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Institute of Nuclear Energy Research
Atomic Energy Council, Executive Yuan

2017 Annual Report

Published in August, 2018

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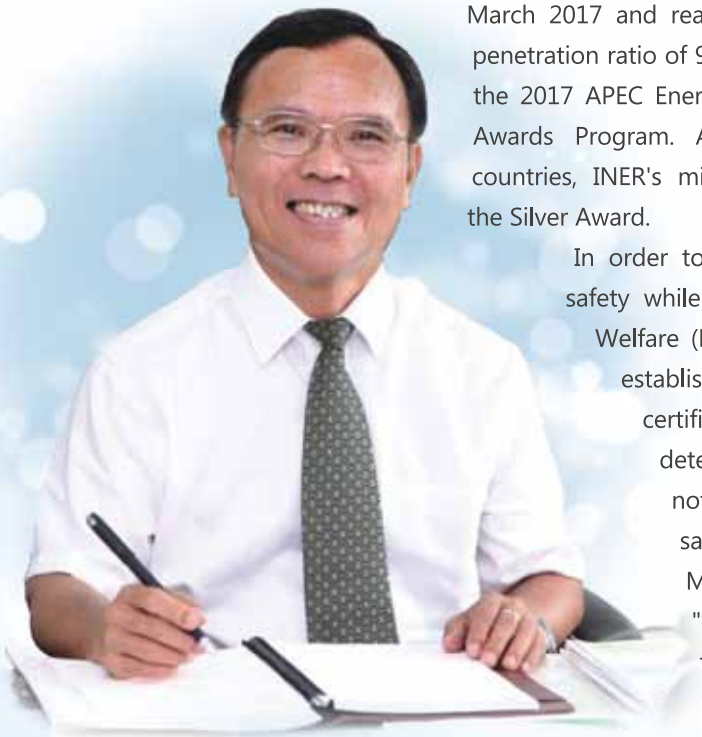
Contents

1.Preface

Caring for Life, Livelihood and Ecology - The sustainable INER

The Institute of Nuclear Energy Research (INER), established in 1968, is the state level research and development (R&D) institute dedicated to atomic energy technologies. Transitions with time and challenges while evolving in concert with the needs of national policy, INER has exploited its research application capabilities to nuclear medicine, high-leveled medical instruments and green energies based on solid research achievements in nuclear technology. Lots of impressive research achievements have been recognized and many awards are honored domestically and internationally.

As the sole national R&D institution that integrates nuclear energy technology, nuclear back-end technology and green energy technology, INER has built up remarkable capabilities in energy field and accumulated abundant evaluation and analysis experience for energy policy. Indeed, INER has been actively promoting as well as transferring its research achievements for industrial application. In 2017, INER made a successful microgrid control technology transferring to Chung-Hsin Electric & Machinery Mfg. Corp., building up Taiwan's first high-renewable-energy-penetration microgrid system at Dongji Islet of Penghu county. This microgrid system went into commercial operation in March 2017 and reached the maximum instant renewable energy penetration ratio of 92.8%. In April, the research team participated in the 2017 APEC Energy Smart Communities Initiative Best Practices Awards Program. Among 197 competition practices from 21 countries, INER's microgrid control technology and its practice won the Silver Award.



In order to enhance the radioactive inspection for food safety while cooperated with the Ministry of Health and Welfare (MHW), a radioactive inspection laboratory was established in INER, which is also the first laboratory certified with TAF ISO/IEC 17025 for food radiation detection in Taiwan. With all the profession, INER not only offers the required techniques for food safety management to those agencies such as MHW, but also well meet multiple goals such as "enhancing detection capacity", "gaining public trust", and "welcoming public visits."

In order to promote our R&D results, we have actively participated in international invention, patent and technology trade shows. In September 2017, we won a total of 18 awards in the Taipei International Invention Show & Technomart, including one highest-honor platinum medal, six gold medals, four silver medals, and seven bronze medals. It means that over 85% of INER's teams were awarded.

In addition, there are two technology projects of INER, " Ge-68/Ga-68 Radioisotope Generator and Innovate Method of Construction Thereof " and " Innovative Mass Production Technology of Hi-end Solar Control Films ", were awarded in the 14th National Innovation Awards sponsored by the Institute for Biotechnology and Medicine Industry.

Besides nuclear safety and green energy, INER has devoted itself to R&D of nuclear medicine and high-leveled medical instruments. With 16 drug-license permits, two medical-instrument-license permits, and PIC/S GMP examination reassurance, INER is the only well-established state agency which legally produces and provides nuclear medicine services. Those high-quality radiopharmaceuticals produced by INER met international quality standards. More than 150 thousands patients and 50 hospitals are benefited by our service annually.

In conformity with the policy needs of energy and economic development and to meet the goal of "2025 Nuclear-free Homeland", INER actively devotes in strategic research of energy economics while maintaining atomic energy research capacity. Moreover, research enhancement will focus on nuclear power plant decommissioning, and nuclear backend technologies, such as radioactive waste process and disposal.

With faith and the UN's goals of sustainable development, we surely believe that caring for dignity of human life, improving quality of livelihood and protecting the ecology are consistent with our mission on sustainable development. INER will keep striving on research innovation to make the mission come true. Indeed, offering comprehensive strategies and technical solutions for security of state energy resources, environmental protection and civil health are our ultimate goals for which we continue to strive. As a competitive and prominent agency, INER is diligently paving the way to earn employees', public and international recognition as a world-class research institute.

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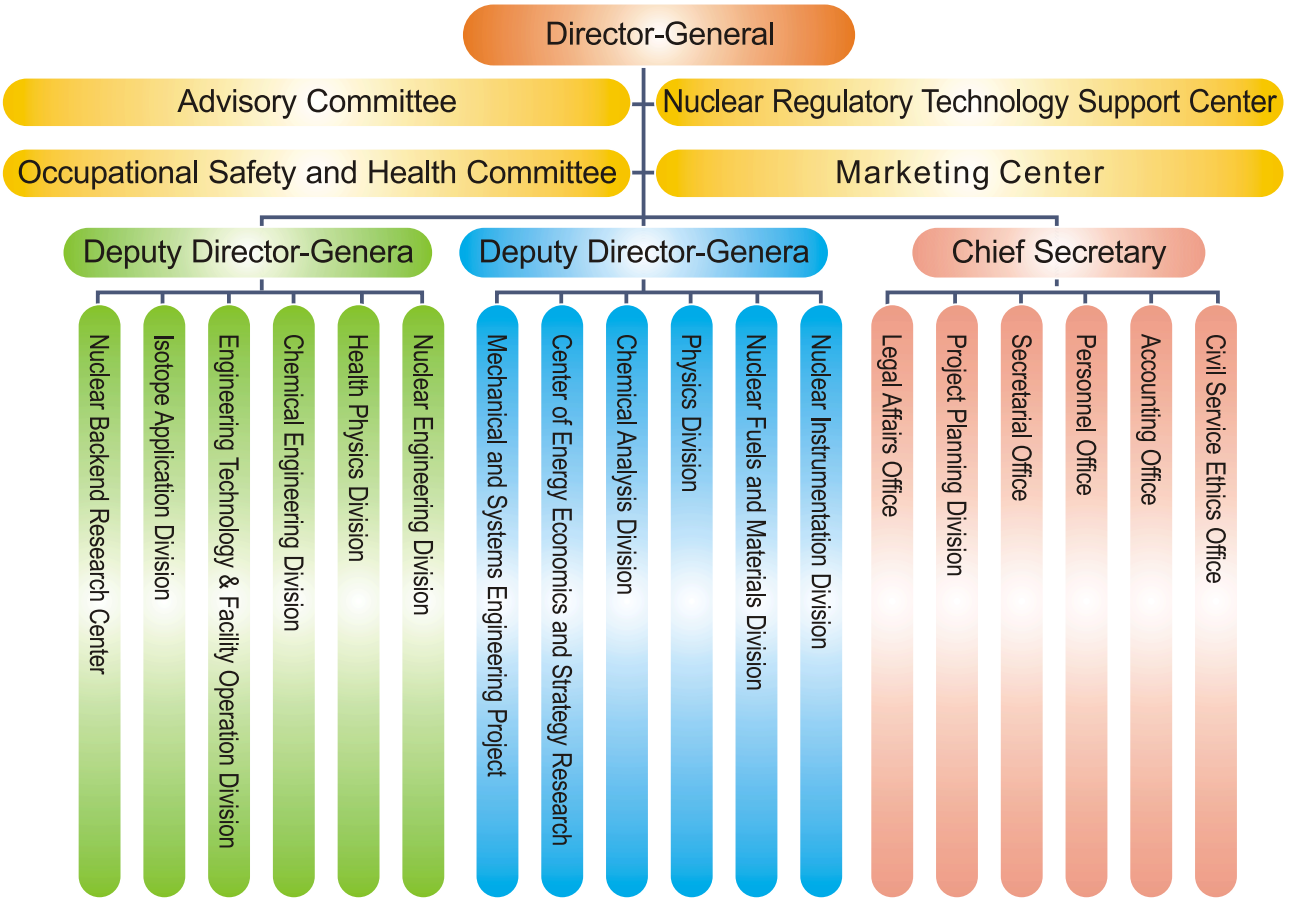
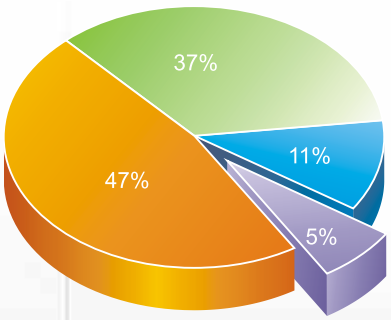
2.Organization Chart、Human Resources and Budgets

