I firmly believe that, with over half a century of expertise and a clear mission to transform research into real-world impact, NARI is poised to play a trailblazing role in shaping the future of atomic energy technology, contributing meaningfully to both society and sustainable progress.

Board Chair Dr. Shin Chang

President's Message

Since its establishment in September 2023, the National Atomic Research Institute (NARI) has inherited a robust technical foundation and resources accumulated over 55 years by the Institute of Nuclear Energy Research (INER).

NARI focuses on three core technical pillars: nuclear safety and back-end processes, nuclear medicine and radiation applications for public welfare, and new energy with cross-disciplinary systems integration. Upholding the values of professionalism, safety, and innovation, we continue to enhance our research capabilities, drive technological advancement, and actively expand international cooperation to contribute to national development and public welfare.

Nuclear Safety and Nuclear Back-End Processes

NARI has over 50 years of extensive experience and technical expertise. We have established an international radiation impact safety assessment system for nuclear incidents, providing timely emergency response measures to ensure nuclear safety. We actively monitor the development of emerging global atomic technologies such as nuclear fusion and Small Modular Reactors (SMRs), ensuring we keep pace with international advancements in nuclear science and technology.

Nuclear Medicine and Radiation Applications for Human Health and Wellbeing

Building on radiological technology, NARI has successfully developed nuclear medicine products and advanced medical devices, which have been introduced into clinical and commercial applications, thus significantly contributing to public health. In 2024, sales of nuclear medicine products surpassed NT$100 million, setting a new record in our institution's history. Over the past four years, we have provided more than 360,000 patients with radiopharmaceutical services. Additionally, we continue to enhance our radiation analysis and testing capabilities to improve national food and environmental safety.

New Energy and Cross-Disciplinary System Integration

To support the nation's energy development goals, NARI actively participates in green energy innovation and promotes diverse technologies, including MW-scale microgrids and smart distribution systems, innovative high-efficiency plasma technology, Solid Oxide Electrolysis Cell (SOEC), Carbon Capture, Utilization, and Storage (CCUS), desiccant wheel drying systems, and energy storage technologies. This drives innovation in support of Taiwan's energy transition.

2024 Milestones: Breakthroughs and Infrastructure Development

NARI achieved notable results across all areas in 2024, marking the first complete fiscal year since our restructuring. Key accomplishments include:

- The construction of Taiwan's first national-level 70 MeV medium-sized cyclotron facility began in July 2024, with a total budget of nearly NT$2.2 billion. The project is expected to be completed in 2026, with trial operations commencing in 2027. This facility will significantly enhance domestic nuclear medicine production and expand the application of neutron and proton technologies in materials science, satellite systems, and semiconductor testing.
- NARI has been actively advancing research in Small Modular Reactors (SMRs) through deepening collaboration with experts in the United States and Japan. In collaboration with leading universities and research institutions in Taiwan, NARI is executing a National Science and Technology Council (NSTC) project on magnetic confinement high-temperature plasma research. The project will begin assembling Taiwan's first spherical TOKAMAK experimental device (Formosa Integrated Research Spherical TOKAMAK, FIRST) in

2025, with operational testing to be completed within two years. This positions Taiwan on the international stage of the nuclear fusion research community.

Technology Promotion and Industry-Academia Collaboration

NARI is dedicated to promoting technology transfer and fostering collaboration between academia and industry. We have signed a Memorandum of Understanding (MOU) with Taichung Veterans General Hospital to co-develop nuclear medicine and AI-driven medical imaging technologies that support precision medicine. Additionally, we established the Precision Health and Intelligent Diagnosis Alliance for Neurodegenerative Diseases in partnership with Kaohsiung Chang Gung Memorial Hospital, Shuang Ho Hospital of the Ministry of Health and Welfare, and National Yang Ming Chiao Tung University, aiming to advance diagnostic technologies for dementia. To facilitate knowledge exchange and practical applications, NARI hosted several major professional seminars in 2024, including the Symposium on the Development of Nuclear Medicine and Molecular Imaging Applications, the Flow Battery Energy Storage Bilateral Technical Symposium, and the Nuclear Back-End Forum and Technical Seminar. These events brought together stakeholders from industry, government, academia, and research sectors to jointly promote technological deployment.

International Collaboration and Enhanced Competitiveness

NARI continues to strengthen global partnerships. In August 2024, we established a significant technical exchange mechanism with the Idaho National Laboratory (INL) in the United States. This collaboration involves reciprocal visits and quarterly virtual technical meetings starting in November 2024. Furthermore, in 2024, we signed an MOU with Best Theratronics Ltd. (BTL) of Canada, authorizing them to distribute our radiopharmaceutical products in India and Brazil. Our international partners have recognized our innovative accomplishments. The following achievements reflect our strong innovation capabilities and technological potential:

- Platinum Award and Special Contribution Honor Award at the 2024 iENA Nuremberg
- Five Gold, one Silver, four Bronze medals, and one HON HAI Special Award at the 2024 Taiwan Innotech Expo
- Two Academic Research Category and one Excelsior Award at the 21st National Innovation Awards

These accolades highlight NARI's exceptional innovation capabilities and the practical potential of our technologies.

Forging Ahead

Since its inception, NARI has been actively recruiting talent. In 2024, our first full operational year, we held four recruitment events, hiring 222 personnel to enhance and maintain our R&D capabilities as a newly formed corporatized research institution. Critical projects approved during this period include:

- Decommissioning and Clearance of National Research Nuclear Facilities (NT$150 million Approved in 2025)
- Renovation and Replacement of Aging Infrastructure (NT$60 million Approved in 2025)
- Additional funding for the "Construction Project of the 70MeV Medium-sized Cyclotron" (NT$200 million Approved in 2024)

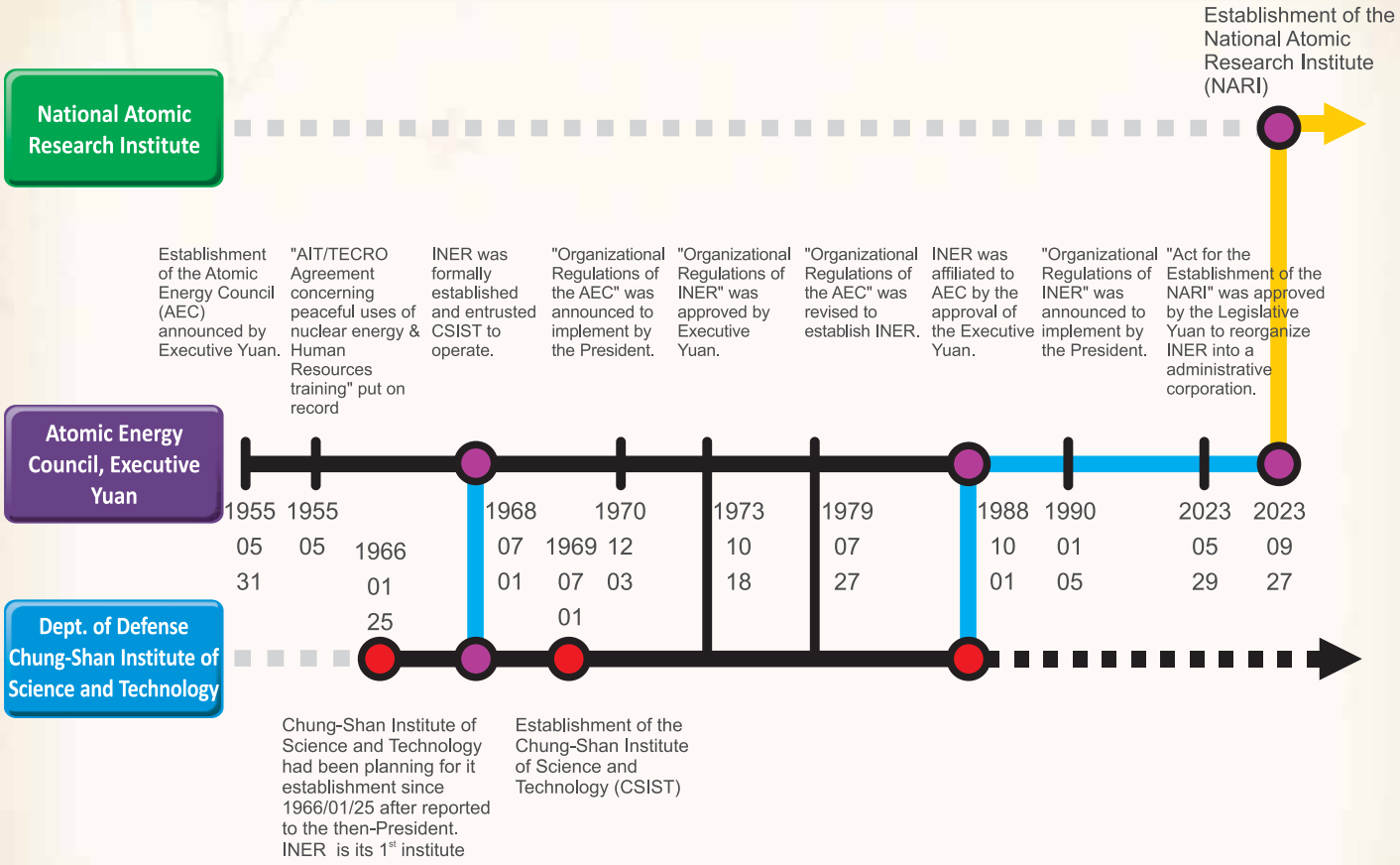
All of these projects have received government backing and have laid a solid foundation for future development.

NARI will adopt a forward-looking vision and pragmatic approach, deepening external relations, strengthening international partnerships, and delivering measurable outcomes. We will continue to enhance our systems, develop professional talent, improve execution efficiency, expand industrial connections, promote transparency, and communicate effectively with the public to earn their trust and support. By focusing on critical national technologies and securing major integrated research projects, NARI will continue to serve as a vital driving force in Taiwan's sustainable advancement of nuclear science and technology.

President Dr. Tsu-Mu Kao

Historical Development

Organizational history of NARI



Establishment of the National Atomic Research Institute

1. National Atomic Research Institute (NARI), formerly known as the Institute of Nuclear Energy Research (INER), is the sole nuclear energy research institute in Taiwan. INER had been planning for it establishment since 1966/01/25 after reported to the then-President.
2. On 1968/05/09 the "Atomic Act" was announced to implement by the then-President. It is stated in the Article 4: For the purpose of promoting research and development of nuclear science and technology, exploiting nuclear energy resources and expanding nuclear applications to agriculture, industry and medicine, the Atomic Energy Council may establish research organizations. On 1968/07/01 INER was formally established and entrusted the Chung-Shan Institute of Science and Technology to operate.
3. On 1973/08/29 the "Organizational Regulations of the Institute of Nuclear Energy Research"was approved by the Executive Yuan.
4. On 1973/09/04 "Organizational Regulations of the Institute of Nuclear Energy Research" was announced to implement by Atomic Energy Council(AEC). It is decided that the date of anniversary of INER is on the 4th September by the Chairman of AEC.
5. On 1988/10/01 INER was affiliated to AEC by the approval of the Executive Yuan.
6. On 1990/01/05 the "Organizational Regulations of the Institute of Nuclear Energy Research" was announced to implement by the then-President.
7. On 2023/05/29 the "Act for the Establishment of the National Atomic Research Institute" was approved by the Legislative Yuan to reorganize INER into a administrative corporation.
8. On 2023/06/21 the "Act for the Establishment of the National Atomic Research Institute" was announced to implement by the President.
9. On 2023/09/27 the National Atomic Research Institute (NARI) was formally established.

R&D Achievements Summary

Nuclear Safety and Nuclear Backend

After transitioning from the Institute of Nuclear Energy Research (INER), National Atomic Research Institute (NARI) has been actively involved in decommissioning and dismantling of nuclear facilities and managing radioactive waste within the institute, also for the safety operations and decommissioning needs of domestic nuclear power plants (NPPs), several technologies were developed in year 2024. These technologies can be separated into three categories, for technologies related to **nuclear power plant operational safety**, they include Probabilistic Risk Assessment (PRA) for Passive ShutDown Seal (PSDS) in Reactor Cooling Pumps (RCPs), and Fluid-Structure Interaction (FSI) technology for spent fuel pools; for technologies related to **decommissioning and dismantling of nuclear facilities**, they include inventorying and dismantling technology, Decommission Engineering Management System (DEMS), stabilization technology for high radioactive waste resins, management technology for low radioactive waste resins, and research on the characteristics of high burn-up fuel; for technologies related to **nuclear power plant accident assessment and emergency response**, they include assessment of emergency response area, key technology for radioactive wastewater treatment, and radiation accumulation tests of tritiated water in marine species. Key achievements are abstracted below:

Technologies related to **nuclear power plant operational safety:** (1) Considering the potential loss of cooling capability from RCP seals during station blackout (SBO) events, Taipower has installed PSDS in Maanshan NPP. Commissioned by Taipower, NARI validated the effectiveness of the design changes using PRA techniques, confirming that the PSDS can reduce the core damage frequency by about 97.5%. (2) NARI has developed FSI numerical analysis technology. Based on the seismic conditions suggested by SSHAC Level 3 process, a three-dimensional finite element numerical analysis of spent fuel pool was conducted, which not only ensures the structural integrity of the pool under beyond-design-basis earthquakes but also identifies structural weaknesses of the pool structures during earthquakes.

Technologies related to **decommissioning and dismantling of nuclear facilities:** (1) NARI has established a set of procedures and methods for the inventorying and dismantling of radioactive waste at Chinshan NPP, optimizing resources usage and cost management to achieve economics and efficiency goals; (2) In conjunction with decommissioning efforts, NARI also developed a DEMS system, consisting of waste inventorying procedures, dismantling methods, waste tracking management, work packages, and engineering information subsystems. It effectively supports the decommissioning tasks of NPPs and traceability of radioactive wastes; (3) NARI has also developed a pioneering stabilization treatment technology for granular waste resins whose radioactive level reaches Greater-Than-Class C (GTCC), which provides an effective way to resolve high radioactive waste problems for NARI and Taipower; (4) In addition to the stabilization technology for high radiative waste resins, NARI also

developed a wet oxidation technology, which transforms low radiative waste resins into liquid inorganic aqueous solution, then converts them into stable salts. The technology can reduce the volume of the radioactive waste by 1/3 to 2/3; (5) NARI previously established a dry storage system (INER-HPS) for spent fuel. Continuing with the effort, for the dry storage need of BWR high burn-up fuel, NARI adopted an internationally recognized fuel behavior analysis code to evaluate high burn-up fuel characteristics under different operational modes, verifying the safety and confirming that domestic BWR high burn-up fuel does not require additional canister to pack, effectively reducing handling cost.

Technologies related to **nuclear power plant accident assessment and emergency response:** (1) NARI has integrated models of fuel activity calculation, severe accident analysis, design basis accident analysis, and nuclear accident dose assessment, to perform an integral calculations of emergency response planning in 2022. The result shows that the emergency response areas can be reduced to 2.5 kilometers for Taipower's NPPs. Although current emergency response areas have not been relaxed due to administrative consideration by Nuclear Safety Commission, but it has demonstrated the NARI's outstanding analysis capabilities in the field of nuclear safety; (2) Similar to the ALPS (Advanced Liquid Processing System) established by Japan to treat radioactive contaminated water after Fukushima NPP accident, NARI has also developed key technologies for radioactive liquid waste treatment, achieving decontamination factors of 755 for I-129 and 1000 for Sr-90 isotopes in radioactive contaminated water; (3) Following the announcement by Fukushima plant to discharge tritiated water into the sea, which induced a big concern on Taiwan's fisheries, NARI has been conducting tests on tritiated water and biological tritium accumulation in fishes and aquatic species commonly consumed by Taiwanese. In 2024, NARI has completed the measurements of Tissue Free Water Tritium (TFWT) activity measurement in fish tissues.

Nuclear Medicine and Radiation Applications for Public Welfare

Nuclear medicine and radiation technologies have been widely applied in modern medicine, industry, and environmental monitoring. Their applications range from disease diagnosis and cancer treatment to non-destructive testing, demonstrating exceptional value. In recent years, breakthroughs in imaging technology, targeted radiopharmaceuticals, and intelligent analysis have enhanced the precision of medical diagnosis and treatment while extending their applications to environmental safety and technological industries. These advancements contribute to societal well-being and industrial competitiveness.

The National Atomic Research Institute (NARI) has long been committed to the research and development of nuclear medicine and radiation applications for civilian use. It continuously refines core technologies and collaborates with domestic and international academic institutions and industries to facilitate technology transfer and practical implementation. This report summarizes the research and development achievements of NARI in 2024 in the field of "Nuclear Medicine and Radiation Applications for Civilian Use." It covers key areas such as X-ray imaging technology, innovative imaging agents, cancer treatment drugs, and radiation detection techniques, showcasing NARI's innovative capabilities and future potential in nuclear medicine and radiation technology.