Organization Chart of INER



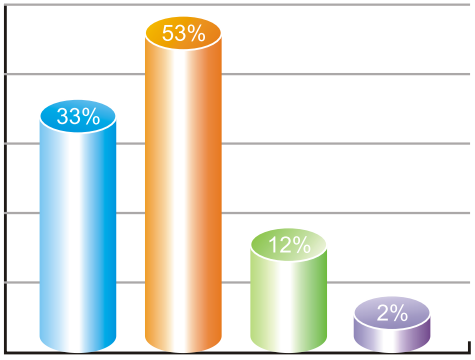
Human Resources and Budgets (Time of data: December, 2017)

Manpower Distribution of INER



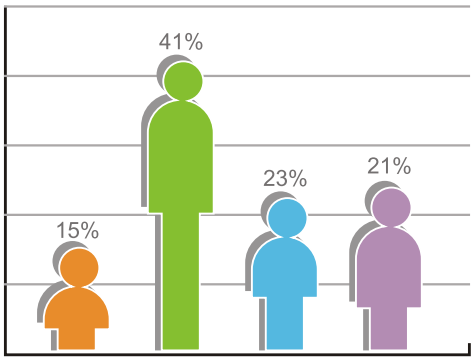
Research Staffs	380 Persons	(47%)
Technicians	297 Persons	(37%)
Administrative Staffs	93 Persons	(11%)
Other Staffs	41 Persons	(5%)
Official Staffs	811 Persons	

Statistics of Educational Background for Research Staffs



Ph.D.	123 Persons	(33%)
Master	201 Persons	(53%)
Vocational School	47 Persons	(12%)
Bachelor	9 Persons	(2%)
Research Staffs	380 Persons	

Statistics of Job Category for Organizational Research Staffs



Researcher	56 Persons	(15%)
Associate Researcher	157 Persons	(41%)
Assistant Researcher	87 Persons	(23%)
Research Assistant	80 Persons	(21%)
Research Staffs	380 Persons	

2017 Annual Budget

Unit: Thousand NTD

Item	Number of Accounts	Percentage
Administration and Safety	1,176,749	59.69%
Management, Operation and Maintenance	101,438	5.14%
R&D Projects	570,529	28.94%
Technology Promotion and Service	119,447	6.06%
General Construction and Equipment	3,429	0.17%
Total	1,971,592	100.00%

3.Current Major R&D Activities

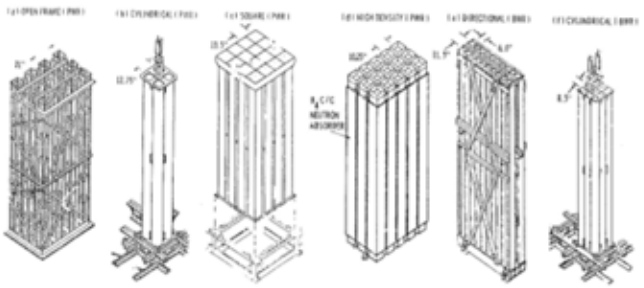
3-1 A Prelude on Nuclear Safety Research Report- Envision a Nuclear-Free Homeland

The nightmare of nuclear disaster still haunts mind of the public, and it causes the application of nuclear energy to be a non-preferred choice. However, the truth is that nuclear technologies have touched different aspects in the daily life of people. Healthcare and various industries have adopted nuclear technology as a way to provide benefits to people. What ensues are the radioactive wastes generated assumedly. Therefore, it requires everyone's intelligence and courage to assess a sustainable way to safely use the nuclear technologies and solve the problem of waste management. The sophisticated nuclear technologies shall be developed to enhance the wealth of people and increase the economic competitiveness of the nation. In addition, the decommissioning of nuclear facility and optimum waste management shall be implemented successfully to protect the environmental and social security.

In 2017, INER has researched and developed many nuclear technologies. First, in the aspect of nuclear application in daily life, a food-specific radioactivity testing laboratory was built and verified to effectively ensure the radiation safety of imported food for the general public. Furthermore, a global nuclear/radiation accident dispersion evaluation system was implemented. It can provide analysis information for the authority to make decision within the shortest time once the nuclear accident/explosion abroad would happen. Also, the radioactivity primary standard of Mn-54 was established and transferred to the secondary national measurement system. It could provide the calibration service and enhance the radioactivity measurement accuracy. Secondly, to ensure the operation safety of nuclear facility, INER established domestic SFP (Spent Fuel Pool) models for severe accident with MAAP5 code, in which several rescue strategies were formulated to alleviate the accident progress and return the SFP to a stable state. Especially, domestic dismantling technologies of the nuclear reactor were investigated by INER. A remote-handling tool, named as Y-shape spreader, was designed specifically for easy interfered components in a narrow operation space. Furthermore, INER completed the Chinshan NPP decommissioning plan, and developed the key technologies, such as decommissioning work schedule planning, 3D engineering simulation and visual auxiliary technology etc. Thirdly , with regard to the spent nuclear fuel disposal study, INER completed the "Technical Feasibility Assessment Report for the Spent Nuclear Fuel Final Disposal Technology in Taiwan (SNFD2017)" to summarize the current stage progressive results and to establish a solid good foundation for the follow-up disposal tasks. In addition, INER conducted the corrosion test of oxygen free copper in the artificial solution of ground water and studied the issue of the sulfide production by SRB (Sulfate-Reducing Bacteria) in the buffer bentonites to understand the integrity of copper canister in the deep underground. Also INER set up a glove box facility to simulate anaerobic reductive environment for the adsorption tests of nuclides in the deep geological host rock or bentonite. It can provide the local input data for performance/ safety assessment and increase the reliability of the sorption parameters.

These research results will facilitate technical service for public, and provide a solid base for the advanced technical investigations.

3-1-1 If the mountain won't move, build a road around it - The analysis and establishment of spent fuel pool model for severe accident



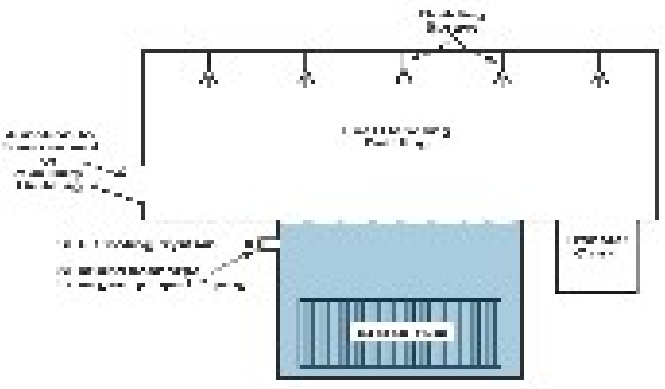
The safety of spent fuel pool(SFP) is usually ignored in a severe accident since assumedly there is plentiful water in it and most of the stored spent fuel is in the low-power level state.

The hydrogen explosion occurred during Fukushima nuclear accident and the spent fuel pool was once suspected of losing injection to cause fuel cladding failure and produce hydrogen.

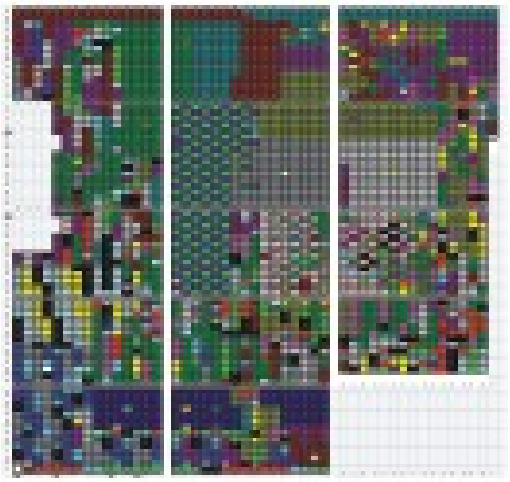
Although subsequent studies ensured that SFP did not cause the hydrogen explosion, the safety of SFP has been taken seriously by the nuclear industry. The decommissioning of domestic nuclear power plants is developing. The SFP will be the first processing storage site for the spent fuel, so its safety should be evaluated carefully. Hence, INER began to establish the domestic SFP model with MAAP5 code. Through sequence analysis, several rescue strategies were developed, which considered the minimum injection flow rate in different pool water level. The injection alleviates the accident progress and returns the SFP to a stable state.