The research outcomes presented in this report can be categorized into the following major areas:

(1) Radiographic Imaging Technology and Diagnostic Applications

- X-ray Imaging and System Technologies: NARI has continued to develop X-ray imaging systems, including 3D image reconstruction, spectral imaging, and intelligent analysis technologies, securing 39 patents. Notably, the "Calculation Method for a Dual-Energy X-ray Imaging System" overcomes limitations in identifying low atomic number materials, enhancing detection capabilities in medical and industrial applications.
- Gallium-68-APD for Atherosclerosis Imaging: A novel positron emission tomography (PET) diagnostic agent for atherosclerosis, developed using AI technology, enables early detection of cardiovascular diseases. This agent is undergoing clinical research and application in collaboration with medical institutions and is expected to become a crucial tool in cardiovascular disease diagnosis.

(2) Innovative Radiopharmaceuticals and Targeted Therapies

- Dolacga (Peptide-Based Liver Function Imaging Agent): The world's first peptide-based PET imaging agent for quantitative liver function assessment, Dolacga, accurately evaluates liver function. Having successfully completed Phase II clinical trials in Taiwan and the United States, it demonstrates significant potential in liver cancer diagnosis and treatment.
- Lu-177-NARI-PSMA for Prostate Cancer Treatment: A long-acting targeted radiotherapy drug for metastatic castration-resistant prostate cancer, Lu-177-NARI-PSMA is expected to reduce treatment frequency and medical costs while providing improved efficacy and safety compared to existing therapies.

(3) Proton Irradiation Testing and Biological Tritium Analysis Technologies

- Proton Irradiation Testing Technology: NARI has established a more advanced domestic proton irradiation testing environment, supporting the testing of space-grade electronic components and the development of radiation-resistant materials. This initiative strengthens the competitiveness of the domestic space and semiconductor industries.
- Interlaboratory Proficiency Testing Program for Biological Tritium Analysis: In response to concerns regarding the release of ALPS-treated water from the Fukushima nuclear power plant and its impact on marine ecosystems, NARI collaborated with domestic laboratories to complete an interlaboratory proficiency testing program. This ensures the accuracy and consistency of biological tritium analysis techniques, providing a scientific basis for environmental monitoring.

(4) Hydrogeological Simulation and Dose Calibration Advancements

- Hydrogeological Simulation and Geological Modeling Technology: Utilizing high-resolution geological modeling, NARI enhances the simulation efficiency of hydrogeological analysis while providing multidimensional insights for interpretation. This technology finds applications in groundwater research, carbon sequestration, and geothermal exploration, offering critical support for environmental sustainability and energy development.
- Linear Accelerator (LINAC) Photon Dose Calibration System: A high-precision photon dose calibration system has been established to improve the accuracy of radiotherapy equipment. This ensures precise treatment doses for cancer patients and lays the groundwork for future advancements in high-energy proton and heavy-ion therapy technologies.

NARI's research and development in radiation applications for civilian use spans medical, industrial, and environmental monitoring fields. These advancements not only elevate the level of nuclear medicine and radiation technology domestically but also provide a solid foundation for innovation and industrialization in the field, ultimately contributing to societal well-being.

New Energy and Cross-Field System Integration

In compliance with the national energy policy, the National Atomic Research Institute (NARI) has committed to the research and development on the environmental and green energy technologies. As a national research institute, NARI has been strategically demanding to support the national energy policy and continues to engage in diverse technology development and industrial promotion. The research projects cover solar energy, wind power generation, smart grids, grid resilience, hydrogen energy and fuel cells, flow batteries, lithium batteries, energy-saving membranes, biogas, biomass refining, negative carbon technology, and plasma technology, applied in areas such as public welfare and waste treatment. To promote the dissemination and application of research results and key technologies, our institute actively participates in the "R&D Matching and Patent Technology Promotion Briefing" organized by the Taoyuan City Government, as well as the technology exhibition and matching activities of the "Taiwan Innotech Expo" hosted by 11 ministries. At the "2024 Taiwan Innotech Expo," our institute received multiple honors, including gold, silver, and bronze medals for inventions, a special award for enterprises, and an award for academic and research startups.

In the 2024 annual report, based on the characteristics, advantages, and application scope of key technologies, as well as the focus of research and innovation, the content is divided into two main themes: "Promotion and Application of Key Technologies" and "Research and Development." The report briefly outlines the progress and effectiveness of these themes, with the project names listed as follows:

Promotion and Application of Key Technologies

- A multi-junction solar cell structure grown on both sides of a substrate and a manufacturing method thereof
- Innovative application of high-efficiency plasma direct melting technology in solid waste treatment
- Environment quality control technology for agricultural and industrial drying processes
- Solid state and gel solid state technologies for improving safety of lithium-ion batteries
- Technology for fabrication of high-performance fuel-to-hydrogen catalyst
- Carbon dioxide capture and carbonation conversion recycling technology from flue gas
- Online predictive diagnosis technology for power transformers
- New flow battery module technology and recoverable capacity

Research and Development

- Innovative technology for enhancing biogas production from lignocellulosic biomass
- Technology for producing polyhydroxyalkanoates with low carbon emissions and sustainability
- Analysis and verification of compressed air energy storage system
- Low-cost, high-efficiency rapid solution-processed electrochromic technology
- High temperature solid oxide cell technology for water electrolysis hydrogen production
- Automatic recognition of relay waveforms and real-time event notification technology
- Provision of ancillary services through NARI's MW-scale microgird

In brief, the NARI is deeply engaged in the research and development of new energy and interdisciplinary system integration technologies. Our technological capabilities have been widely recognized both domestically and internationally, and it has already achieved results in promoting these technologies to the industry. Currently, the government has announced the "Net Zero Transformation Five Major Strategies," including key focuses such as the second energy transition and accelerating the advancement of renewable energy (e.g., geothermal, hydrogen, biomass, and ocean energy) to shape a sustainable green lifestyle for net zero. In line with the national policies, NARI will continue to invest in research and development in the fields of environmental and energy technology.

Looking ahead, in conjunction with the promotion of national sustainable development policies, NARI, based on its innovative and excellence-driven professional expertise, will grasp key autonomous technologies and maintain close cooperative relationships with various sectors, including industry, government, academia, and research, to enhance our country's international competitiveness in the new and renewable energy fields. Specifically, in addition to continuously improving existing research and development capabilities, NARI has expanded its focus to include the sustainable resource utilization of biomass, the development and verification of next-generation sustainable aviation fuel technology, next-generation low-carbon hydrogen technology and verification, net zero smart grids, and the integration of carbon capture and utilization technologies in renewable applications, among others. By embracing the concept of a circular economy, NARI aims to deepen the breadth and depth of energy technology, implement clean low-carbon energy policies, and contribute to the achievement of national sustainability and the goal of a prosperous low-carbon society!

MEMO

Date . .

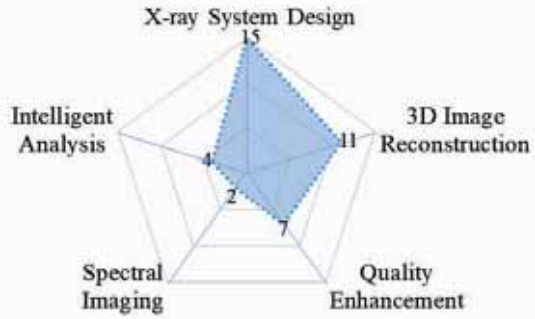
Promotion and Application of Key Technologies

Nuclear Medicine and Radiation Applications for Public Welfare

X-ray Imaging and Radiography System Technologies for Medical and Industrial Applications

The Radiation Imaging Team at NARI has developed X-ray imaging and radiography system technologies for medical, industrial, and academic applications. With 39 patents, key areas include X-ray system design, 3D image reconstruction, quality enhancement, spectral imaging, and intelligent analysis for innovation and IP protection.

The most patent-sensitive aspects of X-ray imaging are mechanical design and scanning, while 3D reconstruction enables tomographic imaging. Thus, system design and 3D reconstruction are our strengths. We also patented spectral imaging and intelligent analysis, achieving preliminary results in spectral imaging.



X-ray imaging technologies is categorized into five types, with a radar chart analyzing related patents obtained by the NARI research team.

Advantages

This patent (Invention No. I776443) enhances dual-energy X-ray material identification, reducing maximum relative error from 16.07% to 8.33%, winning the Gold Medal at the 2024 Taiwan Innotech Expo.

Patented algorithm

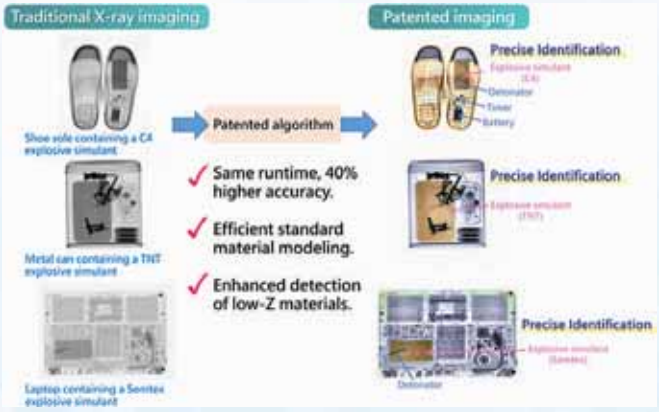
$$R = \frac{c_1 Z_{eff}^2 + c_2 Z_{eff} + c_3}{1 + c_4 Z_{eff}}$$

R-value: high-to-low energy image ratio

The patented algorithm improves low-Z material decomposition by refining the correlation between the R-value and fractional terms.

Applications

Dual-energy X-ray imaging enables material analysis for medical applications such as mammography, bone strength analysis, and multi-contrast CT, and industrial uses such as NDT and foreign object detection. NARI's rational polynomial method improves the identification of low-Z materials with higher accuracy while maintaining computational efficiency.



Explosive detection test utilizing the patented algorithm.

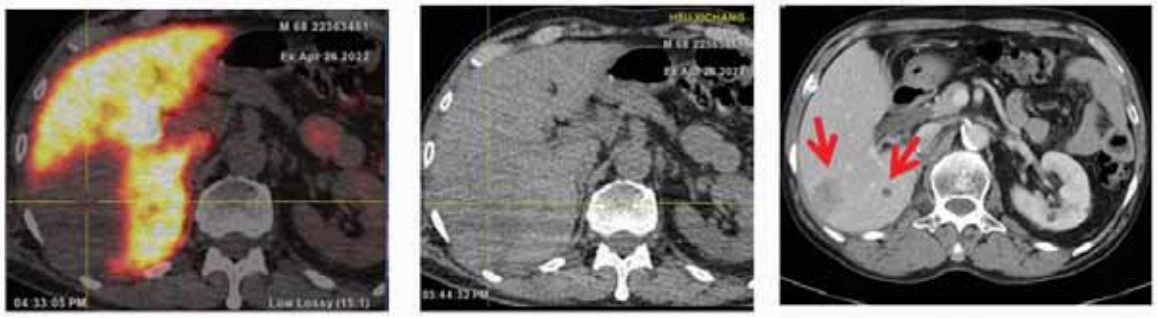
Patent certificates and gold medal award.

Dolacga-The World's First Peptide-Based Quantitative Liver Function Imaging Agent

Preoperative assessment of liver functional reserve is crucial in liver surgery to prevent postoperative liver failure. While indocyanine green (ICG) retention rate and CT volumetry are commonly used, they are unreliable in patients with liver dysfunction, such as cirrhosis or obstructive jaundice. Asialoglycoprotein receptor (ASGPR), primarily localized to the hepatocytes, directly reflects both the number and function of hepatocytes.

Ga-68 Dolacga, a patented all-in-one formulation (Taiwan, US, Europe, and Japan) designed for easy preparation, selectively binds to ASGPR, enabling accurate regional hepatic function estimation via ASGPR density measurement. With approved Phase I and II IND trials in Taiwan and the USA, preliminary data from Ga-68 Dolacga PET imaging demonstrates accurate delineation of hepatoma lesions and liver function evaluation compared to CT. Ongoing trials investigating Ga-68 Dolacga PET in hepatoma patients undergoing proton therapy also suggest its potential for treatment efficacy.

Ga-68 Dolacga PET/CT images | CT images without contrast agent | CT images with contrast agent



Clinical Trial at Linko Chang-Gung Memorial Hospital (2021.6-2023.12)

Advantages

Ga-68 Dolacga PET enables more precise delineation of hepatoma lesions compared to CT. The uptake intensity of Ga-68 Dolacga correlates well with the liver function.

Applications

Diagnosis of liver disease severity, assessment of liver function and hepatoma extent before and after treatment, and efficacy evaluation.

Atherosclerotic PET Diagnosis Ga-68-APD

Metabolic syndrome (high blood pressure, high blood sugar, high blood lipids) is the main cause of atherosclerosis. Thrombosis resulting from chronic inflammation of blood vessels leads to ischemic heart disease (myocardial infarction) and stroke. There is a global need for atherosclerotic PET diagnostic agents to enable early diagnosis of cardiovascular disease.

Ga-68-APD, a new small molecule drug developed through computer AI technology, has demonstrated significant accumulation in the sites of atherosclerotic lesions in mice. Its imaging performance surpasses that of Ga-68-Pentixafor and has been patented in the United States, Japan and Taiwan. (Fig.1)

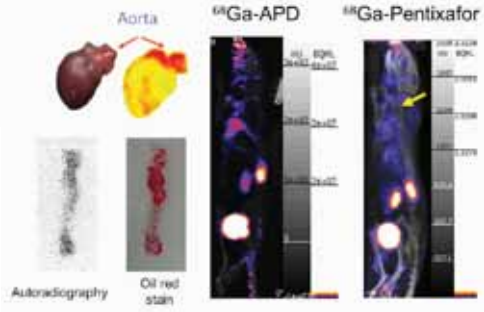


Fig.1. Ga-68-APD has demonstrated significant accumulation in the sites of atherosclerotic lesions in mice.

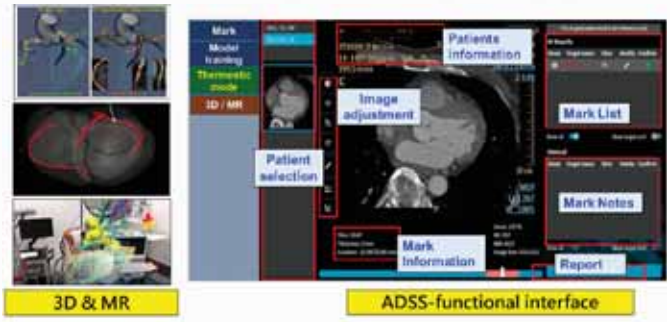


Fig.2. 3D mixed reality (MR) technology ; a lesion localization and grading decision support system (ADSS)

Advantages

Ga-68-APD was recognized as one of the Top 10 Highlight Technologies in the 2023 National Innovation Awards. It has partnered with Solomon Technology Corporation and other collaborations to jointly develop a lesion localization and grading decision support system (ADSS). By integrating artificial intelligence (AI) and 3D mixed reality (MR) technology into medical institutions, this system aids in medical decision-making and diagnosis.(Fig.2) Clinical application research is being conducted in collaboration with Taipei Veterans General Hospital, Taichung Veterans General Hospital, and Tri-Service General Hospital, among others.

The GLP toxicology testing for Ga-68-APD is scheduled to be completed in June 2025. Upon completion of the eCTD document and approval from the hospital's IRB and the TFDA, the world's first human clinical trial will be conducted.

Applications

Cardiovascular disease ranks first among the top ten causes of death in the world. There are no symptoms in the early stages of the disease, but if symptoms such as chest tightness and pain occur, it means that it has reached the end stage. Ga-68-APD, when combined with ADSS, aims to target atherosclerosis throughout the body. AI lesion localization and grading enable early-stage disease diagnosis. We look forward to Ga-68-APD entering clinical applications as soon as possible to achieve the goals of early diagnosis and early treatment, and benefit mankind worldwide.

New Energy and Cross-Field System Integration

A Multi-junction Solar Cell Structure Grown on Both Sides of a Substrate and a Manufacturing Method thereof

The current mainstream structure design for solar cells used in satellite applications is the triple-junction GaInP/Ga(In)As/Ge. However, the Ge bottom subcell, due to its low material bandgap, contributes only a relatively lower conversion efficiency of about 10% of the total output power. To replace the Ge bottom subcell, the National Renewable Energy Laboratory (NREL) in the United States proposed the inverted metamorphic (IMM) technology (Fig.1), significantly advancing the conversion efficiency of traditional triple-junction solar cells. This technology was recognized with the Global Top 100 Technology R&D Award. While the IMM approach benefits from using only a single metamorphic buffer layer to maintain high epitaxial quality for GaInP and Ga(In)As subcells, it involves the removal of the original epitaxial substrate and the transfer of the thin-film structure to a carrier. The fabricating processes are complex, time-consuming and prone to thin-film stresses and potential damage, making it very challenging to achieve high process yields. At NARI, we develop an innovative approach that avoids substrate transfer while using only a single metamorphic buffer layer.

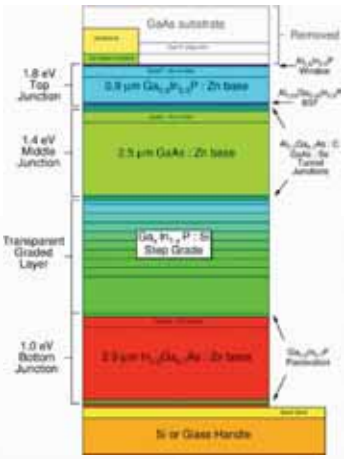


Fig.1. The inverted metamorphic triple-junction solar cell technology, developed by the National Renewable Energy Laboratory (NREL), marked a significant advancement in photovoltaic efficiency. This innovation earned the Global Top 100 Technology R&D Award. (Image source: Appl. Phys. Lett. 91 (2007) 023502)

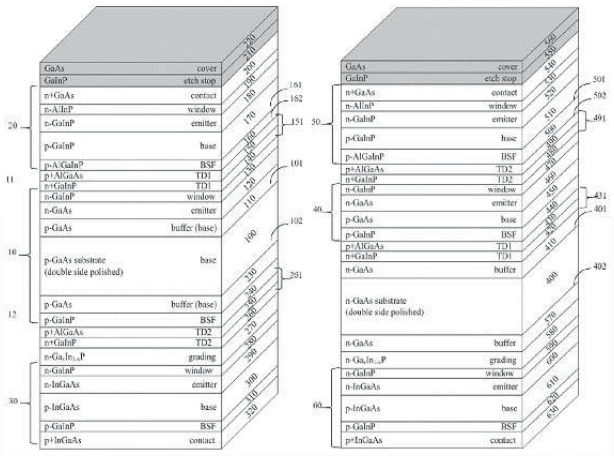


Fig.2. The double-sided substrate growth technology developed by the National Atomic Research Institute (NARI) facilitates the fabrication of conventional triple-junction solar cells on both P-type and N-type substrates, offering enhanced device process yield.

Advantages

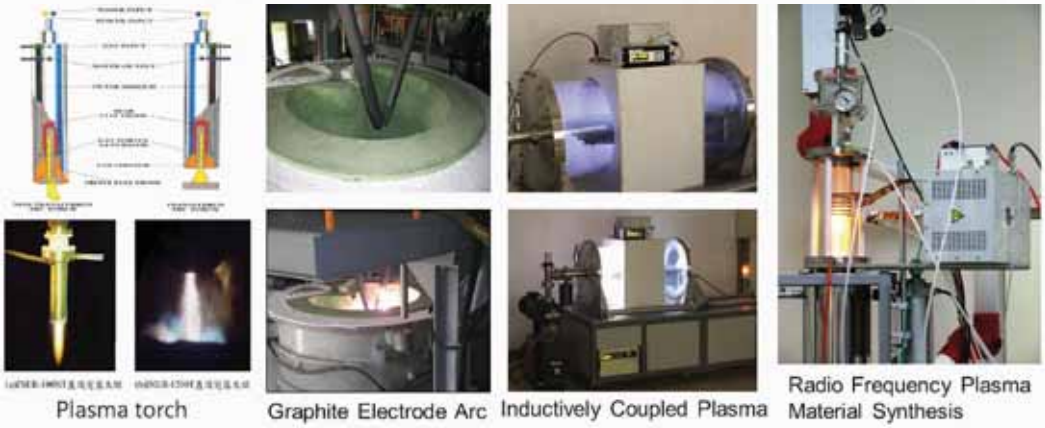
To address the challenges mentioned above, the NARI has developed an innovative double-sided substrate growth technology, as illustrated in Fig.2. This approach sequentially forms the top, middle, and bottom sub-cells on both sides of the substrate, enabling the creation of an upright triple-junction solar cell. The primary advantage of this patent lies in its use of a single metamorphic buffer layer, which ensures high epitaxial quality for each subcell. Moreover, it eliminates the need for removing the original epitaxial substrate or transferring the film, resulting in a higher process yield that is expected to surpass that of IMM technology.

Applications

This technology can be applied to III-V solar cells, particularly for satellite application batteries with niche markets. It can enhance the conversion efficiency of the cells while maintaining a good process yield.

Innovative Application of High-Efficiency Plasma Direct Melting Technology in Solid Waste Treatment

By integrating the energy advantages of plasma physics and plasma system engineering, this technology expands the application of plasma in nuclear back-end processing and environmental pollution control. Utilizing the characteristics of solid waste and appropriately modifying its composition, the waste is processed into rod-shaped feedstock for direct melting. This allows direct contact with the high-temperature plasma zone, significantly enhancing thermal treatment efficiency. Unlike traditional plasma applications where it functions merely as a furnace heater, this technology enables direct melting of waste materials, improving heat treatment performance and extending plasma lifespan. The furnace design is miniaturized for more efficient heat utilization, broadening its application scope. Heavy metals are encapsulated within the molten solidified mass, preventing leaching and enabling effective treatment of hazardous waste. After classification as hazardous or non-hazardous, further consideration can be given to potential reuse.



Plasma torch | Graphite Electrode Arc | Inductively Coupled Plasma | Radio Frequency Plasma Material Synthesis

Advantages

1. High-Efficiency and Versatile Solutions: Plasma direct processing and resource recovery technology can handle various gaseous, liquid, and solid wastes. It achieves stabilization, volume reduction, and recycling, addressing critical environmental issues from both national and industrial levels.
2. Localized Technology to Reduce Production and Installation Costs: By integrating industry, government, academia, and research institutes, the technology is well developed domestically. This approach reduces costs associated with materials, components, equipment, and system manufacturing, as well as production, transportation, and installation expenses.
3. Sustainable Win-Win for Environment and Economy: Plasma treatment and green materialization technologies resolve industrial waste disposal challenges while minimizing improper disposal impacts on the environment. Additionally, the commercialization of derived products, equipment, and systems creates new business opportunities.
4. High-Value Resource Recycling for a Sustainable Living Environment: By substituting raw materials, the technology reduces natural resource extraction and carbon emissions. It enhances material circularity, lowers dependence on imported raw materials, and maximizes industrial benefits.

Applications

1. Plasma melting, new material synthesis, and green materialization technology.
2. Plasma system engineering integration, evaluation, and diagnostics.
3. Design, planning, and construction of complete plasma system facilities.
4. Target Industries: Machinery and equipment manufacturing, Environmental protection equipment manufacturing, Refractory materials manufacturing, Resource recycling and regeneration industries. Other applicable sectors beyond the mentioned industries.

The Environment Quality Control Technology for Agricultural-and-industrial-drying-processes and Residential-and-commercial-dehumidification-and-cleanness

Taiwan's climate is mostly hot and humid throughout the year. Dehumidifier and dryer are essential equipment for industry and people's livelihood. Its electricity consumption accounts for an important proportion of the country. After analyzing commercially adsorption dryer, it was found that there is still improvement room for energy consumption and cost. In regard to power consumption, commercially available machines mostly use electric heater to heat regeneration air so that energy efficiency is low. In terms of cost, currently, the core part, the honeycomb desiccant wheel, is imported and results in high cost. To solve the above problems, NARI has devoted to the research and development for independent core technology of desiccant wheel drying equipment so that equipment cost can be effcectively reduced and build up domestic capability. Currently, we have developed the integrated drying technology of environmentally friendly desiccant wheel and heat pump to strengthen energy saving, low noise, no air pollution and drying capacity. This technology is beneficial to the energy saving, environmental protection, and economy growth.

Desiccant wheel dryer

Desiccant wheel made from aluminum waste

Advantages

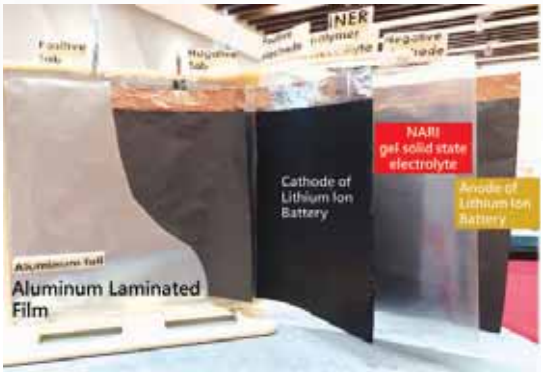
The raw material of the desiccant wheel of NARI's environment quality control technology comes from aluminum smelting industry waste, so the product cost is reduced by more than 30%, and each kilogram reused waste can reduce carbon dioxide emissions by 1.02 kilograms. The drying equipment is used in the drying process of garlic. Unlike the traditional diesel combustion hot air technology, it can reduce energy consumption, shorten drying time, reduce noise, and eliminate air pollution. It is used in the drying process of vanilla pods, antrodia camphorata, and orchids. Compared with traditional condensation dehumidification technology, it can not only reduce energy consumption and shorten drying time, but also maintain aroma and color. In the future, it will be used in industrial and residential air-conditioning systems. Low-energy/low-temperature regenerative solid adsorption materials will be used to process latent heat (dehumidification) and sensible heat (cooling) separately. The temperature of chilled water will be increased from 5°C to over 12°C. At the same time, it will be combined with heat pump systems, solar energy or waste heat for regeneration, so the electricity consumption of the entire air-conditioning system is reduced by 15~30%.

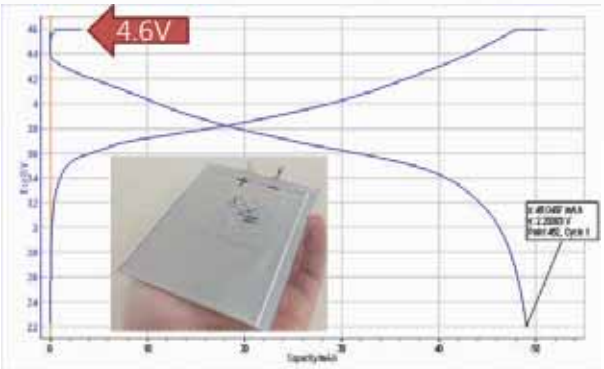
Applications

The technology can be well implemented in agriculture, such as: the drying process of agriculture product with high economic value such as garlic, vanilla pods, antrodia camphorata, orchids. In terms of residential and commercial applications, it is applicable to dehumidification and clean environment air conditioning systems for commercial offices and hotel buildings. In future, the applications can be extended to industry, including clean room air conditioning systems for the biotechnology and semiconductor industries.

Solid State and Gel Solid State Technologies for Improving Safety of Lithium-Ion Batteries

Nowadays, most commercial lithium-ion batteries use liquid electrolyte. However, the liquid electrolyte is difficult to meet the high safety standard and high energy density requirements. Therefore, the NARI focuses on gel solid/solid state electrolyte technologies for lithium batteries to enhance its safety. The main features of the gel solid/solid state electrolyte technology are high flame retardancy, high ionic conductivity at room temperature, simple and fast production process in the atmospheric environment, and commercial competitiveness for the future high safety lithium battery applications.





Advantages

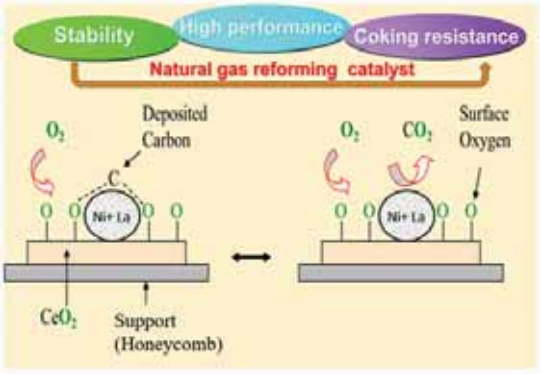
Gel-solid electrolyte technology can be applied to roll-to-roll process. The ionic conductivity at room temperature is around 10^{-4} S/cm, tens of times larger than that of the conventional solvent-free electrolyte. Furthermore, it is applicable for 4.6 V high voltage electrode to increase the battery energy density and suitable for the 80°C high-temperature demand. This key technology inhibits the growth of lithium dendrites and further reduces the risk of short-circuit. Currently, the 3.8 Ah lithium battery cell has been verified and numbers of patents have been granted. Meanwhile, the NARI has been engaged in technical cooperation with domestic manufacturers to accelerate the industrialization process.

Applications

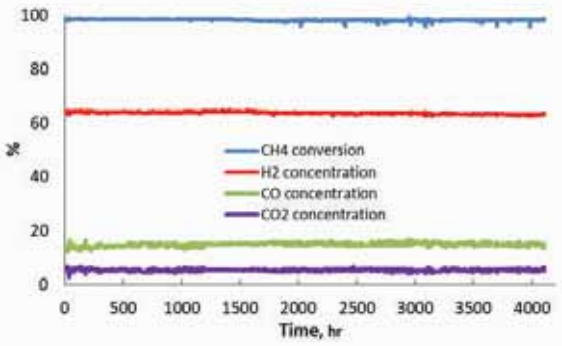
This key technology can provide future applications of high safety lithium batteries. It not only effectively improves the safety, but also increases the energy density and cycle life of the battery. Thus, it will be beneficial to promote the growth of electric vehicles, energy storage and AI industries.

Technology for Fabrication of High-performance Fuel-to-hydrogen Catalyst

This technology is aimed at the fabrication of reforming catalyst in Solid Oxide Fuel Cell (SOFC) power generation systems. Currently, precious metal catalysts such as platinum exhibit superior carbon deposition resistance, maintaining high activity over prolonged reactions. However, precious metal catalysts are of high cost, and nickel-based catalysts are prone to carbon deposition and sintering, which lead to catalyst deactivation. We have developed high-performance catalyst, containing highly active nickel metal supplemented with lanthanum and cerium oxides as additives, successfully overcoming the issues of carbon deposition and high-temperature sintering commonly associated with nickel catalysts. After acid treatment of a honeycomb support, the surface roughness of the support is elevated. Catalyst is then coated onto the honeycomb support, which enhances specific surface area of the support. This technology effectively raises methane conversion rates, increases long-term operational reliability and durability, and boosts energy utilization efficiency, thereby improving the performance of the SOFC power generation system.



Characteristics of Ni-La-Ce catalysts



Testing of Ni-La-Ce catalyst for SOFC system

Advantages

The novel Ni-La-Ce fuel reforming catalyst developed by NARI possesses competitive advantages such as high stability, high efficiency, and carbon deposition resistance. In traditional methane reforming conversion reactions, methane is prone to high-temperature cracking, which generates carbon atoms. This technology adopts cordierite as the catalyst support with merits of high mechanical strength, low-pressure drop, and suitability for high space velocity gas reaction processes. A layer of cerium and lanthanum oxides is coated on the support as co-catalysts. As carbon atoms are deposited on the surface of the nickel catalyst during the conversion reaction, the oxygen release/oxygen storage properties of the co-catalysts enable the carbon atoms to react and form carbon dioxide, which then desorbs. This process provides the resistance to carbon deposition. Moreover, the manufacturing cost of the catalyst is reduced significantly in comparison with commercial products.

Applications

The catalyst can be used in the chemical processes and SOFC power generation system for high conversion efficiency of methane reforming.

The Carbon Dioxide Capture and Carbonation Conversion Recycling Technology from Flue Gas

The "Pilot-Scale CO_2 Capture and Carbonation Conversion Process and System" developed by NARI can be implemented to various factories. In the process, CO_2 is absorbed by the alkaline solution and then converted into carbonate. Through the CO_2 capture and carbonation conversion process, it can effectively reduce the recovery costs of CO_2 and beneficial to subsequent storage issues as well as lower the greenhouse gas emissions. Meanwhile, its by-products, carbonated salts, are economically valuable. It transforms the wastes into recycled resources, achieving greenhouse gas reduction and advancing the goals of carbon recycling and environmental sustainability.

CO_2 Capture and Carbonation Conversion System

Advantages

1. The Gibbs free energy change of the process is less than zero. It is a low-energy consumption reaction process while operates at room temperature and normal pressure.
2. The flue gas can be directly connected to the reaction system without any pre-concentration or purification.
3. The product of this conversion process is carbonate with a low-carbon footprint. It processes competitive strength in the commodity market.
4. The carbon reduction benefits for producing one ton of sodium bicarbonate is approximately 539 kg CO_2^e.

Applications

This technology is suitable for various flue gas emission plants, such as chemical plants, steel industries, sugar industries, and various industries with boiler combustion equipment. The carbonate salt products can also be used as raw materials for acid gas treatment or wastewater neutralization.