The establishment of this technology can provide a technical base in SFP safety operation for authority and utility, ensure the integrity of spent fuel in accident, and increase the public confidence of nuclear safety.

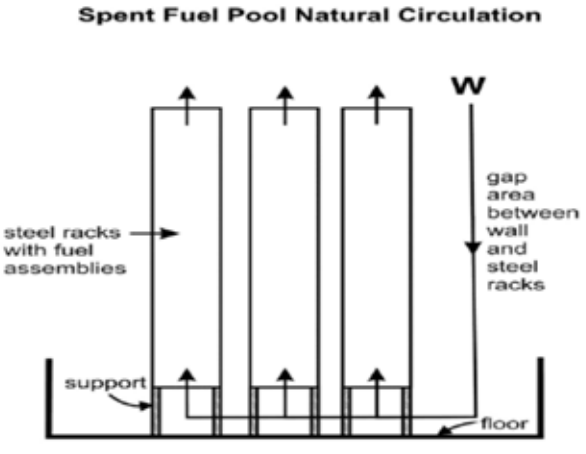
Since MAAP5 code can process thermal-hydraulic and source term release calculation simultaneously, it can access saturate timing of SFP, core uncover timing, minimum flow rate of rescue equipment, producing hydrogen timing and mass, molten mass of fuel assemblies, and release fraction of source term according the user designed sequence such as SBO, LOCA event.



SFP and Building Model in MAAP5



CS Unit1 SFP Structure in MAAP5



SFP Natural Circulation in MAAP5

At present, CS unit 1 SFP is almost full. Before dry storage of spent fuel is officially enabled, the safety of SFP is the significant issue in public.

CS unit 1 SFP model, established by INER, is based on realistic spent fuel shutdown date, cycle outage length, and the position of cycle outage fuel in SFP.

The MAAP5 SFP model has also compared with Computational Fluid Dynamics (CFD). It turns out that MAAP5 results are consistent with CFD.

Hence, MAAP5 code possesses the calculation ability in SFP simulation.

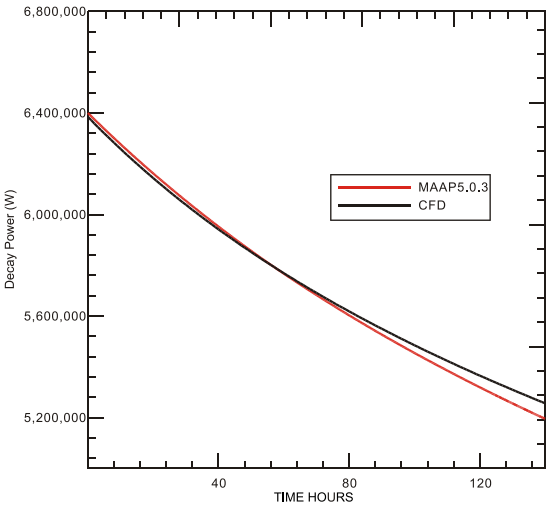
INER used MAAP5 code to analyze the injection issue of CS unit 1 SFP in accident. The model, which was established on realistic information of CS unit 1 SFP, has calculated the injection test analysis in SBO case. And the success criteria of PCT was less than 1500K. The results show that:

When SFP water level at 1/3 core height, the minimum injection and spray flow is 200gpm and 100gpm, respectively.

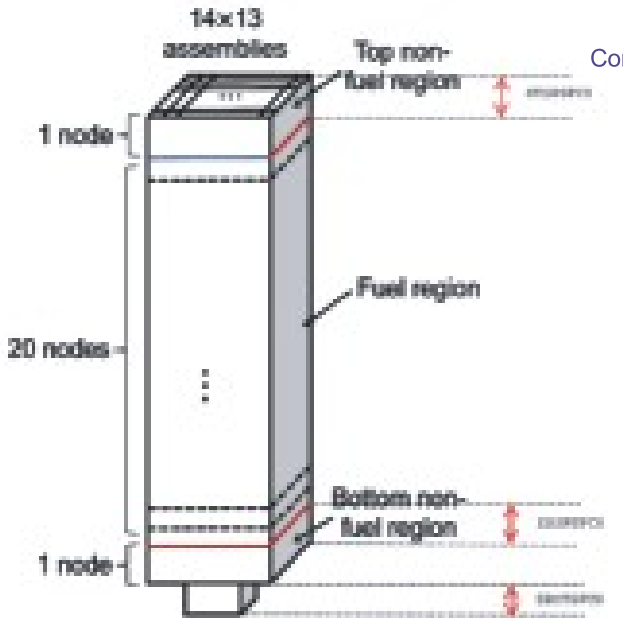
When SFP water level at 2/3 core height, the minimum injection and spray flow is 50gpm.

MAAP5 SFP model will add the RHR system to verify its ability and simulate different sequence including LOCA and splash water caused by earthquake events in the future.

Therefore, no matter what nuclear power plant state is in operation, decommission, or nuclear safety exercise, MAAP5 can be used as an effective assessment tool to ensure nuclear power safety.

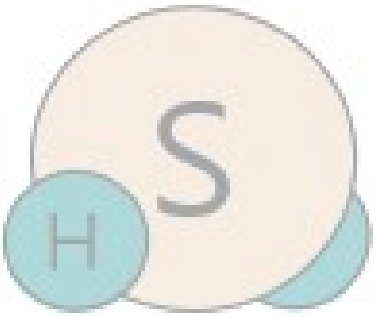


Comparison of decay heat calculation between MAAP5 and CFD

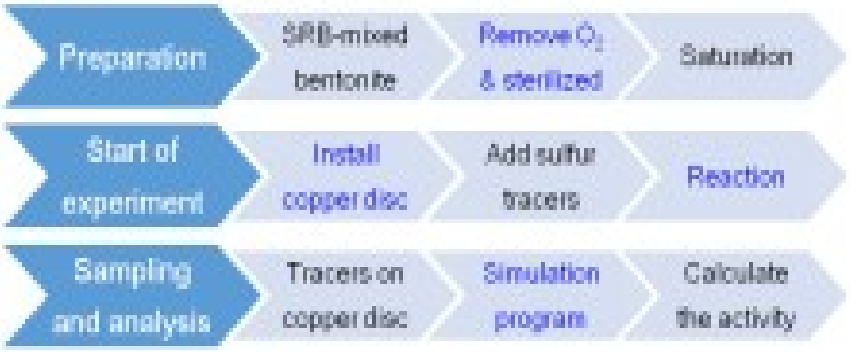


Fuel axial node in MAAP5 model

3-1-2 Copper Canister Corrosion behavior by Sulfate-Reducing Bacteria in bentonites



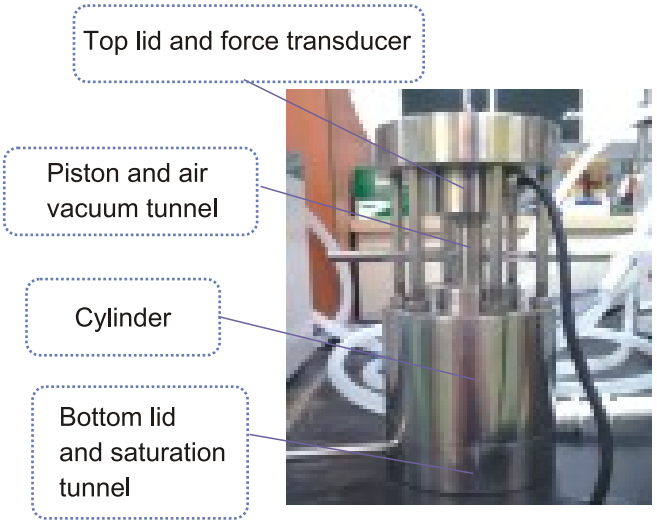
In the safety assessment of the Spent Nuclear Fuel Final Disposal Program, the corrosion behavior of copper canister caused by the sulfide is an important issue. Sources of sulfide in the repository environment include sulfide minerals contained in rock and buffer, generation by the Sulfate-Reducing Bacteria (SRB), solute in the groundwater, etc. If bentonites adjoining the canisters are adhered by SRB, the produced sulfide may corrode the copper canister, resulting negative effects. Therefore, to study the issue of the sulfide production by SRB in the buffer bentonites, the experimental method of SRB activity test was established.