Online Predictive Diagnosis Technology for Power Transformers

After long-term operation and environmental factors, the insulation materials in power transformers are suffering of degradation, leading to insulation failures and subsequent events. This research aims to develop an online predictive diagnostic technology for power transformers. Various parameters, including partial discharge, cooling system performance, body vibration, ground current, oil and coil temperatures, on-load tap changer activity, and dissolved gas analysis, are continuously monitored. This technology has already been implemented in Taipower's operating substations to reduce unexpected power outages caused by insulation failures.

Advantages

1.Online Advanced Predictive Diagnosis

We offer dynamic alerts for power transformers to detect potential faults based on a baseline model.

2.Accurately Grasping the Status of the Equipment

The improved k-Nearest Neighbors (kNN) algorithm is proposed to enhance the prediction accuracy of the oil and coil temperature baseline model.

3.Ensuring Voltage Switching

We integrate various types of vibration analysis for the online diagnosis of on-load tap changer switching devices, thereby enhancing the stability of the power supply.

1.A Novel Dissolved Gas Analysis

We utilize changes in the ratio of carbon oxides to evaluate the severity of carbonization in power transformer windings.

Applications

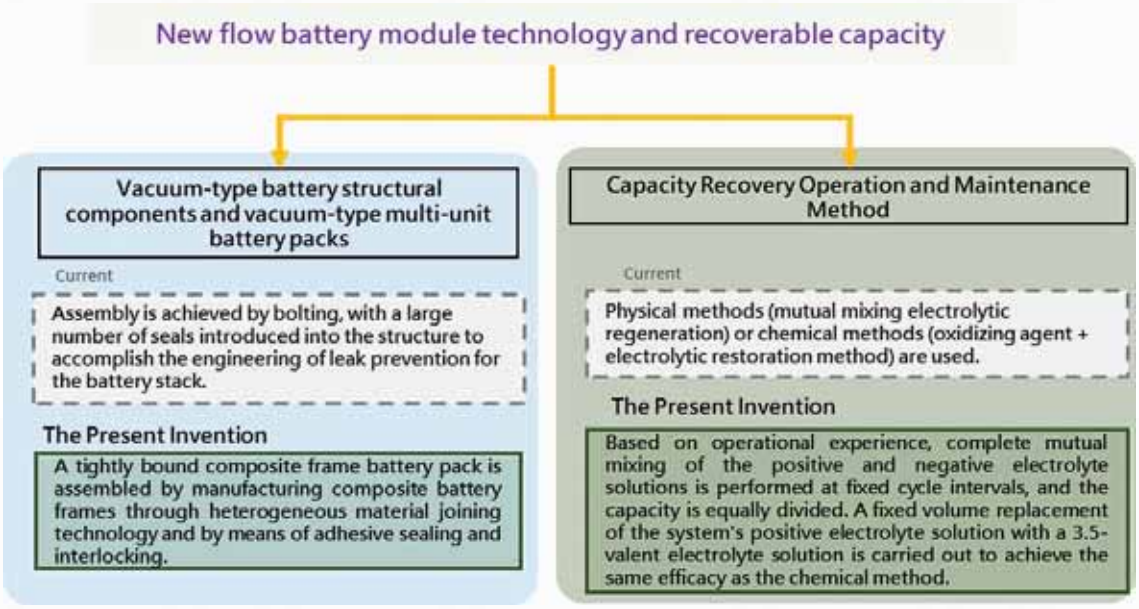
Power Transformers, High Voltage Devices

Diagnosis Platform GUI

Online Diagnosis of Power Transformer

New Flow Battery Module Technology and Recoverable Capacity

Innovative solutions for flow battery structural design and operation and maintenance (O&M) management are proposed. By replacing traditional bolt-fastening with vacuum adsorption, it improves assembly stability while reducing module size and weight. Specific cycling and replacement mechanisms allow capacity restoration to design levels without complex analysis, ensuring long-term system efficiency. With novel frame design and intelligent maintenance, it effectively addresses performance degradation issues in traditional flow batteries, enhancing battery lifespan and energy density.



Advantages

1.Vacuum adsorption replaces bolt-fastening, reducing module area by 22%, saving 30% in materials, and increasing volumetric power density by 1.6 times.

2.It improves assembly precision, maintaining carbon felt compression within 3%, significantly enhancing charge/discharge performance.

3.Electrolyte circulation and valence 3.5 replacement restore over 80% of original capacity without extra equipment, simplifying maintenance.

4.It reduces by-product accumulation and internal imbalance, extending battery life and lowering operational costs to US $ 0.05 / kWh / cycle.

Applications

This technology is suitable for energy storage grids, renewable energy integration, and industrial power management, especially in modular applications requiring long-term stability and efficient operation, such as smart grids, data center UPS systems, and power supply for remote or island areas.

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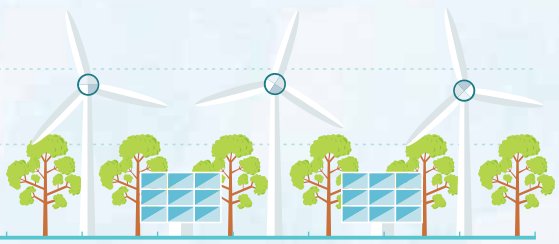


Research and Development

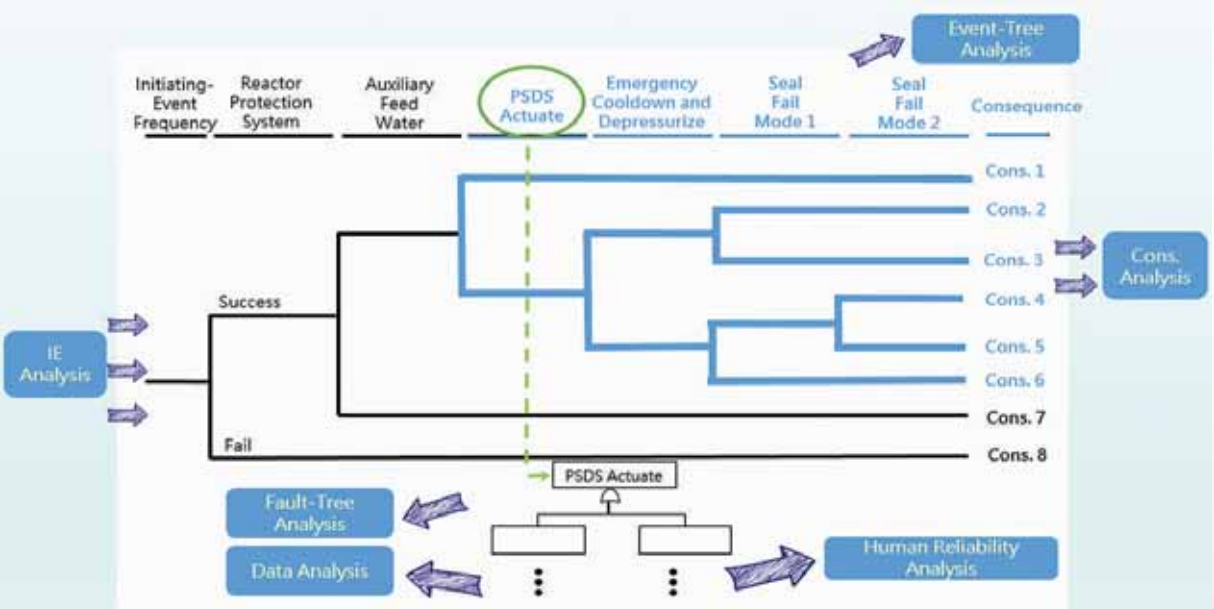
Nuclear Safety and Nuclear Backend

Enhancing Operational Safety of Nuclear Power Plants — Passive ShutDown Seals on RCPs

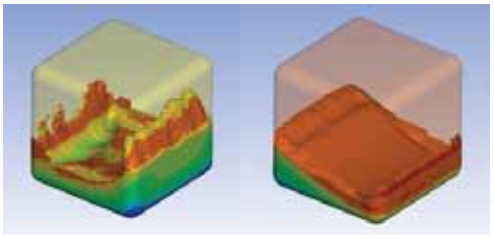
In 2011, the Fukushima Daiichi Nuclear Power Plant in Japan experienced a station blackout (SBO) caused by a tsunami that exceeded the design basis, which was triggered by a major earthquake, resulting in core meltdown. For pressurized water reactors (PWRs), a station blackout could result in the loss of cooling for the reactor coolant pump (RCP) seals, potentially causing reactor coolant to leak from the RCP seals and lead to core meltdown. In response, Taiwan's Nuclear Safety Commission (NSC) required Maanshan Nuclear Power Plant (MNPP) to address the risk of coolant leakage from the RCP seals and the potential for core meltdown during a station blackout as part of nuclear regulatory actions.

To mitigate this risk, MNPP installed Passive Shutdown Seals (PSDS) in the RCPs of both reactor units. These passive devices significantly reduce the amount of coolant leakage during an SBO, thereby enhancing the operational safety of the plant. The National Atomic Energy Technology Research Institute (NARI) used quantitative risk assessment techniques to verify the effectiveness of this design modification in improving the safety of the plant, based on the current design changes implemented at Maanshan Nuclear Power Plant.

Based on the design and operational characteristics of PSDS, NARI defined potential failure scenarios of the RCP seal during an SBO event and estimated the corresponding reactor coolant leakage rates. This information was used to redevelop the progression of accident sequences, calculate the time available for operators to mitigate the accident, and conduct related human reliability analyses (as shown in the figure below). The assessment results indicate that, in the initiating event of a loss of offsite power, the PSDS can reduce the core damage frequency by approximately 97.5%. The quantitative risk assessment model developed in this technical research project reflects the current status of MNPP after installing the RCP PSDS. The evaluation results have assisted Taiwan Power Company in passing the NSC's review. Furthermore, the related technology has been extended and applied to enhance and refine probabilistic risk assessment models for internal and external events at MNPP.



Seismic Analysis of Fluid-Structure Interaction for Spent Fuel Pool



The SFP (Spent Fuel Pool) (as shown in Fig.1) is an important safety related structure used for interim storage of spent nuclear fuel and removes the decaying heat by the pool water. For years, various international research studies have been conducted on structural integrity analysis of SFP in nuclear power plants under seismic events. In the early stages, the structural integrity analysis of SFP was limited by both software and hardware performance. Therefore, the evaluation methods primarily relied on simplified calculation equations and a single wall panel model for mechanical analysis and safety assessment. After the Fukushima nuclear accident in Japan, international researchers focused on three-dimensional finite element numerical analysis models to assess the structural integrity of SFP under BDBE (Beyond-Design-Basis Earthquake). Taiwan is situated in an earthquake-prone zone, and in light of the Fukushima nuclear accident in Japan, the structural integrity of SFP under BDBE has drawn significant attention.

Therefore, NARI adopted FSI (Fluid-Structure Interaction) numerical analysis techniques to conduct three-dimensional finite element numerical research, and based on the seismic conditions derived from the Level 3 procedure established by the SSHAC (Senior Seismic Hazard Analysis Committee), aiming to investigate the sloshing phenomenon of pool water (as shown in Fig.2) and the structural response of SFP (as shown in Fig.3) during seismic events. This approach not only ensures the structural integrity of SFP under BDBE but also identifies structural weaknesses during seismic events. These research results could provide suggestions to the regulatory commission and Taiwan Power Company, to further improve the public safety.

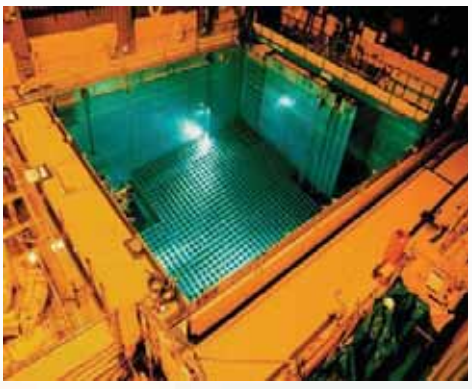


Fig.1. Schematic diagram of SFP

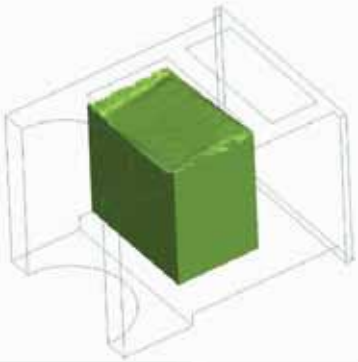


Fig.2. The sloshing response of SFP

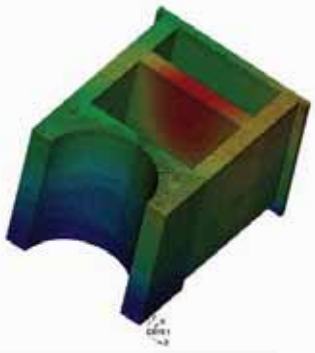


Fig.3. The FSI analysis of SFP

Inventorying Model of Nuclear Power Plant Decommissioning Waste and Dismantling Engineering Plan

Decommissioning a nuclear power plant is a technically complex and challenging task that involves multiple disciplines such as engineering, radiation safety and management, which all need to be considered during the whole life time of the task. The first critical step in decommissioning is to conduct a comprehensive inventorying of waste. This process directly influences the precision and safety of waste treatment and disposal. The inventorying requires detailed documentation of the weight, dimensions, and radioactive characteristics of each item followed by effective classification to meet radiation protection and environmental standards to ensure the health of personnel and environmental safety. Moreover, dismantling operations should optimize resource utilization and cost management to achieve an economically efficient decommissioning process. Successfully implementing these steps not only ensures the smooth progress of decommissioning work but also minimizes environmental impact, laying a foundation for sustainable development.

NARI has established a methodology for waste inventorying and dismantling (as shown in Fig.1 and Fig.2) that encompasses various aspects such as waste classification, transportation, treatment methods and cost estimation, aiming to create comprehensive inventory data. The development of this model uses internal information related to mechanical, instrumentation, and electrical equipment as well as civil structures within the nuclear power plant. It is further supplemented by on-site investigations and interviews with plant personnel to obtain detailed information, including weight, dimensions, and levels of radioactivity. This information forms the foundation of decommissioning planning, which facilitates accurate assessment of waste disposal requirements while ensuring the safety and efficiency of dismantling operations. Currently, this methodology has been successfully implemented at Chin-Shan Nuclear Power Plant (as shown in Fig.3) and is applicable to subsequent decommissioning projects at other nuclear power plants.

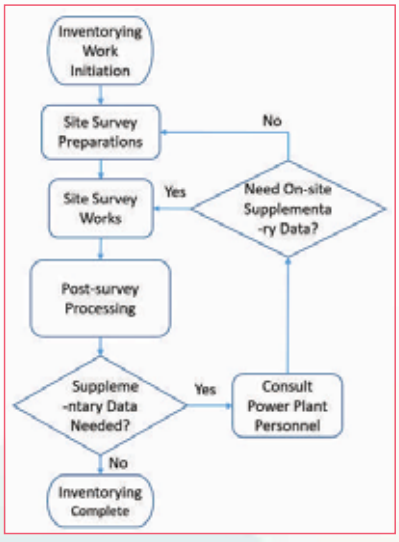


Fig.1. Procedures for Inventorying of Nuclear Power Plant Decommissioning Waste

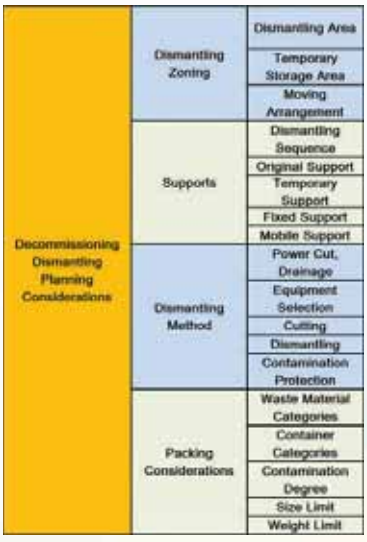


Fig.2. Planning Considerations for Nuclear Power Plant Decommissioning and Dismantling Projects

Fig.3. The Combined Building and Turbine Building of the Chin-Shan Nuclear Power Plant: Unit 1 is on the left, and Unit 2 is on the right.
(The image source is from the website of Taiwan Power Company.)

Development of Decommission Engineering Management System Used for Nuclear Power Plant Decommissioning and Waste Tracking

Chinshan nuclear power plant has already obtained decommissioning approval. Still, decommissioning process faces challenges such as waste disposal quantities estimating, decommissioning sequence planning, decommissioning costs estimating, and waste disposal process tracking solutions. In order to deal with above mentioned issues, also enhance the capabilities of domestic decommissioning technology, Chinshan nuclear power plant has collaborated with NARI to establish the Decommission Engineering Management System (DEMS). Detailed waste inventory data can be established in the system to provide a basis for dismantling cost assessment, while also recording the entire waste disposal process. Eventually, statistical charts can be presented to managers, giving them up-to-date information to effectively monitor project progress and management cost.