Flow diagram of the SRB activity test

Sulfate-reducing bacteria is one of the old forms of anaerobic bacteria, common in water and soils. SRB will oxidize organic compounds while reducing sulfate to hydrogen sulfide, and the latter contributes to corrosion of metal structures. Foreign in situ studies showed that the SRB activity decreased with increasing of bentonite density, and was inhibited at saturated density of 1,900 – 2,100 kg/m^3. This effect was one of the important parts in the safety assessment of sulfide corrosion process. Consequently, the goal of this study was to evaluate the SRB activity inhibition effect in MX-80 bentonite when the density increases.

Incubation of microbes was done by Nuclear Science and Technology Development Center at National Tsing Hua University, SRB was well cultivated in anaerobic environment following the instructions by German Collection of Microorganisms and Cell Cultures (DSMZ). Method of pre-mixing bentonite clays with SRB before compaction was established as well, and samples were taken between each process to test the survival rate.



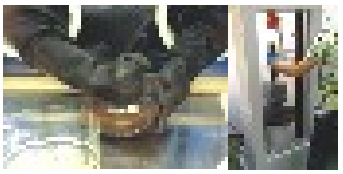
Test cell of the SRB activity test

In the experiment, test cells were designed to hold the bentonite clay in a constant volume, with isolated and anaerobic environment. Different conditions of cells were set with different saturation density and different treatments of bentonite shown as the table below. Saturation process using the anaerobic SRB growth medium lasted until the monitored swelling pressure become steady. After saturation, sulfur radioactive tracers and copper disc was added. After added tracers and copper disc, cells will be left for serval months.

In the clays, reaction will occur and Cu_x35S will be formed on the disc. The amount of tracers will be detected after experiment. Using computer simulation program, results will be obtained. It is expected that microbial activity will decrease for about 1,000 times between 2 sets, with bentonite density 1,750 kg/m^3 and 2,000 kg/m^3. The data can be given as the feedback to the long-term safety assessment of the repository.

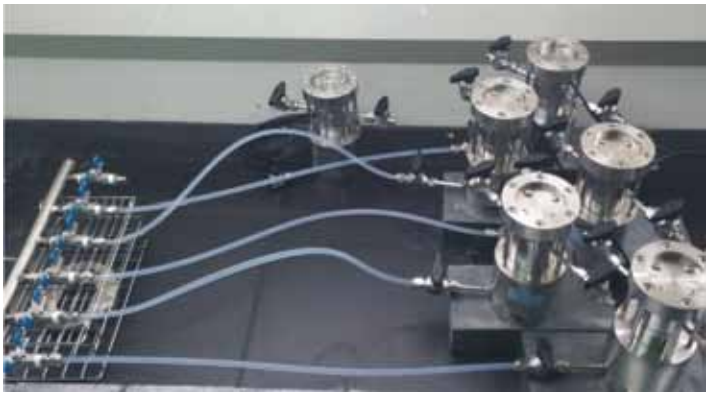
Incubation medium

Pre-mixed in glovebox



Grinded and compacted

SRB survival rate analysis



Test cells linked with saturation process system

Saturation density [kg/m^3]	Bentonite clays treatment	
	Sterilized	Pre-mixed with SRB
1,750	Cell 1	Cell 2
2,000	Cell 3	Cell 4

Experimental conditions of each test cell

3-1-3 Corrosion Test on Copper Shell of Canister for the Spent Nuclear-fuel Final Disposal

With reference of SKB program for the spent nuclear-fuel final disposal in a deep geological repository, the canister is designed to contain the spent fuel and it can act as a barrier to ensure that the fission products would not leak out. Due to remarkable corrosion resistance, oxygen-free copper is selected for the shell of canisters which provide the integrity over hundreds of thousand years in the repository environment.

This study was to conduct the corrosion test of oxygen free copper in the artificial solution of ground water. The prepared corrosion solution contained sulfate ion, chloride ion, and hydrogen carbonate ion, which are crucial constituents for metal corrosion in the ground water. Furthermore, various levels of sulfate ion were adopted to evaluate its effect of concentration, as shown in the Table 1. Copper specimens were immersed in the artificial solution and placed in the chamber with constant temperature(30˚C) for 450 days (Fig. 1). The corrosion behavior was assessed by measuring the mass change and the analysis of corrosion products.

Fig. 1 Immersion corrosion experiment in temperature controlled chamber

Table 1 Artificial solution constituents of ground water

constituent	$[Cl^-]$ (mol/L)	$[HCO_3^-]$ (mol/L)	$[SO_4^{2-}]$ (mol/L)	pH	temperature
value	[illegible]	[illegible]	[illegible]	[illegible]	30 °C

After 450-day immersion, all the specimen appearances were gray dark (Fig.2) and XRD showed that the corrosion products were mainly copper(I) oxide(Cu_2O) and copper(II) oxide (CuO), but also minor copper hydroxide hydrate ($Cu(OH)_2H_2O$) was detected (Fig.3). The results are similar for the different concentrations of sulfate ion.

$[SO_4^{2-}]$: 0.0001 M $[SO_4^{2-}]$: 0.0002 M $[SO_4^{2-}]$: 0.0005 M $[SO_4^{2-}]$: 0.001 M

Fig. 2 Specimen appearances after corrosion of 450 days

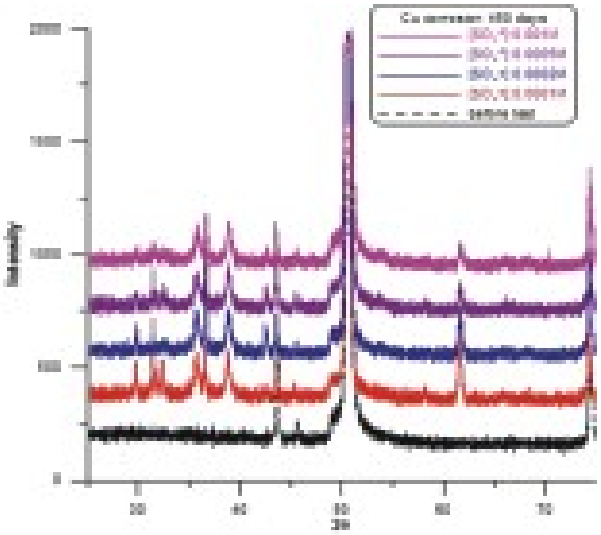


Fig. 3 Corrosion products identified by XRD

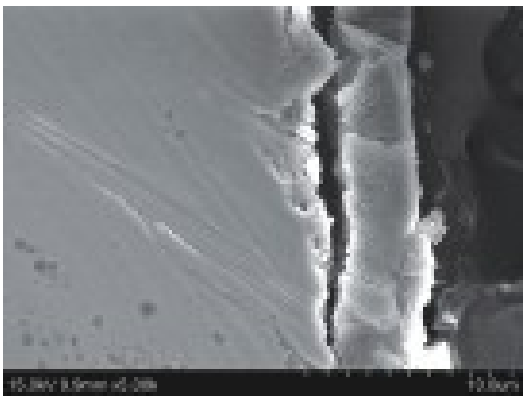


Fig. 4 Surface morphology and cross-sectional oxide layer observed by SEM

SEM observation of the specimen surface after immersion for 450 days (Fig. 4), demonstrated that the surface revealed a compact grains morphology with few aggregate flake-like product on the top. And the cross-section of corrosion products displayed continuously uniform thickness of about 4 μm. From the results of XRD and SEM, it implied that a continued uniform oxide layer composed of Cu_2O and CuO was formed after long term exposure.

The mass change of the tested specimens indicated that mass loss took place during the initial period. The length of time period of mass loss increased with the increasing sulfate ion level. However, after the early immersion period, a linear dependence of mass gain and corrosion time was obtained as shown in the Fig. 5. The equation of corrosion rate was established from the 0.0001 M condition. Also conservatively presuming that Cu_2O is the only oxide structure, accordingly the copper thickness loss calculated from this equation was about 3.4 μm per year.

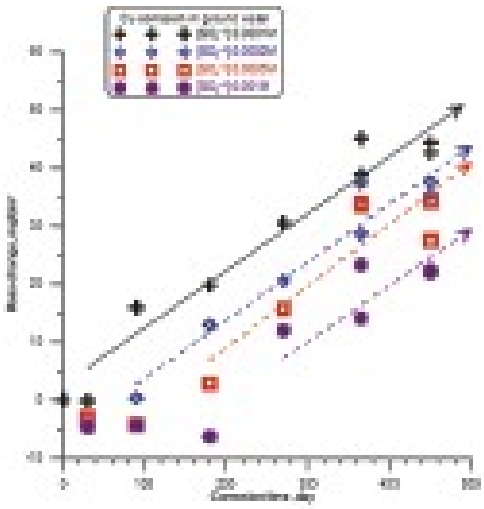


Fig. 5 Relation of mass change and corrosion time

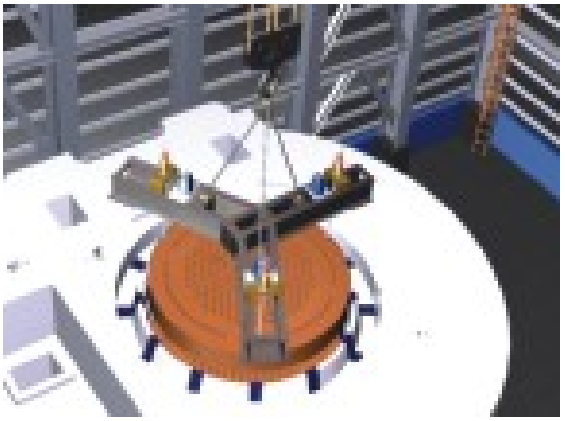
Equation of corrosion rate

$$Y(mg/dm^2) = 0.101 \times X(day) + 1.666,\ R^2 = 0.952$$

It could be concluded that oxygen-free copper corrosion in the artificial solution of ground water formed a continued uniform oxide layer and the corrosion rate conservatively calculated was only about 3.4 μm per year.

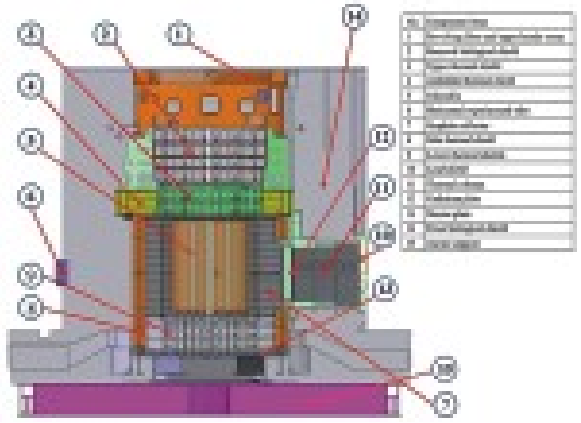
3-1-4 The developing of TRR dismantling tool- a domestic nuclear reactor decommissioning state-of-the art technology

Taiwan Research Reactor (TRR) is stored safely in one piece currently. The internal components of TRR are ascribed to be highly activated radioactive waste, therefore, developing safely dismantling methods are required. Recently, both of the establishing of segmentation methods and the developing of various dismantling tools are progressed. The dismantling sequence of internal components are from top to bottom, from inside to outside; all of the monolith components will be retrieved from inner part to a specific cutting station, and then be segmented piece by piece for further packaging. The domestic dismantling technologies of the nuclear reactor include the tools designing, manufacturing and demonstration. All will be performed by INER.



items	dimension (mm)	one side gap (mm)	weight (MT)
Removal biological shield A	4038.6	6.35	18.7
Removal biological shield B	3962.4	6.35	17.9
Removal biological shield C	3886.2	6.35	17.5
Removal biological shield D	3810	6.35	16.7
Upper thermal shield A	3689.35	3.18	17.3
Upper thermal shield B	3638.55	3.18	16.2

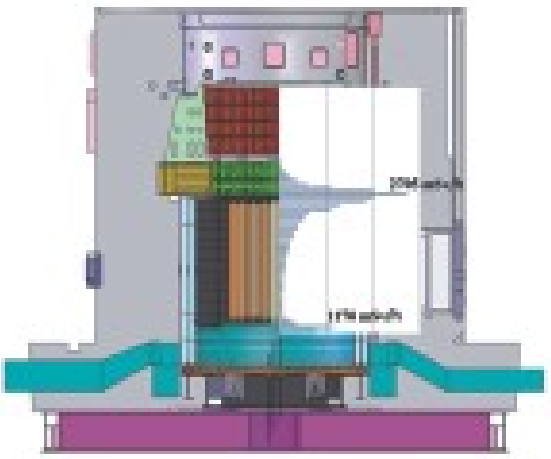
Properties of the major components in TRR



The components of reactor waste

Challenge

The margin between components and bio-shield is narrow (the minimum gap of one side is 3.18 mm). Through the operation, shutdown, and one piece removal periods of the TRR, some parts of the components in reactor may have been corroded or deformed. The dismantling process may be hindered by these mentioned problems. In addition, the neutron activation effect on the reactor during the 15 years operation was led to the high radiation dose rate of some components. Hence, the manual dismantling is not feasible in consideration of the worker safety and radiation protection requirements.

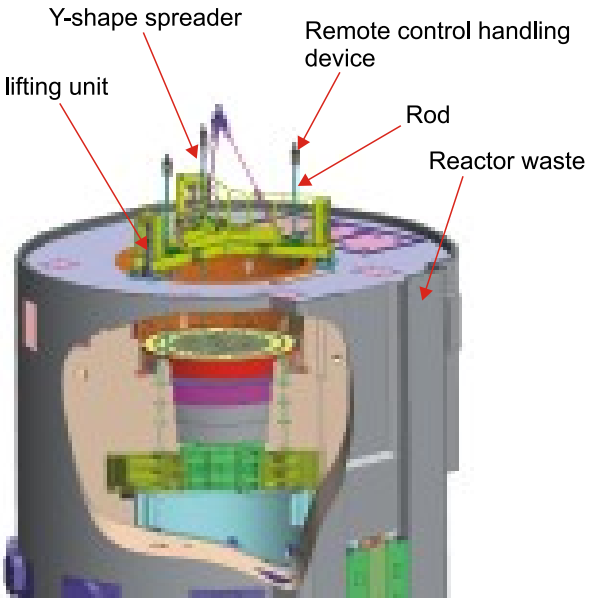


The distribution of radiation dose rate in TRR

Solution/R&D

A remote-handling tool, named as Y-shape spreader, is designed for easily interfered components or high radiation dose rate components. Before retrieving the internal components, Y-shape spreader is applied to loosen and to lift components smoothly within the margin.

A special device composed by controller and operation rod is equipped on the Y-shape spreader so that the operator can safely manipulate and meet the ALARA (as low as reasonably achievable) principle during the dismantling activities.



3D model of Y-shape spreader

Demonstration and testing

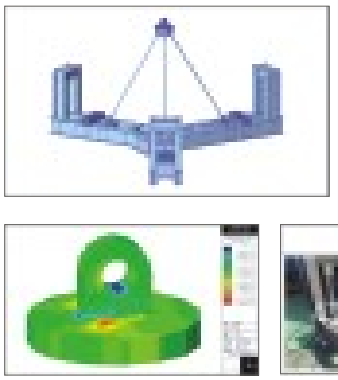
The specifications of steel beams of Y-shape spreader is based on NUREG-0612 and ANSI N14.6. The safety factors of yield strength and ultimate strength have been designed to be greater than that of the standard 3 times and 5 times. After the Y-shape spreader was completely manufactured, a series of testing items including lift load testing, non destructive inspection, structural stress analysis, calibration of load cell and displacement sensor, steel material certification and cable inspection were performed to verify the quality requirements.

Characteristic

To satisfy the ALARA principle and remote-handling requirement, the rod rotation mechanism is designed to be pneumatic rather than manual.

The Y-shape spreader is equipped with three lifting units which is composed by hydraulic jack, load cell and displacement sensor. Each lifting unit is able to load up to 25 tons. By means of the hydraulic control, the 3 lifting units can move simultaneously, smoothly and stably to keep the lifted components balance and prevent from tilt.

The maximum lifting distance reaches to 400 mm. When the Y-shape spreader reaches the highest lifting distance, the component is expected far from bio-shield. Afterwards, the 35 tons of fixed crane can be employed to lift up both of the Y-shape spreader and the component; the dismantling interference between each component is reduced.



Testing items

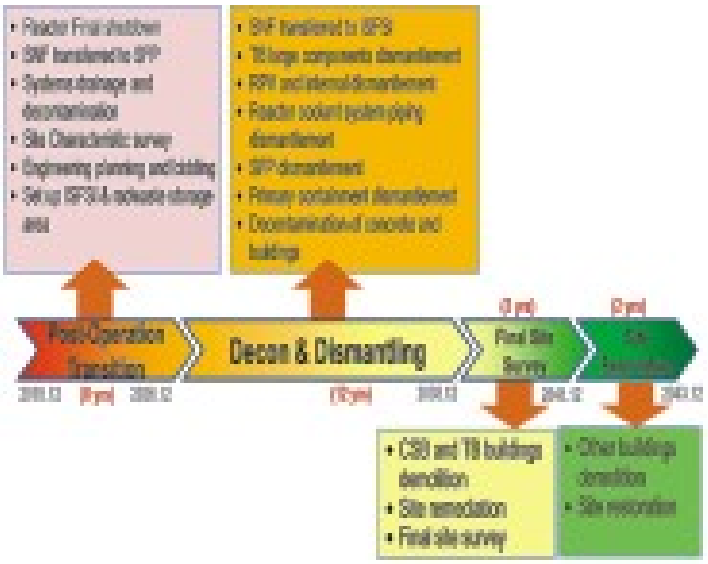
Y-shape spreader

3-1-5 INER has developed the first and approved by the competent authority nuclear power plant decommissioning planning technology