DEMS is the first domestically developed system for nuclear power plant decommissioning tasks. It effectively supports designing of the removal of components, equipment, instruments, and pipelines within nuclear facilities. The system also manages the waste handling process, allowing accurately tracking of waste history. Furthermore, all decommissioning-related information and charts are real-time recorded and presented, which create permanent digital records serving as reference data for future operations.

DEMS is built with a modular design, enabling users to customize workflows. It has been successfully implemented in dismantling operations at the 69 KV switchyard and turbine generator of Chinshan nuclear power plant. In the future, the system can also be applied to Kuosheng, Maanshan nuclear power plants, or any other operations that require logistics management.

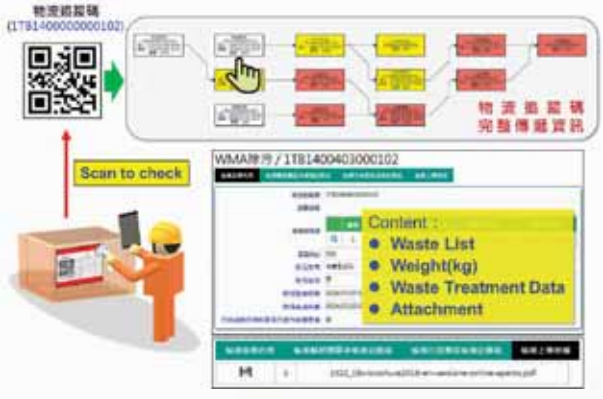


Fig. 1. Waste Treatment History Inquiry

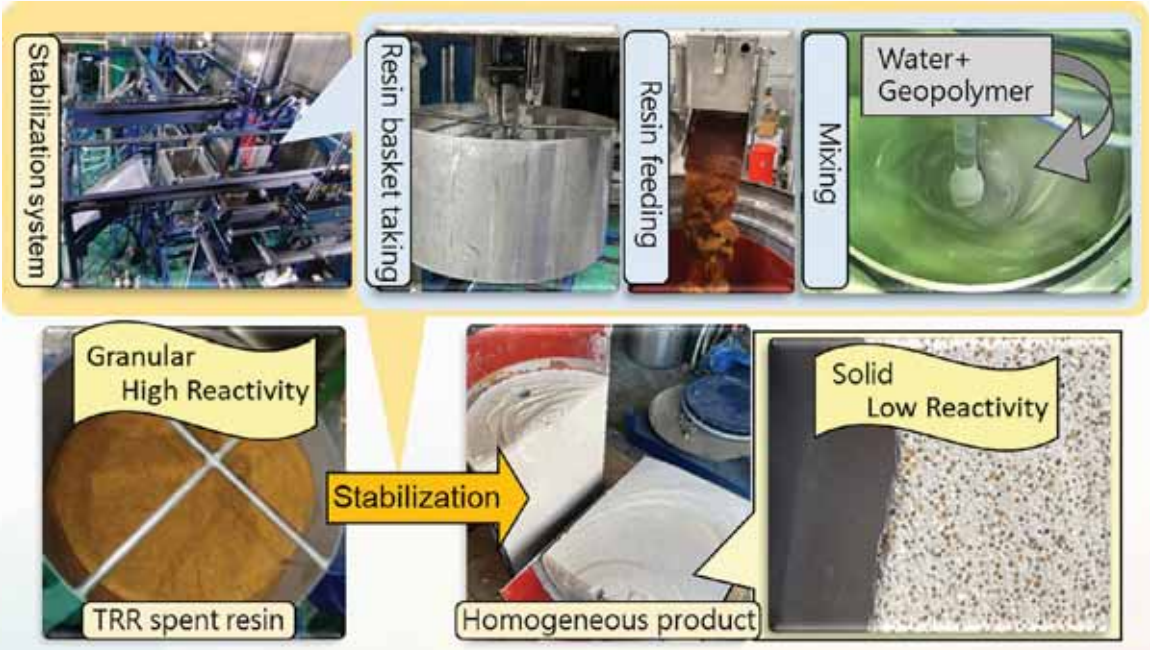
Fig. 2. Waste Treatment Status Chart

Technology Development of Stabilizing Radioactive Contaminated Resin

There were sludge containing fine particles of spent fuel spread throughout the spent fuel pool of the Taiwan Research Reactor (TRR) due to rupture of several fuel rods in the past. As a result, bead-type spent ion exchange resins were accumulated from water treatment processes. These TRR spent resins were classified as Greater-Than-Class C (GTCC) waste. According to the Regulations of the Treatment and Storage of Radioactive Waste and Safety Management of Facilities and the TRR decommissioning plan, the TRR spent resins must be stabilized. These resins present a treatment challenge due to their high radioactivity. Currently, the spent resins are loaded into drums for temporary storage awaiting stabilization.

To solve this problem, NARI has developed a stabilization process for TRR spent resins, incorporating reclassification technology, geopolymer technology, and a specialized stabilization system. Through reclassification, approximately 60% of TRR spent resins can be downgraded to non-GTCC waste, reducing container usage and disposal costs. Geopolymer was adopted to enhance solidification efficiency and stability much better than Portland cement, and the treatment system was designed with radiation shielding and remote operation capabilities to minimize personnel exposure.

This is Taiwan's first treatment technology for GTCC bead spent resins. In 2024, NARI established the stabilization system and completed functional verification tests. Efforts are ongoing to optimize the TRR spent resins stabilization process, with comprehensive testing planned for 2025. This stabilizing technology for radioactive contaminated spent resins offers an effective waste management solution for NARI's facility and TPC's nuclear power plants.



Stabilization process of TRR spent resins

Key Technologies for Radioactive Waste Resin Management — Volume Reduction and Stabilization

According to technical reports from International Atomic Energy Agency (IAEA), radioactive ion-exchange resins may degrade and release radionuclides under prolonged radiation exposure. Additionally, these resins cannot be directly solidified using cement and are currently stored in barrels at storage facilities.

Research Achievements

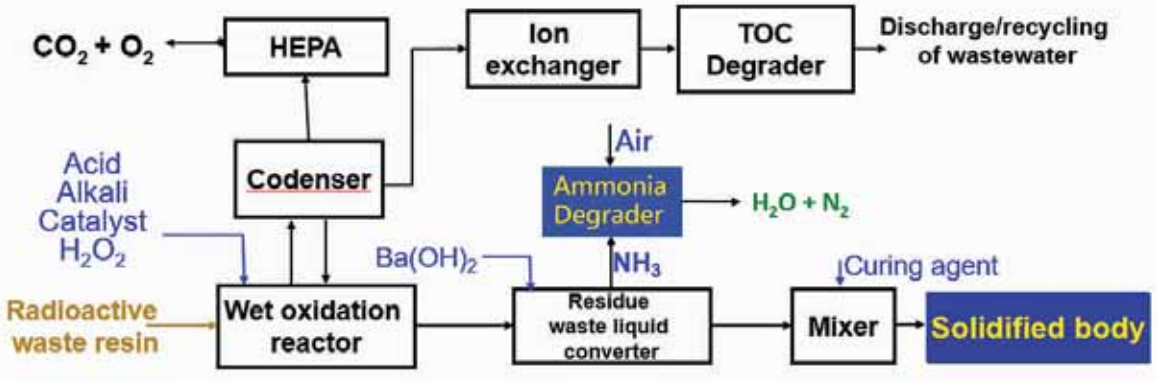
1.This patented technology employs wet oxidation to convert waste resins into inorganic aqueous solutions, which are then transformed into stable salts. Simultaneously, radioactive nuclides are concentrated and reduced in volume, forming a stable solidified waste form.

2.After stabilization, the volume of waste resins can be reduced by one-third to two-thirds.

3.Using a copper-based catalyst, ammonia can be safely oxidized into nitrogen gas and water under temperatures below 450°C.

Research Benefits

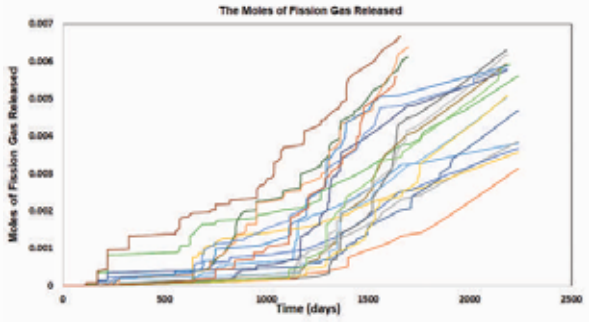
Currently, Taiwan has accumulated approximately 20,000 barrels (55-gallon drums) of radioactive ion-exchange resins, which are stored in facilities awaiting treatment. By applying this technology, the volume can be reduced to approximately 6,700 barrels of solidified waste. It is estimated that this will save approximately NT$2 billion in final disposal costs.



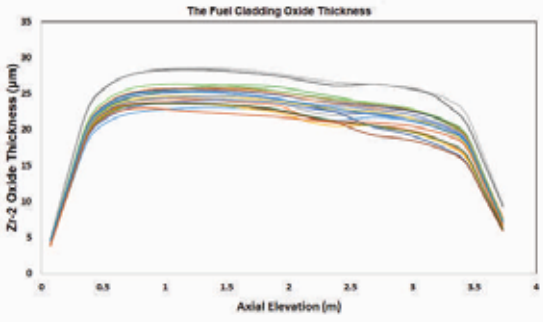
BWR High Burnup Fuel Characterization Analysis Technology

The nuclear fuel behavior analysis code is an essential tool for predicting fuel performance during operation and storage. Through precise numerical simulations, key fuel characteristics under various operating and storage conditions can be evaluated, providing a technological basis for fuel design, core operation safety assessments, and backend fuel management strategies. As nuclear power technology advances, global plants are increasingly adopting high burnup fuel to enhance utilization efficiency and reduce spent fuel production. However, high burnup fuel experiences greater radiation damage, leading to cladding oxidation and hydrogenation, which may affect its long-term storage and final disposal integrity. To ensure fuel safety under different conditions, it is crucial for Taiwan to establish its own fuel analysis technology and expert team to support long-term storage and disposal of high burnup fuel.

NARI has successfully introduced and implemented an internationally recognized nuclear fuel behavior analysis code to complete simulations of irradiated BWR high burnup fuel in Taiwan's NPP. The study evaluated key fuel characteristics under various operational modes, including fuel centerline temperature, rod internal pressure, fission gas release, cladding stress, oxidation layer thickness, and hydrogen pickup. The analysis results confirm that domestic BWR high burnup fuel can be directly stored in dry storage systems without additional canisters, significantly reducing costs and improving management efficiency. NARI has also established a dedicated fuel behavior analysis team capable of efficiently assessing nuclear fuel performance and providing technical support for spent fuel management strategies. This technology can be further applied to various fuel types and storage conditions, supporting long-term safety assessments of high burnup fuel and strengthening Taiwan's technical self-reliance in nuclear fuel management.



Analysis Results of Fission Gas Release Distribution Over Time



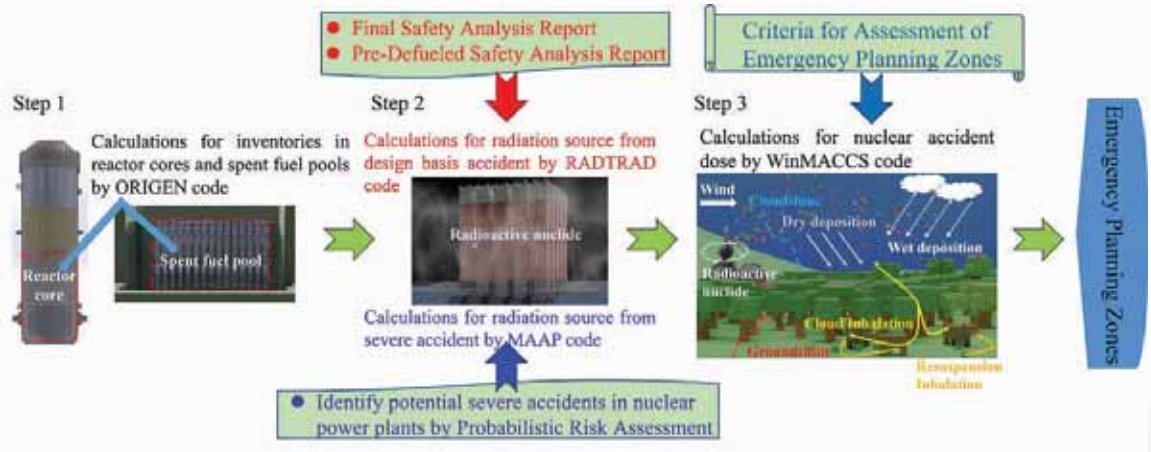
Analysis Results of Axial Distribution of Cladding Oxide Thickness

Analysis Results of Irradiated BWR High Burnup Fuel Rods in Taiwan's NPP

Ensuring Public Health and Property Safety — Defining the Emergency Planning Zones of Nuclear Power Plants through a Systematic Evaluation Approach

Based on the principle that disaster prevention is better than disaster response, the government has established Emergency Planning Zones (EPZs) to plan and prepare for disaster response, thereby ensuring public safety and health. Concurrently, the government enacted the Nuclear Emergency Response Act, which asks the nuclear facility operator to periodically review and update current EPZs associated with the nuclear reactor facility. Thereby, National Atomic Research Institute (NARI) developed an innovative systematic analysis technology that includes calculations for inventories in reactor core and spent fuel pool, severe accident analysis, design basis accident analysis and nuclear accident dose assessments. This system integrates upstream and downstream analytical tools (e.g., ORIGIN, MAAP, RADTRAD, and WinMACCS), as illustrated in below figure. This integrated technology combines the strengths of various analytical tools, ensuring that each stage of the analysis is comprehensively considered and accurately calculated. The integrated system also features an intuitive graphical interface, enabling faster data interpretation and assisting the decision makers in making accurate judgements. This is critical for establishing EPZs and ensuring public safety.

The result in 2022 suggested that the EPZs for the domestic Nuclear Power Plants (NPPs) are within 2.5 km. However, due to the announcement from government, the EPZs remain at 8.0 km. Should requirements arise to relax the EPZs for NPPs in the future, the land around the NPPs can be revitalized for use, aligning with the nation's greatest public interest and optimal regulatory practices. Currently, however, EPZs remain unaltered under existing policy. Regularly, the nuclear facility operator conducts reviews and updates of the EPZs. This is crucial for NPPs to identify potential risks, safeguarding public health and property. Furthermore, It can also enhance the public's positive perception of government's commitment on nuclear power safety and improve public trust in the safety of NPPs.



Systematic Analysis Process and Tool Integration Techniques for EPZs

Key Technology of Advanced Liquid Processing System (ALPS) for Treatment of Radioactive Wastewater

After the accident of Fukushima Daiichi Nuclear Power Plant, a large quantity of radioactive wastewater was generated due to the fact of seawater and groundwater had been introduced into the reactor core of the damaged nuclear power plant. In light of the lessons learned from that, it is imperative to develop advanced liquid processing system as key technology for the treatment of radioactive wastewater, ensuring preparedness for handling future accident.

Research Achievements

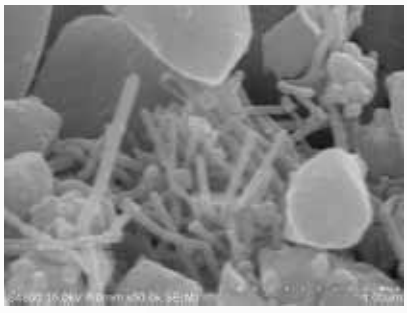
1.Calcium and magnesium ions in seawater-based wastewater can be removed using the carbonate co-precipitation process.

2.The decontamination factor for I-129 of the composite material of nanoscale silver supported on activated carbon can reach up to 755, ensuring that the water quality complies with I-129 regulatory standards.

3.An adsorbent designed for the removal of strontium, featuring an adsorption capacity of 5.0 meq/g and a Sr-90 decontamination factor exceeding 1000 has been prepared.

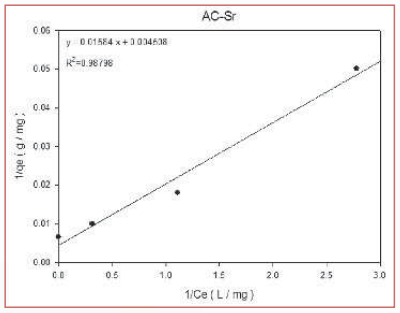
Research Benefits

Establishing the ALPS process, which combines chemical co-precipitation with adsorption, along with the development of high-performance adsorptive materials, enhances the treatment capacity for responding to accidents. This approach can also be applied to manage complex wastewater from nuclear facilities at NARI or during the decommissioning of nuclear power plants, targeting removal of nuclides other than tritium.