The non-nuclear homeland in 2025 has been recognized as a government policy. The operating licenses of Chinshan Nuclear Power Plant (NPP) Unit 1 and Unit 2 to be expired on 5th December 2018 and 15th July 2019, respectively. Chinshan NPP will be the first NPP faced with decommissioning in Taiwan. Since 2013, Institute of Nuclear Energy Research (INER) has executed the project of "Application for Decommissioning License and Decommissioning Operations Planning for Chinshan Nuclear Power Plant", which was entrusted by Taiwan Power Company (TPC). As completing the Chinshan NPP decommissioning plan the decommissioning key technologies have been developed as follows:

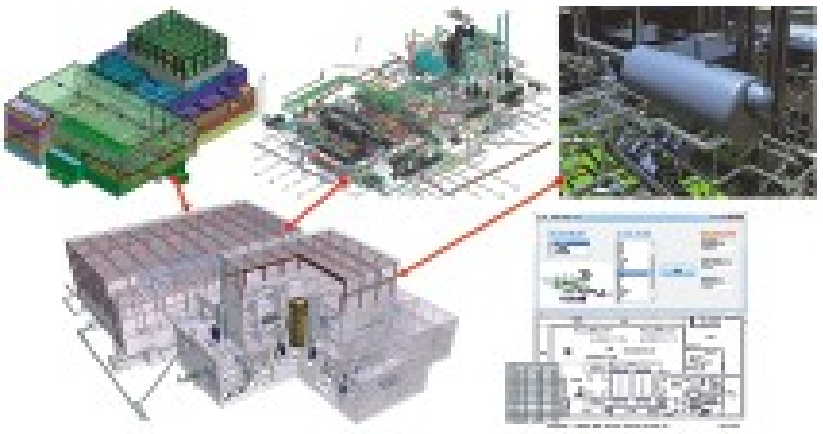
Decommissioning work schedule planning

The decommissioning of Chinshan NPP shall legitimately adopt the dismantlement method and be implemented within 25 years upon obtaining the permit for decommissioning granted by the competent authority. The work schedule plan for Chinshan NPP decommissioning is divided into four phases in sequence: transition phase (8 years), dismantlement phase (12 years), final site survey phase (3 years) and site restoration phase (2 years).



3D Engineering Simulation and Visual Auxiliary Technology

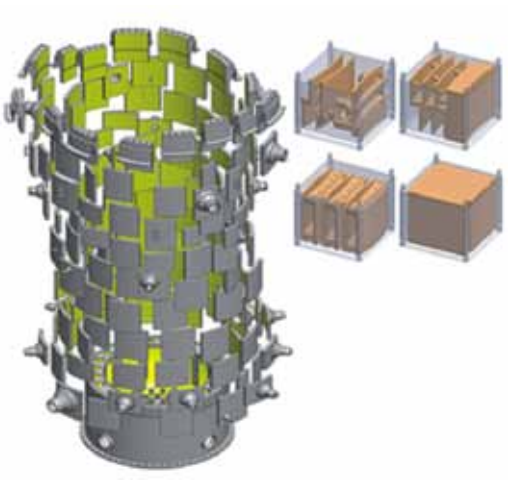
INER completed the 3D engineering simulation for systems, structures and components of the NPP to be decommissioned. It would be combined with the application of radiation measurement data and engineering visual auxiliary technology. Through the accurate engineering parameters analysis, the first domestic 3D-digital model database and decommissioning information management system for Chinshan NPP were set up to provide information on the decontamination, dismantlement, safety management of radioactive waste and personnel training for the NPP decommissioning.



The research of safety management for Spent fuel pool during NPP Decommissioning

After the Chinshan NPP operating license expired, the Units will enter a permanent shut down state. The spent nuclear fuels in the reactor core shall be removed and safely stored in the spent fuel pool (SFP) before all spent nuclear fuels can be removed to the dry storage facilities. INER completed the detailed research and proposed a safety management plan for the cooling, water replenishment and electricity power supply of SFP during Chinshan NPP decommissioning period. The SFP safety management plan has been accredited by the international peer review (Electric Power Research Institute, EPRI, USA) and granted by the competent authorities.

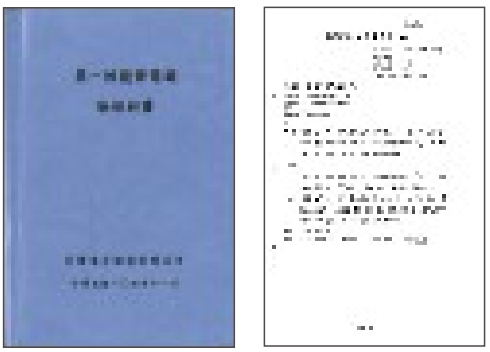
Site characteristic survey



Cutting and packaging planning

Radiological Characterization Survey, Radiological Waste Inventory and Packing Plan

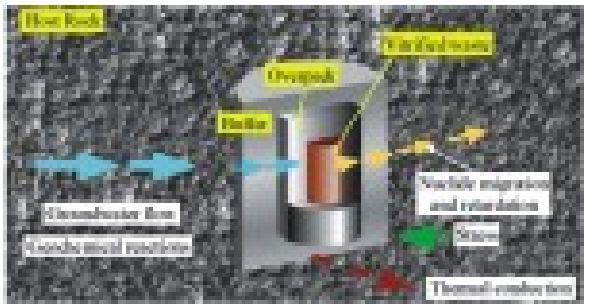
According to multi-agency radiation survey and site investigation manual (MARSSIM), INER completed the radiation characteristics survey planning, investigation and evaluation for Chinshan NPP. Besides, INER also established NPP waste inventory estimation technology and completed the containers to be applied to accommodate the waste of domestic NPPs decommissioning. The radioactive waste inventory calculated results of Chinshan NPP were consistent with that of the foreign reference NPPs.



Approved by the competent authority

As the Chinshan NPP decommissioning plan rigorously reviewed by an international peer (EPRI), it is the first completed NPP decommissioning plan in Taiwan. The associated operations plan and key technologies establishment are internationally recognized. In addition, the Chinshan NPP decommissioning plan passed three rounds rigorous domestic review and approved by the competent authority on June 28, 2017. It proves that INER' s decommissioning technical development, planning capabilities and the decommissioning plan quality have been affirmed.

3-1-6 Establishment of a buffer retention characteristics research facility with the ability to simulate an anaerobic environment in deep geological disposal



In regards to the technological development of spent nuclear fuel (SNF) final disposal, the concept of deep geological disposal is adopted for most countries. With the concept of "multi-barrier" isolation by a combination of engineered (clay) and natural barriers (host rock), the spent nuclear fuels are buried in the depth of approximately 300 to 1000 m of underground bed rock. Furthermore, with canister and buffer/backfill materials, the containment can be effectively functioned to have sufficient time to retard radionuclides released from multiple-barrier systems by migration. In this way, the radioactivity of nuclides can be decayed to a negligible level before entering the biosphere.

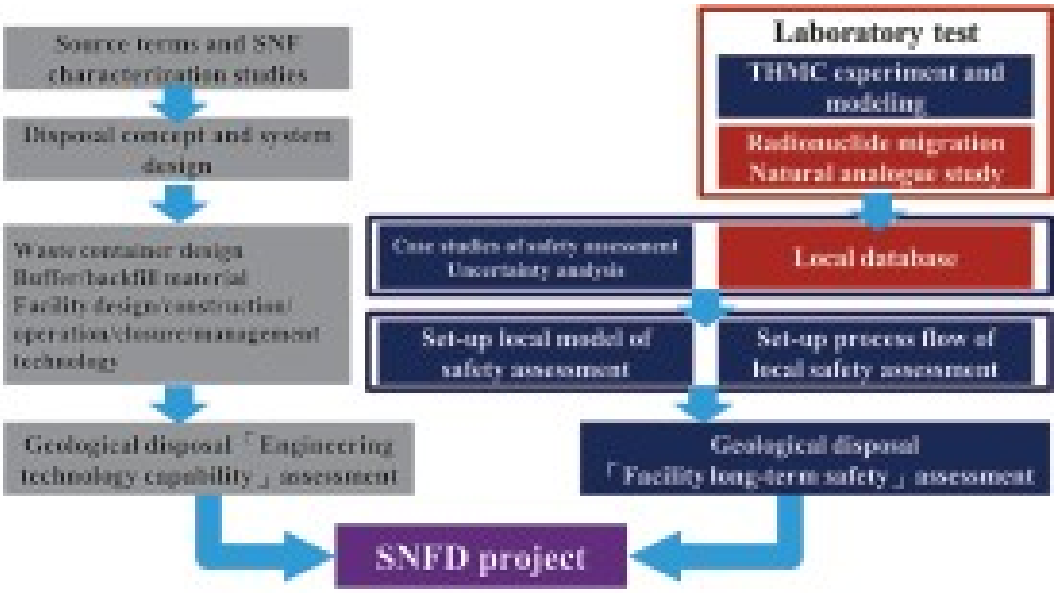


Fig. 1 The role of radionuclide migration laboratory in the SNFD program

Fig. 2 The glove box simulating the anaerobic environment of deep geological disposal

The key issue of disposal safety assessment includes factors that dominantly affect nuclide migration and retardation in the various stages of the barrier. Figure 1 represents the role of radionuclide migration laboratory in the spent nuclear fuel final disposal (SNFD) program.

Several countries have already invested many years and resources toward implementing final disposal of spent nuclear fuel in a geological repository. With respect to evaluate nuclides retardation ability, the diffusion and migration of nuclides in the media of geological environment, complex reaction of organic and inorganic compounds with nuclides, the geochemical reaction, the influence of colloid formation and transport , microbial activity and organic matter on nuclides migration and the dissolution of nuclides in the waste canister must be studied.

Due to the specific hydrogeological conditions in each country, it is necessary to evaluate nuclides retardation using the local crushed host rock, synthetic groundwater (such as Eh, pH) and bentonite materials in an simulated anaerobic reductive environment in deep geological disposal system. These evaluations must be based on the scientific theories.

The set-up of a glove box facility simulating an anaerobic reductive environment (Figure 2) allows the adsorption tests of nuclides in the deep geological host rock or bentonite (the results shown in Figure 3), it provides the local input data for performance assessment and increases the reliability of the sorption parameters. In this way, the reasonable results can be obtained to ensure the safety of the repository and to achieve the objectives of non-nuclear homeland and safety management of radwastes.

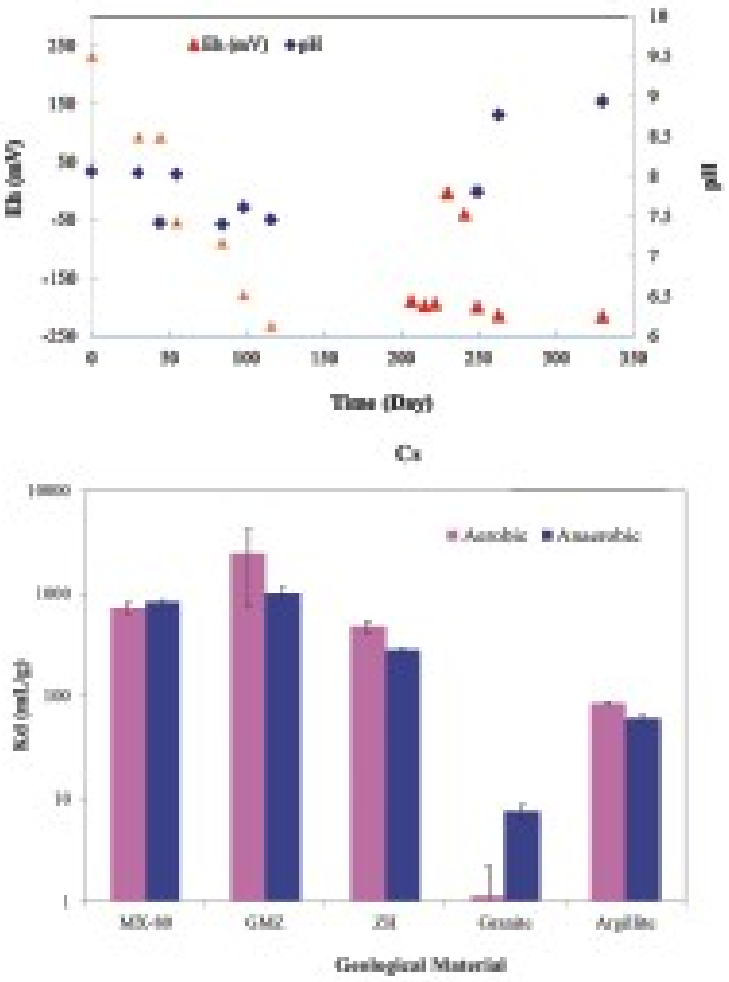


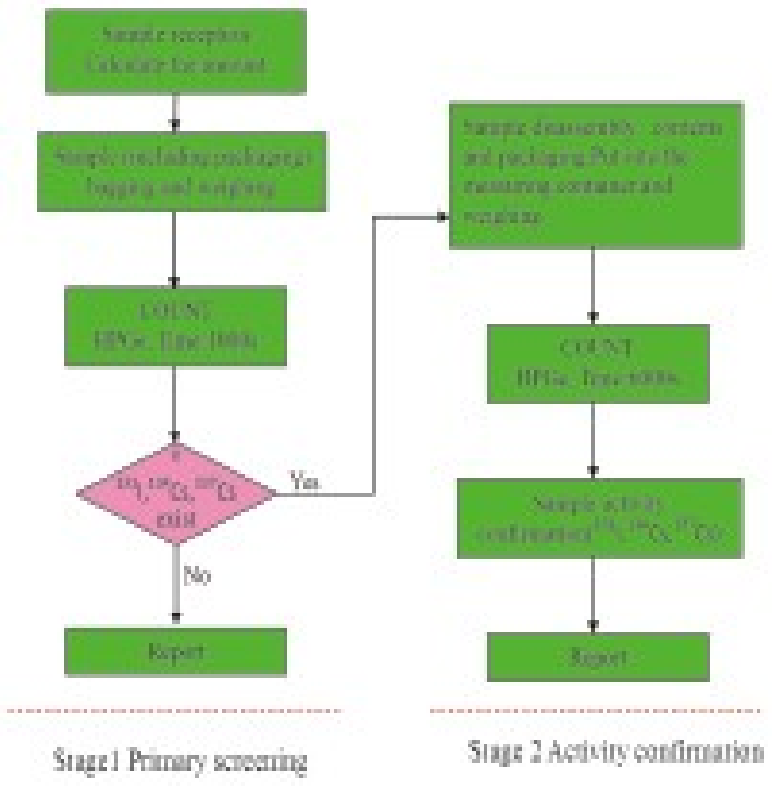
Fig. 3 (a) The equilibrium between Eh and pH after several months of synthetic groundwater in an anaerobic environment of glove box; (B) The distribution coefficients (Kd) of Cs in different types of crushed rocks and bentonite

3-1-7 The first Food-specific Radioactivity Testing laboratory in Taiwan-Food Radioactivity Testing Team

In response to the 311 Fukushima nuclear power plant accident in Japan, Institute of Nuclear Energy Research(INER) has assisted government agencies such as Food and Drug Administration(FDA), Council of Agriculture, National Treasury Administration (NTA) , Bureau of Standards, Metrology and Inspection(BSMI), and other non-governmental enterprises to conform to the national food and safety policy since 2011. In order to provide the relevant government agencies real time information of the test results to ensure the radiation safety about Japan imported food，the radioactivity of various types of food were measured. Until the end of December 2017, more than 100,000 cases of food sample have been tested.

The numbers of Foods radioactivity test samples by INER

The method for determination of gamma-ray emitting radionuclides in food samples by INER is implemented according to the " Method for Testing Radioactivity Nuclear Contamination in Foods" promulgated by the Ministry of Health and Welfare on May 19, 2016 (MOHW Food No. 11951900834) and divided into two phases . Stage 1: Primary screening for all foods samples, the minimum detectable amount (MDA) at this stage must be less than 5 Bq / kg (Soft drink and bottled water) or 10 Bq /kg (milk and milk products, infant foods and other foods). IF quantitative measurement of the presence of radioactive iodine -131, cesium -134 or cesium -137 is found, then it needs to process the second phase of quantitative analysis. The second stage: quantitative analysis of suspected contaminated food to confirm the activity. At this stage, the MDA should be less than 1 Bq / kg.

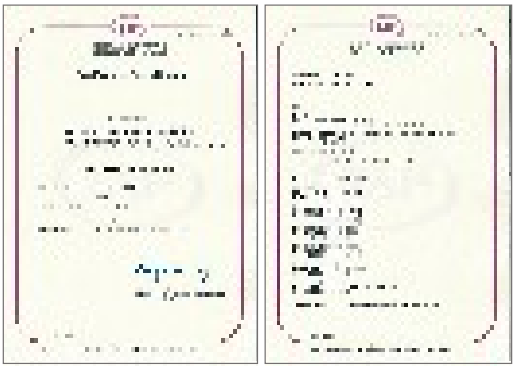


Flowchart of Foods Radioactivity Test.