Composite material of nanoscale silver supported on activated carbon

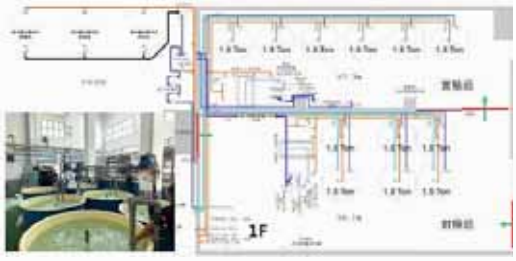
High performance granulated strontium adsorbent



Isotherm fitting curve of high performance of strontium adsorbent (adsorption capacity 5.0 meq/g)

Annual Test Results from the National Biological Tritium Testing Facility at National Atomic Research Institute

In response to Japan's discharge of tritiated wastewater treated by Advanced Liquid Processing System (ALPS), this project aims to simulate a tritiated seawater environment for aquaculture breeding experiments. A National Biological Tritium Testing Facility has been established at National Atomic Research Institute for indoor seawater aquaculture experiments involving tritiated seawater and biological tritium. Starting in June 2024, tritium was added to begin biological testing using commonly consumed seafood species. Scientific data will be analyzed to assess the relationship between inorganic tritium levels in seawater and organic tritium present in seafood. This analysis will establish a model to measure trends in metabolic coefficient changes and to evaluate the health risks posed by tritium isotopes to human health. The data obtained will provide the government with necessary information to implement appropriate management measures, thus ensuring the safety of seafood consumption for the public.

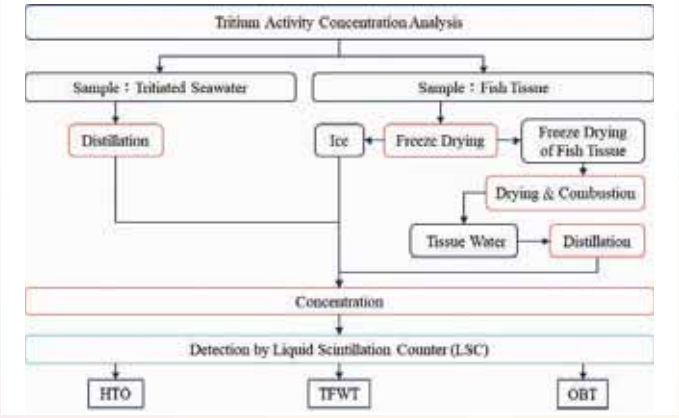


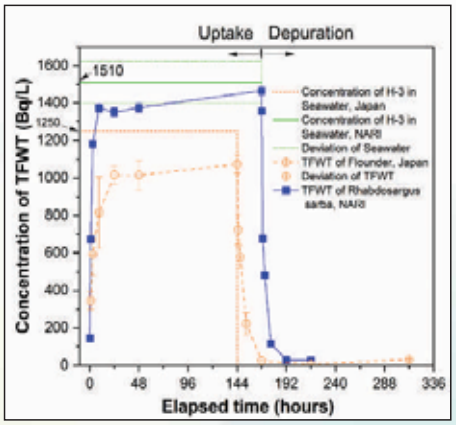
At the National Biological Tritium Testing Facility of the National Atomic Research Institute, tritiated seawater aquaculture of marine organisms is being conducted, along with metabolic and accumulation trials for sampling. Preliminary test results have been completed, summarizing the following key points:

1.The TFWT in fish reaches equilibrium within approximately 24 hours and is expelled from the fish's body within 24 hours.

2.The tritium activity of free water tritium (TFWT) in fish tissue has a ratio of about 0.9 compared to the tritium concentration in seawater.

3.Tritium does not remain in the biological organism but is expelled through metabolism





Nuclear Medicine and Radiation Applications for Public Welfare

Proton Irradiation Testing Technology at NARI

The Proton Irradiation Testing Technology at NARI is led by the Proton Irradiation Verification and Analysis Laboratory, offering a range of proton-related verification and measurement services, specifically focusing on the screening and verification of satellite components.

With two cyclotrons planned (15-30 MeV and 28-70 MeV by 2027,as shown in Fig.1) and medical proton therapy platforms (70-200 MeV), the testing energy range will extend from 15 to 200 MeV to meet various application requirements.

The laboratory is equipped to measure proton beam profiles, energy, and flux, and it also provides irradiation dose assessment services. Furthermore, it has established equipment for single-event effect testing of electronic components, enhancing its capabilities to meet a wider range of future testing requirements and improving the reliability and durability of satellite components(as shown in Fig.2 and Fig.3).

NARI's space proton irradiation testing technology addresses a critical gap in proton testing, enhancing space radiation testing capabilities and supporting the development of national space programs. It drives growth in space technology, electronics, and semiconductors. The laboratory focuses on validating advanced materials and components, testing quantum materials, and exploring emerging technology applications. By strengthening radiation-resistant verification infrastructure, it provides robust support for space science research and industrial technical services, advancing national space technology.

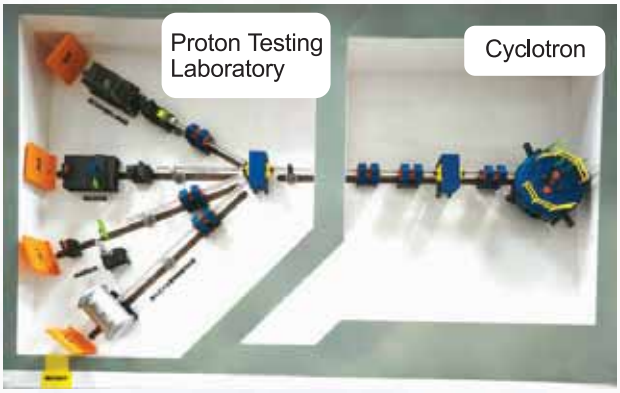


Fig.1. Structure Diagram of the Proton Testing Laboratory

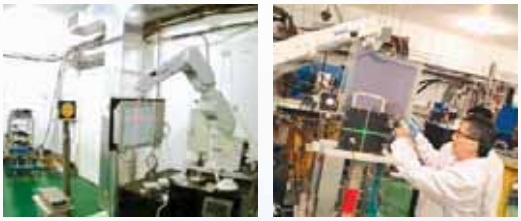


Fig.2. 30 MeV On-Site Testing Setup

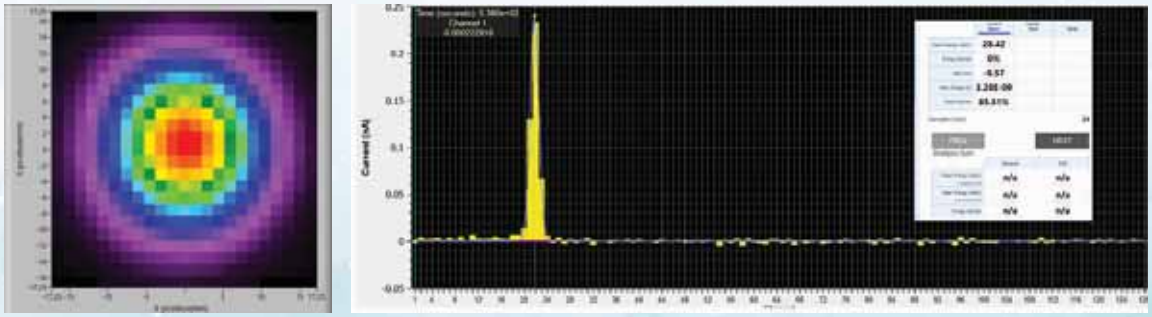


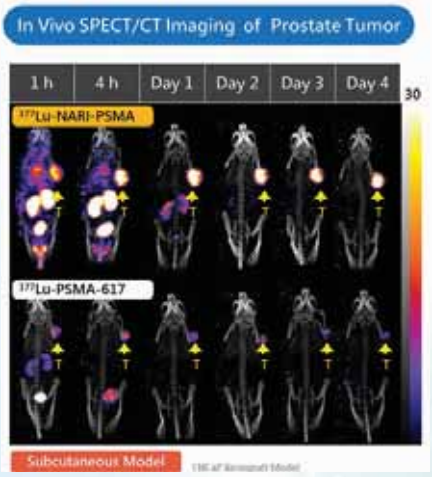
Fig.3. Proton Source Profile and Energy Measurement

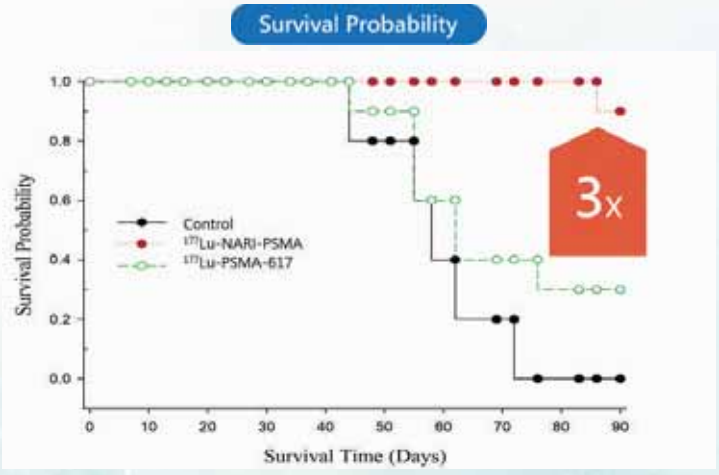
Development of Long-Acting Targeted Radiotherapeutic Agents for Prostate Cancer: A Focus on Lu-177-PSMA-Based Molecular Innovation

Prostate cancer is the fifth most common cancer in Taiwan, increasing annually, mainly affecting the older men. Early-stage prostate cancer often presents without symptoms, making it easy to overlook. Early treatment options include Da Vinci robotic surgery and high-intensity focused ultrasound (HIFU) therapy, while hormone therapy is used for intermediate-stage cancer. In advanced stages, chemotherapy and radiation can slightly extend survival, but hormone therapy resistance reduces effectiveness, creating a strong need for new treatments, especially for metastatic castration-resistant prostate cancer. The National Atomic Research Institute has developed Taiwan s first "long-acting" targeted radiotherapy drug, Lu-177-NARI-PSMA. This drug combines prostate-specific membrane antigen (PSMA), a chelator, a linker, and an albumin-binding site with the radioactive isotope Lu-177. It offers advantages such as high safety, long-lasting effects, high specificity, low background radiation levels, and is easy to synthesize, making it a promising treatment for prostate cancer.

Lu-177-NARI-PSMA is designed to extend its circulation time in the body, making it "long-acting." Animal studies showed that 96 hours after injection, tumor accumulation was 6.4 times higher than the benchmark drug, Lu-177-PSMA-617. Furthermore, the survival rate of treated animals was also tripled by day 90 showing clear therapeutic benefits In Toxicity tests at 1,000 times the clinical dose revealed no significant toxicity, confirming its safety.

In clinical applications, Lu-177-NARI-PSMA is expected to require only 50% of the radiation dose of the benchmark drug while achieving similar or superior results. With just 1-2 injections, the treatment could be completed, reducing medical costs by over 50% and significantly easing the financial burden on patients.



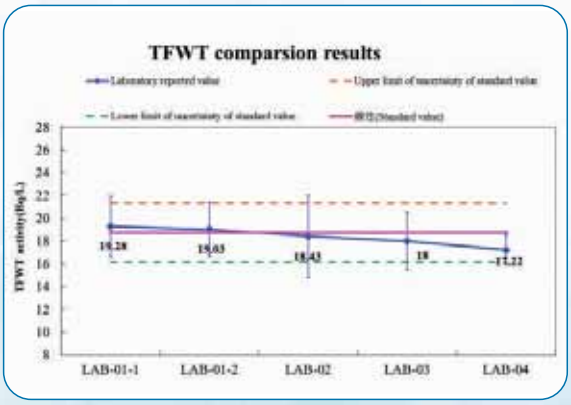


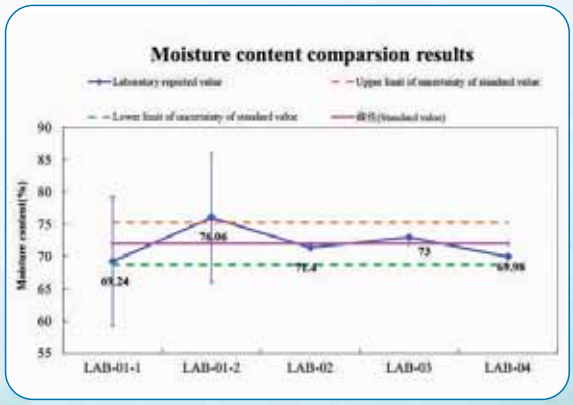
Interlaboratory Proficiency Test for Biological Tritium Analysis

In response to Japan's long-term practice of discharging ALPS (Advanced Liquid Processing System)-treated water from the Fukushima nuclear power plant into the ocean, the accurate detection and analysis of tritium absorbed and accumulated in marine organisms through metabolism are essential. These efforts provide crucial data for assessing the impact of prolonged discharges on the marine ecosystem and human radiation safety through seafood consumption. Currently, domestic radiochemical analysis laboratories focus on tritium analysis techniques for environmental water samples, primarily associated with routine nuclear facility operations. However, considering Japan's discharge of APLS-treated water, monitoring targets have shifted to marine organisms. Developing and validating tritium analysis techniques for marine life requires professional, impartial, and independent institutions (for example, TAF) to conduct capability verifications using scientific methods.

The NARI convened four domestic laboratories engaged in biological tritium detection. On April 25, 2024, an informational meeting was held to outline the interlaboratory proficiency test schedule, matrix types, tritium activity ranges, and acceptable minimum detectable activity (AMDA). The test sample distribution was completed on May 28, 2024, with results submitted by June 14, 2024. A summary meeting was held on June 20, 2024, marking the successful completion of the interlaboratory proficiency test. For this test, commonly encountered sample types during analysis were selected, using fish as the matrix. Edible portions of the fish were extracted following pre-treatment, with tissue water removed using freeze-drying technology. The samples were then rehydrated with tritiated water, allowed to stand overnight to remove excess tritium solution, sealed, and refrigerated for delivery to participating laboratories. Additionally, each laboratory was provided with an untreated bonito weighing approximately 1.2-1.4 kilograms to test for moisture content. Each laboratory conducted tests using either the first-phase screening method for tissue-free water tritium (TFWT) as published by the Ministry of Health and Welfare's FDA or their own procedures. They reported tritium activity (TFWT) and moisture content results for comparisons.

Results of the interlaboratory proficiency test for biological tritium: participating laboratories used either the publicly disclosed testing method by the FDA (freeze-drying) or laboratory-developed methods (heat distillation). The tritium (TFWT) activity in fish samples compared to the standard value showed a relative deviation ranging from -8.1% to 2.9%. Additionally, the moisture content in the fish samples compared to the standard value had a relative deviation ranging from -3.8% to 5.7%. In summary, the analysis results from the four laboratories participating in this year's proficiency test had $|E_n$(error normalized)| values all below 1.0, meeting the requirements ($|E_n \leqslant 1|$) set by the organizing institution.





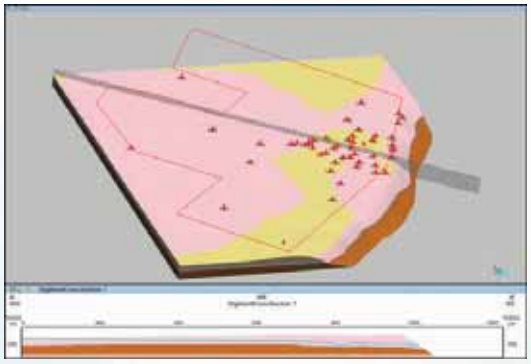
Integration of Hydrogeological Simulation and Geological Modeling: Case Study of Sandstone and Conglomerate Layers

Limited by the resolution of traditional geological surveys, hydrogeological simulations have usually applied simplified models for computation. However, three-dimensional geological modeling technology can establish high-resolution geological models, offering a multifaceted perspective to analyze subsurface geological conditions.

In this study, drilling data and hydrogeological simulation results, based on the region of National Atomic Research Institute, are integrated and presented through 3D visualization. The 3D geological model provides feedback on the hydrogeological simulation results while demonstrating its application benefits, execution challenges, and future prospects.

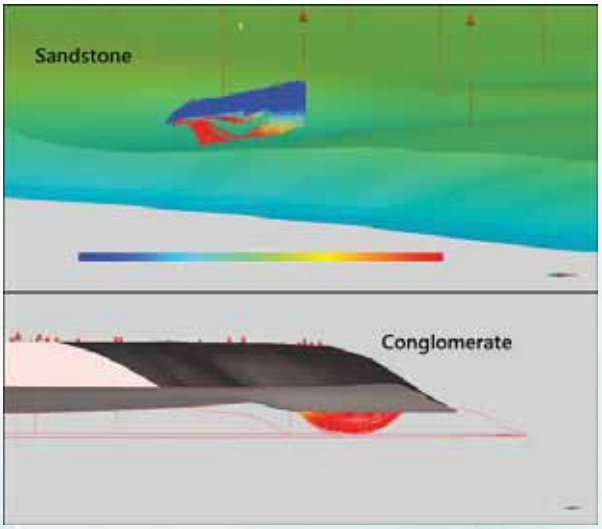
This study employs SKUA-GOCAD for 3D geological modeling and overlays the hydrogeological simulation results computed using simplified models in FracMan to conduct a comprehensive comparison of geological information. The high-resolution geological model assists in interpreting hydrogeological simulation results while demonstrating multi-perspective observation, thereby enhancing the objectivity of geological interpretation.

The integrated application of geological modeling technology enables complex geological survey and simulation data to be presented visually. By combining information from multiple fields, it facilitates comprehensive interpretations in environmental and earth sciences, providing intuitive and objective information for applications and decision-making. This has significant value in various domains, including engineering geology, groundwater research, carbon sequestration, geothermal exploration, and radioactive waste disposal.



(3D Geological Model)

- Yellow, pink, and brown color represent different lithologies.
- Red dots represent borehole locations.
- The gray area is the profile location. The lithology and structure can be observed in profile.



(3D Geological Model Overlaid on Hydrogeological Simulation Results)

The New Cornerstone of Radiotherapy — LINAC Photon Dose Calibration System

The National Radiation Standard Laboratory (NRSL) of NARI is responsible for establishing the highest measurement standards for ionizing radiation in Taiwan. NRSL provides radiation measurement and standard transfer services to ensure accurate calibration and traceability for radiation measurement equipment.

Radiation standards are crucially important to radiotherapy. They serve as the cornerstone for determining the doses received by patients. Generally, output doses of facilities used in radiotherapy such as Linear Accelerator (LINAC), CyberKnife, TomoTherapy and Novalis are measured and specified using ionization chambers calibrated with the Co-60 beam at the standard laboratory. However, these treatment devices mostly generate high-energy photon beams, whose energies are different from the Co-60 beam used for calibration, additional corrections are required during the dose specification process in the hospitals to obtain the actual output doses.

NRSL has spent several years developing a LINAC photon dose calibration system suitable for clinical radiotherapy facilities. The essence of the system is a graphite calorimeter whose core is a pure graphite block measuring 1.6 cm in diameter and 3 mm in thickness. The total mass of the graphite block is only about 1 gram. By measuring minute temperature differences of the graphite block after irradiation, dose measurement for high energy photon beams can be performed accurately. The system was also validated through cooperation with NTUH, CGMH and other medical institutions. As a result, calibration services with higher accuracy and without the need for corrections can therefore be provided.

Based on this achievement, NARI has not only set up a LINAC photon dose calibration system but is also heading towards the development of measurement technologies for the thriving proton and heavy ion beams, to further support and facilitate the growth of Taiwan's biomedical and space industries.

The NRSL (NARI) self-developed graphite calorimeter system

The NRSL (NARI) LINAC photon absorbed dose calibration system

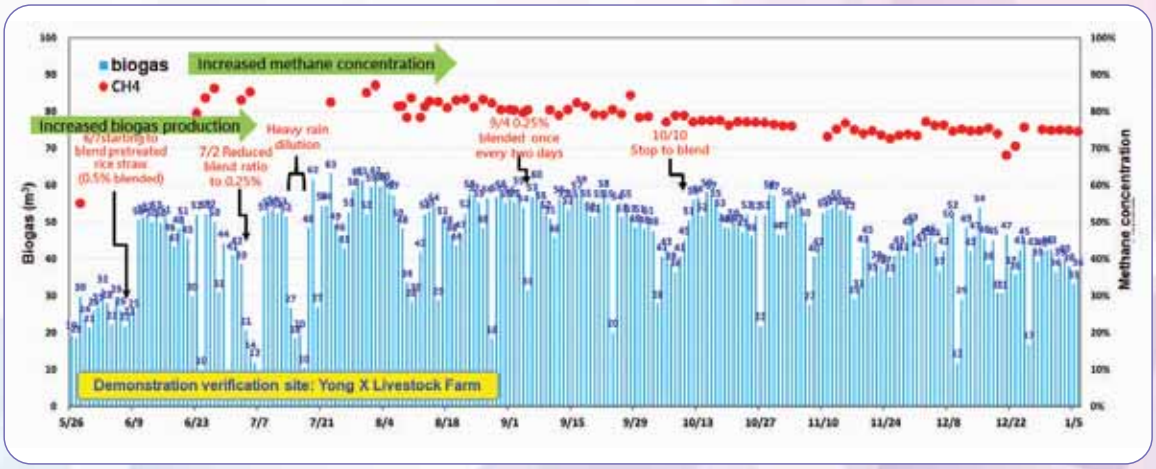
New Energy and Cross-Field System Integration

Innovative Technology for Enhancing Biogas Production from Lignocellulosic Biomass

In recent years, government-supported biogas facilities have been established to process livestock manure, food waste, and industrial sludge through anaerobic digestion, converting biogas into electricity. Taiwan's biogas industry mainly relies on livestock farming, with pig manure accounting for 85% of feedstock. However, most pig farms are small and dispersed, making its collection challenging. While larger farms enable initial-scale biogas production, relying on single feedstocks limits its available output. Co-digestion with pretreated agricultural residues and fruit peels can enhance biogas yield, making it a viable method to expand Taiwan's biogas capacity and promote low-carbon biofuel production.

This innovative, low-energy, low-carbon technology enhances biogas production from lignocellulosic biomass with livestock wastewater, significantly increasing yield and economic value. It expands biogas feedstock to include fiber-rich biomass, allowing a 1.5- to 2.8-fold yield increase through anaerobic co-fermentation with livestock waste. By use of NARI's method, it shortens biogas production from three months to 14 days and boosts yield by 10 to 100 times. The process also generates lignin by-products for biochemical applications. Now we have conducted commercially technical-transfer so as to validate the technology in a demonstration field. We set forth to advance the domestic biogas industry, bridging gaps in the biogas value chains.

Verification results at demonstration site operation

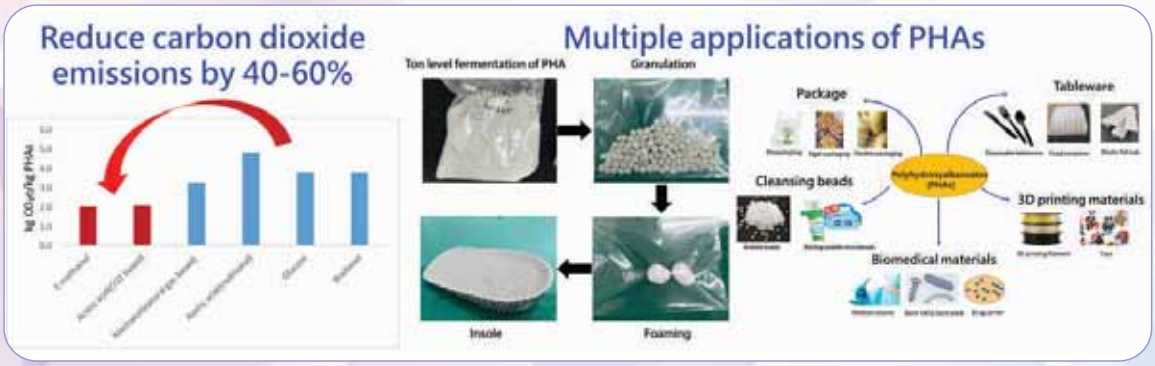


- Significant Biogas Production Increase: Daily biogas yield doubled (100% increase) after mixing with Napier grass residues.
- Notable Methane Concentration Improvement: Methane concentration increased from 55-60% to approximately 70-95% (average 80%).

Technology for Producing Polyhydroxyalkanoates with Low Carbon Emissions and Sustainability

To minimize the impact of greenhouse gases on climate change, governments worldwide are committed to decreasing carbon dioxide emissions and aiming for net-zero carbon emissions by 2050. The use of CO_2 capture and utilization (CCU) technology to produce fuels, chemicals, and materials is one of the options for achieving a circular economy and environmental sustainability. NARI integrates CCU and biorefinery to develop a low-carbon process to produce sustainable and environmentally friendly marine biodegradable plastic-polyhydroxyalkanoates (PHAs). Compared to using food crops as raw materials for microbial fermentation in plastic production, utilizing methanol or acetic acid derived from CCU offers the potential advantage of replacing petroleum-based/petrochemical-made plastics and a path to meet net-zero emission requirements. Furthermore, carbon dioxide in the atmosphere could serve as abundant resource for the plastics industry within the circular economy in the future.

NARI develops a domestication method to yield a strain with quadrupled acetic acid tolerance. A mutation method is used to genetically modify a strain for enhanced methanol utilization, leading to a 1.5-fold increase in PHAs production. The research and development achievements are validated through a ton-scale demonstration facility, completing the production and purification verification of PHAs. Insoles are then manufactured using granulation and foaming technology. This marks the first time in Taiwan that single-carbon and double-carbon compounds be used as raw materials to produce marine biodegradable plastics through ton-level fermentation. PHAs is one of the few materials that are marine degradable and have biodegradability and biocompatibility. PHAs also offer excellent gas barrier and thermal processing properties, making it suitable for various industries such as packaging, tableware, building materials, and biomedical materials. By combining the characteristics of a low-carbon bioconversion process with methanol or acetic acid produced by CCU in the domestic petrochemical industry to produce PHAs, it can not only extend the carbon sequestration cycle, but also significantly reduce carbon dioxide emissions.



Analysis and Verification of Compressed Air Energy Storage System

In alignment with the national strategy for large-scale renewable energy deployment, the development of a long-duration, cost-effective energy storage system is essential to address the intermittency and variability inherent in renewable power generation. Compressed Air Energy Storage (CAES) is a viable technological solution that utilizes off-peak electricity to compress air, which is then stored as high-pressure gas in suitable geological formations such as abandoned mines, submerged gas tanks, salt caverns, or depleted oil and gas reservoirs. During periods of high electricity demand, the stored compressed air is released, mixed with natural gas, and combusted to produce high-temperature gas, which is expanded through turbines to generate electricity. The advancement of CAES technology, in coordination with the energy and power dispatch requirements of large-scale renewable energy systems, can significantly enhance grid stability, improve energy security, and contribute to the realization of national carbon reduction targets.

This work encompasses three key projects: system design analysis, gas reservoir multiphase flow analysis, and comprehensive financial evaluation. The system design analysis involves selecting mechanical components on the ground, designing operating parameters, and estimating overall system performance based on site characteristics. Gas reservoir multiphase flow analysis ensures safe reservoir operation while providing sufficient gas output to drive turbines for electricity generation. Based on the designated conditions, the financial feasibility evaluation is conducted. The levelized cost of energy storage (Fig.1) and cash flow (Fig.2) are illustrated. It indicates that there still room for the CAES to be explored. Currently, we are collaborating with industry partners on a technical service project titled "Benefit Estimation for the Application of Compressed Air Energy Storage (2MW) System" to help domestic companies develop technical expertise. The demonstration and verification can be conducted. The industrial applications can also be expanded in the future.

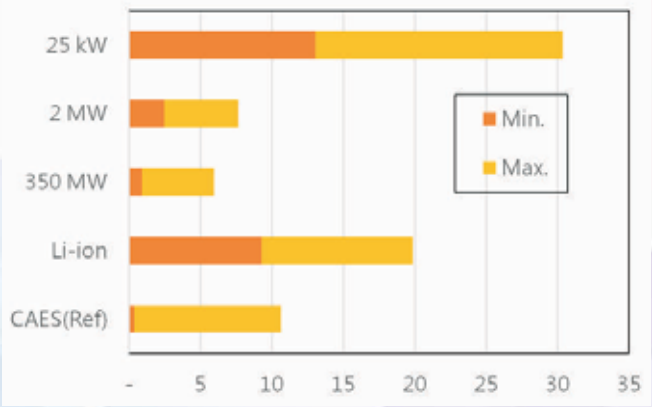


Fig.1. Comparison of levelized cost of energy storage

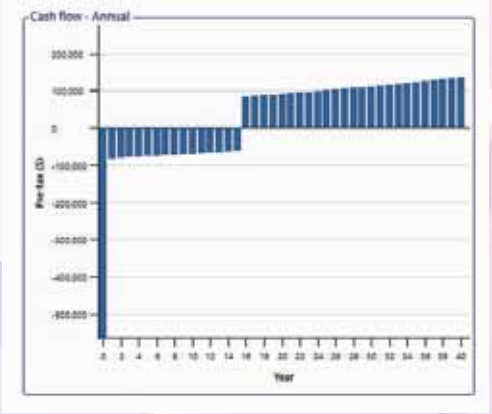
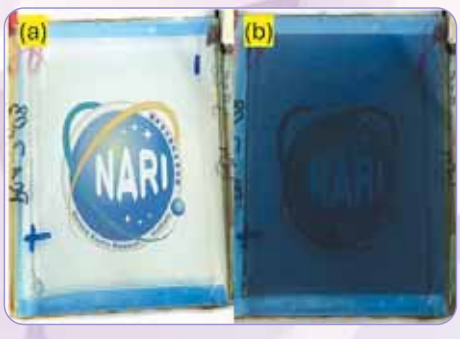


Fig.2. Pre-Tax Cash Flow Diagram for the 2 MW CAES system

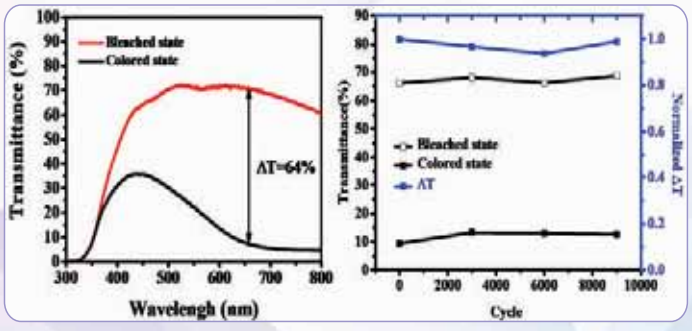
Low-cost, High-efficiency Rapid Solution-processed Electrochromic Technology

Electrochromic glass is a type of dimming element characterized by its ability to adjust light transmittance while maintaining a clear view. Buildings that use electrochromic glass can improve energy-saving efficiency. However, the high price and cost of such products, mainly due to the use of glass substrates and vacuum process technology, limit their widespread application in the general construction market. Additionally, the 2050 net-zero carbon emission plan requires industry to adopt low-carbon process technologies. Therefore, developing low-cost, fast, low-energy consumption, and low-carbon emission process technologies will help Taiwan gain a competitive advantage in the rapidly growing electrochromic film market. Solution printing processes, with advantages such as low carbon emissions, low energy consumption, rapid production, the ability to process in atmospheric environments, and low equipment setup costs, are considered one of the emerging technologies. In the future, the development of this technology is expected to become an industry choice for low-carbon processes.

NARI has been focusing on the development of innovative technologies for over ten years, dedicated to novel processes related to solution printing, and has extensive process equipment and R&D experience. In 2024, NARI first invested in the development of solution-printed electrochromic technology and achieved significant results. Solution-coated films usually require proper annealing to achieve good properties, often needing high temperatures for several hours or long durations at low temperatures to optimize the film. However, long annealing times are not suitable for rapid mass production processes and flexible plastic substrates. NARI developed a rapid near-infrared annealing technology, capable of completing annealing within one minute, with excellent color-changing properties and lifespan, addressing the drawbacks of traditional high-temperature and long-time annealing. This technology can be applied to flexible substrates, thereby reducing process costs. This technology was highly recognized at the 2024 Taiwan Innotech Expo (TIE), winning the gold medal in the invention competition.



Solution printed electrochromic device (a) bleached and (b) colored state.

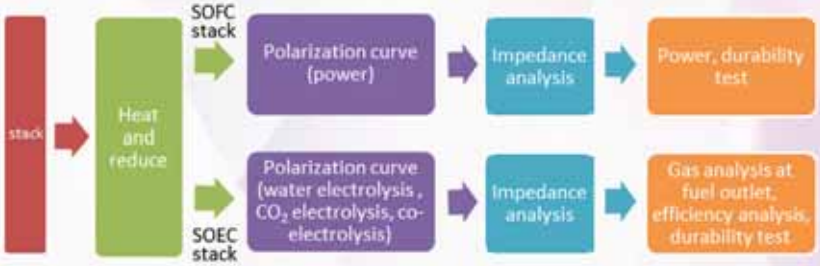


High contrast between colored and bleached state (ΔT=64%) and a cycling lifetime of nearly ten thousand cycles

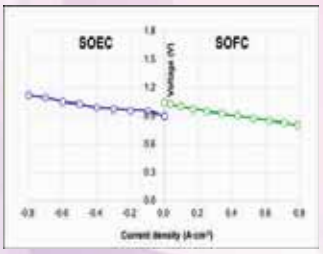
High Temperature Solid Oxide Cell Technology for Water Electrolysis Hydrogen Production

Following the trend of net zero emissions in 2050, the government is implementing five Net-Zero-Transformation policies, including activating second energy transformation, accelerating the development of recycling energy such as geothermal energy, hydrogen energy, bio-mass energy and ocean energy, to promote dual-axis transformation of digital and green industries. Nine billion dollars from the government fund are expected to be invested for carbon reduction including 24% energy share from recycling and hydrogen energy. Water electrolysis technology for hydrogen production with high temperature solid oxide cell is among the key technologies for net-zero carbon release and prospective hydrogen energy applications including hydrogen energy in replacement of fossil fuels and carbon-negative technologies for Co_2 reduction and utilization.

SOFC developed at NARI is an application of hydrogen energy for power generation with high efficiency and low emissions. Hydrogen production and syngas production are key technologies for green hydrogen production and CO_2 reduction and reuse. These can be achieved by SOEC with electric power from surplus power and/or renewable energy. A homemade stack with 10 metal-supported cells is tested in a dual-mode testing facility for both electricity and hydrogen production. At 700°C, electric power of 500 W with efficiency over 45% and a hydrogen production rate of 6 liters per minute are accomplished. In addition, homemade kW SOEC stacks are employed for hydrogen production at a rate of 1.1 m^3 per hour with 86 % conversion efficiency. The relevant SOEC testing configuration and apparatus have been filed patents both in Taiwan and the US patents to reserve intellectual protection and enhance the strength for co-opetition globally.



SOFC/SOEC testing procedures



SOFC/SOEC performance

Automatic Recognition of Relay Waveforms and Real-Time Event Notification Technology

With the introduction of versatile power sources into the electric grids, the power systems become more complex. And, it becomes more important to monitor and manage data from relay equipment. To maintain the equipment running safely and steadily, it strictly depends on real-time monitoring and data analysis. In fact, it is an essential challenge to handle abnormal events in relay equipment accurately. In this study, we present a complete system for managing data and handling events for relay equipment. This system combines features like waveform generation and notifications, automatic status updates, and data management. These tools increase the efficiency of power grid and enhance our capability to deal with the outages and recovery of power grids.

A key feature of this system is its automated event waveform data processing and real-time notification capability. When an abnormal event occurs, the system quickly collects and processes data, sending a real-time signal/file to operators, thus significantly speeding up incident response times. The automatic extraction of key data provides a reliable basis for response actions and analysis afterwards. This system can be equipped with different electric brands and models, resolving traditional manual processing and accuracy issues. In the future, it can be implemented to more facilities to improve the efficiency and stability of grid further.

● Automatic Relay Recognition and Waveforms Push Notifications

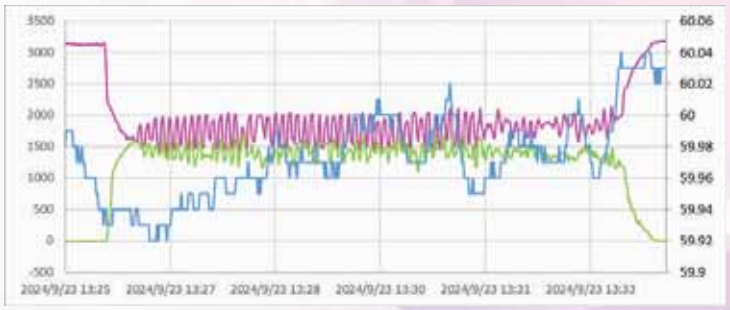
● Relay Analysis Management Platform and Field Deployment

Provision of Ancillary Services through NARI's MW-scale Microgrid

As a large amount of intermittent renewable energy feeds into the grid, the associated power dispatch will become more complicated, and the reliability of electricity will be significantly impacted. The microgrid (MG) can provide ancillary services to the distribution network in balancing power supply and demand, and maintaining power stability. NARI has devoted to develop power ancillary service techniques applicable for the MG, and validated them in the first domestic MW-scale MG. Of which, it comprises 100 kW PV, three 65 kW micro-turbines, a 750 kW diesel generator, a 750 kW battery energy storage system as well as a 250 kW hybrid active/reactive power regulation system. By means of numerous successful in-situ practices, it shows that the robust MGs can effectively integrate renewable energy into a flexible power entity.

- Developing energy dispatching technique based on the response time and duration of each distributed generator (DG), the MG can output more than 1 MW active power within 1 minute by power aggregation to reduce 33% of peak load consumption and last at least for 2 hours after receiving the Taipower's dispatching demand.
- Developing emergency decision-making and dynamic power compensation strategies to meet the execution indicator required by the Taipower's energy trading platform in case of the generator failures in DG or load demand changes during implementing ancillary service.
- Implementing 8 times of power ancillary services in total, including frequency regulation reserve, spin reserve and supplemental reserve as of February 18, 2025, which reduces 10,000 kWh of electricity consumption.
- Technology transfer to domestic industries to assist improving the capabilities of distributed energy integration and dispatching technology, and the total licensing fee reaches NT $5.74 million.

MW-scale microgrid



Electric energy consumption of NARI while microgrid providing frequency regulation reserve

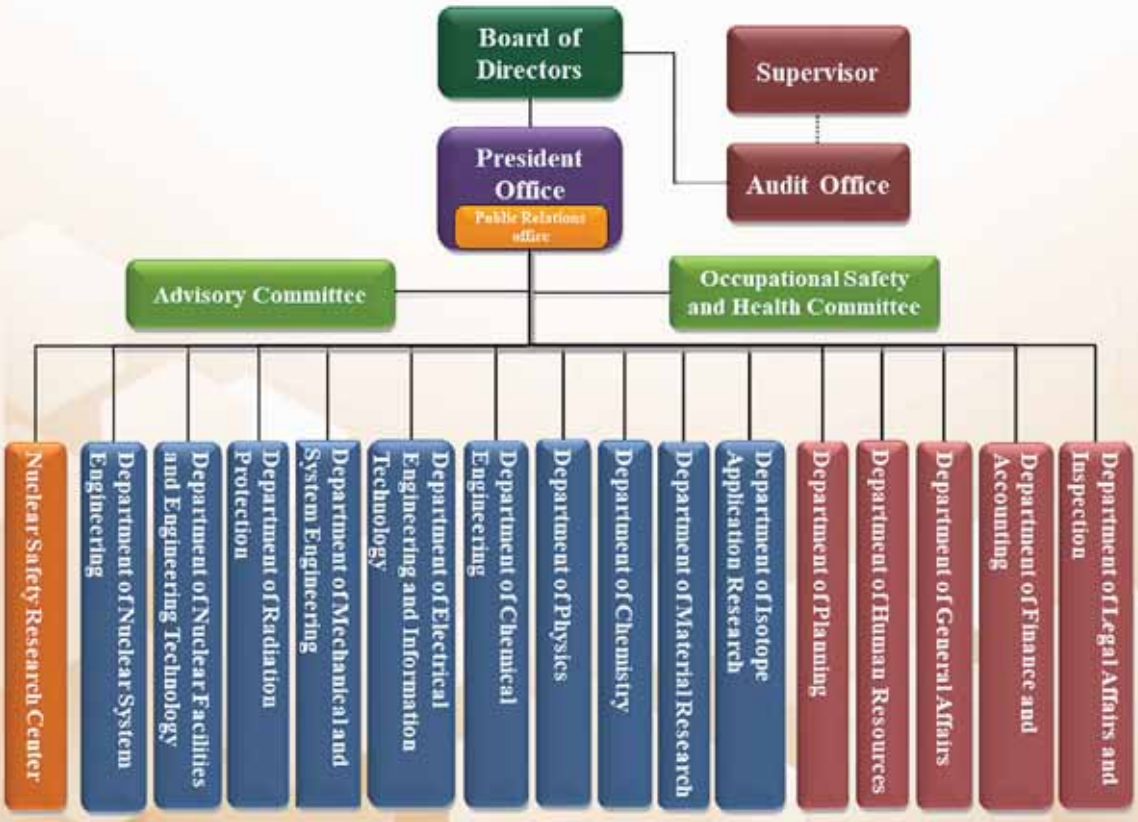
Current Operations and Management

Board of Directors and Supervisors

(Data Date: May 7, 2025)

Board Chair	Shin Chang
Director	Cheng-Wei Yu、Yao-Win Peter Hong、You-Min Huang、Chih-Kang Chiang、Qiu-Ying Qiu、Shu-Ling Huang、Susan Shur-Fen Gau、Jong-Shinn Wu、Faa-Jeng Lin、Szu-Li Chang、Hwen-Fen Hong、Chieh-Liang Wu
Executive Supervisor	Jia-Hang Li
Supervisor	Yun-Ying He、Hung-Yu Chuang

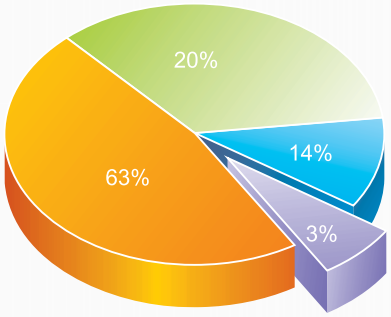
Organizational Chart



Human Resources

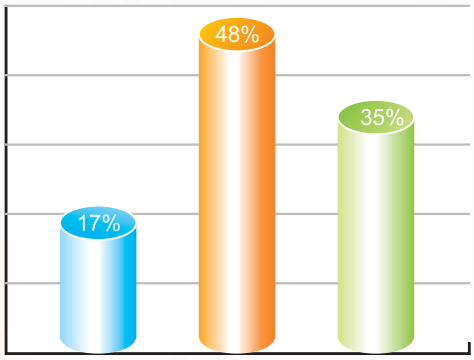
(Dec. 2024)

Number of Employees: 888 ／ Average Age: 46 years



Research Staffs	557 Persons	(63%)
Technicians	179 Persons	(20%)
Administrative Staffs	129 Persons	(14%)
Other Staffs	23 Persons	(3%)

Statistics of Educational Background



Ph.D.	151 Persons	(17%)
Master	430 Persons	(48%)
Bachelor's degree or below	307 Persons	(35%)

Financial Statements

Income and Operating Statement (Unit: NT)

Item	2024	2023
Income		
Business Revenue	2,768,372,888	783,834,868
Non-operating Income	8,204,340	475,384
Total Revenue	2,776,577,228	784,310,252
Expenses		
Business Costs and Expenses	2,508,877,403	734,690,473
Non-operating Expenses	0	225,411
Total Expenses	2,508,877,403	734,915,884
Net Income (Loss) before Taxes	267,699,825	49,394,368
Income Tax Expense (Benefit)	53,539,964	9,923,956
Net Income (Loss) for the Period	214,159,861	39,470,412

Balance Sheet (Unit: NT)

Item	2024	2023
Assets		
Current Assets	1,033,031,734	866,453,235
Property, Plant, and Equipment (PP&E)	941,148,207	1,076,284,089
Intangible Assets	176,556,814	165,435,208
Other Assets	2,140,807,990	1,760,979,645
Total Assets	4,291,544,745	3,869,152,177
Liabilities		
Current Liabilities	721,807,834	595,619,927
Other Liabilities	3,271,234,003	3,227,194,084
Total Liabilities	3,993,041,837	3,822,814,011
Net Worth		
Reserves	44,647,224	6,642,343
Accumulated Surplus	253,855,684	39,695,823
Total Net Worth	298,502,908	46,338,166
Total Liabilities and Equity	4,291,544,745	3,869,152,177

2024 highlighted events

2024.3.13 Mr. Chun-Jung Su, Minister of Directorate-General of Personnel Administration (DGPA),Executive Yuan, led an administrative corporation service team to visit NARI and give guidance. The team members include: heads of relevant units of DGPA, as well as representatives from the Directorate-General of Budget, Accounting and Statistics, the Ministry of Finance and Public Construction Commission.

2024.3.19-22 NARI in coorperation with civil companies won the "2024 Smart City Innovative Application Award". By applying the technologies of "Intelligent Distribution Network Management System (iDNMS) " to develop a Smart Grid System in the Wang'an Township, Penghu County.

2024.3.25 Colonel Yung-His Cheng, the CEO of the International Development Course of National Defense University, accompanied by 22 foreign guests visited NARI. The members of those guests are from 11 countries of Central and South America, including dignitaries, officials, parliament members, media representatives, entrepreneurs, and civil servants.

2024.4.13 The Science Exhibition of "Infinite Technology Knowledge of Nuclear Safety" organised by both NSC and NARI was held at the Green Tunnel Station in Gukeng Township, Yunlin County. A total of 2,209 individuals were attracted to attend the event including teachers and students, parents and civil persons.

2024.5.24 A group of officials from the Control Yuan which included Vice President Hung-chun Lee and Committee member Sun-Lu Fan who leads the Committee on Educational and Cultural Affairs, as well as eight other members, visited NARI for conducting an inspection. This instection event was accompanied by Dr. Tsu-Mu Kao, President of NARI, Shin Chang, Vice Chairperson of the National Safety Council (NSC), and Tung-Yang Chen, the former Chairperson of the NSC.

2024.5.27 NARI has partnered with Kaohsiung Chang Gung Memorial Hospital, Shuang Ho Hospital of the Ministry of Health and Welfare and National Yang Ming Chiao Tung University to create the "Precision Health and Intelligent Diagnosis Alliance for Neurodegenerative Diseases." On the same day, the signing ceremony for the alliance and a symposium were held.

2024.6.7 The ground-breaking ceremony for the construction of the 70 MeV Medium-sized Cyclotron was held at NARI. Those honourable guests from NSC, TYCG, NCSIST, TASA, as well as the central and local officials, NCCU Graduate Institute of Technology, Innovation and Intellectual Property Management, NTHU College of Nuclear Science, SNMROC, and distinguished guests from companies in nuclear medicine were invited and participated in the ceremony.

2024.6.20 NARI held an inauguration ceremony of the "National Biological Tritium Testing Facility ". On the same day, NARI conducted the first tritium analysis for seawater aquaculture testing to ensure the health and safety of seafood consumption for the public.

2024.7.27 The "2024 Symposium on the Development of Nuclear Medicine and Molecular Imaging Applications" took place at GIS NTU Convention Centre. It was held by both NARI and the Society of Nuclear Medicine of the Republic of China(SNMROC).

2024.8.6 NARI and Best Theratronics LTD from Canada signed the Memorandum of Understanding (MOU) to promote and execute the collaboration in the field of Nuclear Medicine.

2024.9.13 NARI held the "2024 Nuclear Backend Forum and Technical Symposium". Honorable guests from NSC, experts and scholars from TPC, academia and industry were invited and participated in the discussions.

2024.9.26 Distinguished guests was invited by NARI to attend " The First Anniversary Celebrating Ceremony of NARI". Cerebration activities includied "Research and Technological Innovation Competition" and "Run and Walk for Health" events.

2024.10.5-6 The Science Exhibition of "Infinite Technology Knowledge of Nuclear Safety" organised by both NSC and NARI was held at the Hsinchu County Stadium. A total of 7,182 individuals were attracted to attend the event including teachers and students, parents and civil persons.

2024.10.15 NARI and Taichung Veterans General Hospital (TVGH) signed the Memorandum of Understanding (MOU) to promote and execute the collaboration in the field of Nuclear Medicine and AI in Medical Imaging together.

2024.10.17 In the "R&D Achievements and Patented Technology Promotion Negotiation and Matchmaking Conference" held at Taipei World Trade Centre Exhibition Hall 1, NARI promoted its Top-9 Highlighted Technology Applications. A total of 42 manufacturers and 68 representatives from diverse fields attended the event.

2024.10.19 The "2024 Taiwan Innotech Expo, TIE" awarding ceremony was held. In this contest, NARI won five gold medals, one silver medal, four bronze medals and one special award for the extraordinary enterprise.

2024.10.22 NARI took part in the "2024 Kiss Science" science exhibition event for the first time. The "Kiss Science" event was organised by the National Science and Technology Council. Students and teachers from the Long Tan Senior High School participated in the event with help with NARI colleagues to explore atomic knowledge.

2024.11.4 Officials from Idaho National Laboratory (INL) including Dr. Todd E. Combs, Deputy Laboratory Director for Science and Technology and Ms. Marsha McDaniel, Director of International Engagement, along with Mr. Cal Chen, representative from the Idaho Asia-Pacific Office, the three distinguished guests visited NARI to explore opportunities for future collaboration.

2024.12.3-5 "2024 The TECRO-AIT Joint Standing Committee Meeting on Civil Nuclear Cooperation" was held at the Lawrence Livermore National Laboratory(LLNL) in the USA, where NARI delivered a keynote presentation entitled "Overview of the Research Programs at NARI and Future Prospects," and participated in group discussions throughout the meeting.

2024.12.27 "The 21th Innovation Award in Taiwan" awarding ceremony hosted by the Research Center for Biotechnology and Medicine Policy(RBMP). NARI secured two medals for "Research Innovation award" and one medal for "National Innovation award".

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2024 Annual Report

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