High-purity germanium spectrometers

To facilitate the public to visit the food radioactivity detection process but to avoid interference in the implementation of testing operations, the existed food testing laboratory was relocated to a large conference room, where the indoor space is about 1.5 times larger than that of the original laboratory. The new laboratory is equipped with five pure germanium detectors of high-precision detection. With the increase of manpower, the number of tests can be increased by 20% or more. It is expected to significantly increase the detection efficiency. In addition, some measurements were adopted to aid the visitors, such as transparent glass windows were set up on the external walls of the laboratory , production posters were printed, the planning public visiting line was sophisticated. Video clips of food testing were also uploaded to the Internet to be transparently introduced. In addition, through media interviews, the optimum measuring and analysis procedures and the government's determination on food safety were communicated. So that people could "eat safely"in daily life.

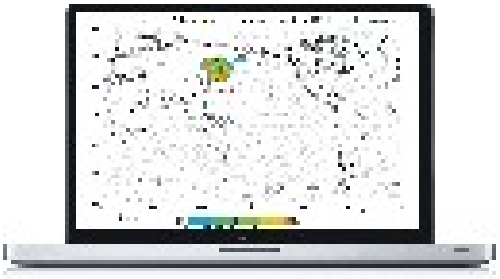
In March 2017, INER filed an application for TAF Food Radioactive Testing Laboratory Quality Assurance Certification. In June 2017, INER passed the TAF food radioactive testing and certification, it was first in Taiwan. The laboratory has established a complete food safety management system, which has made INER's testing results professional and credible. Future it will also be approved by other countries through TAF's international mutual recognition mechanism.



Certificate of Accreditation

INER Built and completed Taiwan's First Food-specific Radioactivity Testing Laboratory in June 2017 by expanding the original laboratory testing capacity and obtaining the TAF food radioactive testing certificate. Aside from fulfilling the requirements of government agencies for food safety management as well as technical services, the laboratory has achieved the multiple objectives of "enhancing the quality of inspection," "gaining the confidence of the public," and "facilitating the public visiting and understanding" so as to effectively ensure the radiation safety of food for the general public.

3-1-8 The First Warning Line For Global Nuclear Explosion & Accident :Radiation Evaluation System

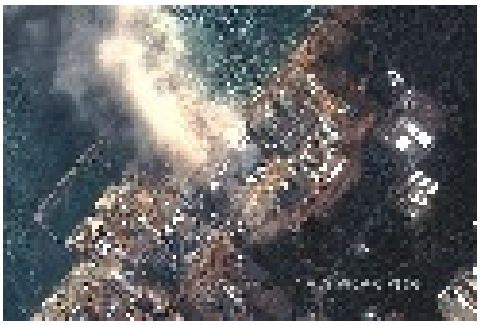


For developing the radiation evaluation system for emergency condition, Institute of Nuclear Energy Research (INER) and Central Weather Bureau (CWB) have focused on integrating meteorological forecasting, atmospheric dispersion and dose assessment technologies for years.

The effect of transboundary radioactive pollutants has been a major concern of the competent authority since the Fukushima accident of Japan and the nuclear threat from Korean Peninsula happened recently .

This project has developed a global nuclear accident dispersion evaluation system. The routine operation has been established to provide simulation and analysis information to the authority for decision making within the shortest time once the nuclear accident/explosion abroad happened.

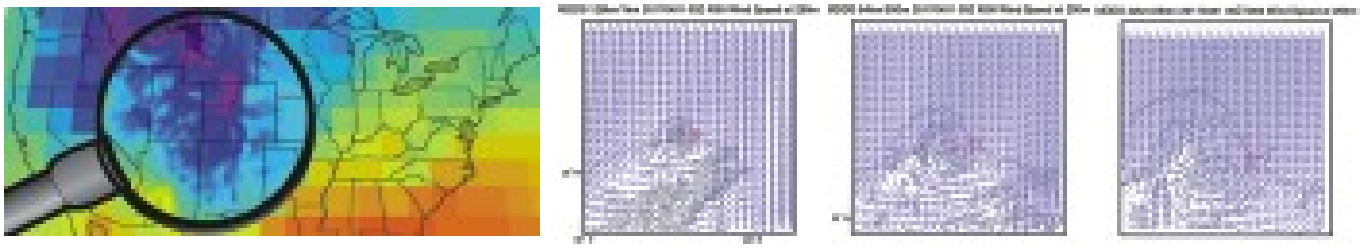
Threat of North Korea nuclear test



Fukushima nuclear accident of Japan

The downscaling technology applied to generate meteorological forecasting data was developed by CWB and National Oceanic and Atmospheric Administration (NOAA). It could highly reduce the computing time for weather forecasting without loss of detail.

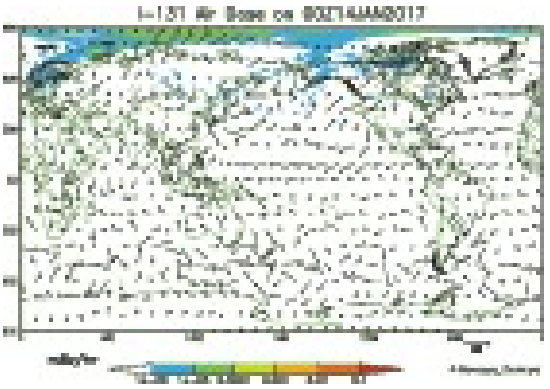
The dose evaluation model was integrated to atmospheric dispersion model. Deposition was adopted and modified from HYSPLIT model to consider the depletion effect.



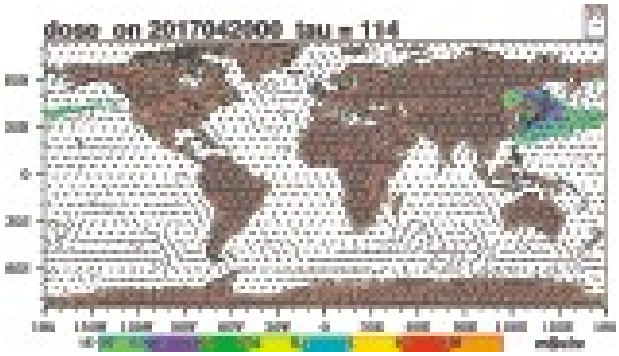
Downscaling forecasting meteorological Data generation

This project has simulated the suspected nuclear test explosion on polar regions in early 2017, the hypothetical nuclear attack by North Korea on Apr. 2017, and the hydrogen bomb test by North Korea on 3rd Sep. 2017.

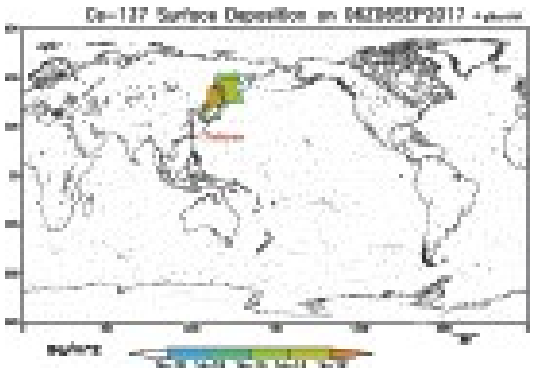
The simulation analysis offered the authorities of the whole picture of the dispersion tendency of radioactive material. It had great benefit to communicate the radiation influence to the public.



Simulation for possible nuclear test on polar regions



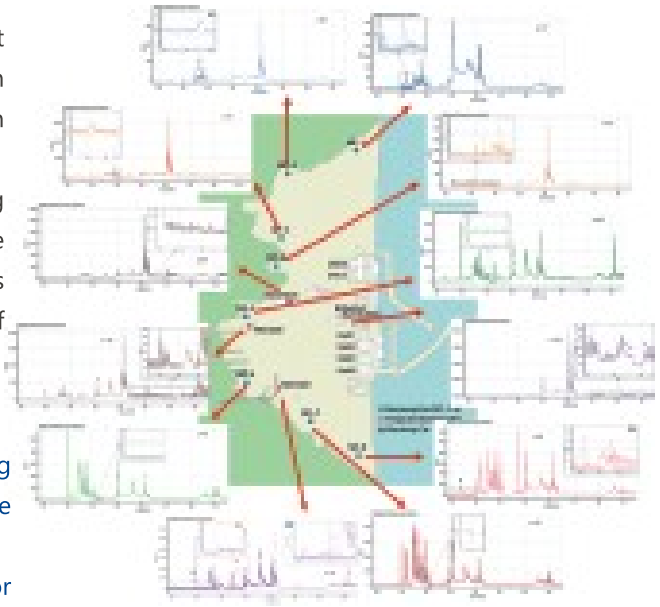
Simulation for hypothetical nuclear attack by North Korea on Apr. 2017



Simulation for hydrogen bomb test by North Korea on 3rd Sep. 2017

Learning from Fukushima accident, it revealed that the dose evaluation system could not provide any valid information without the released source terms.

This project has developed reversing estimation by monitoring data to get the released source term. The methodology has been verified by utilizing monitoring data of Fukushima daiichi nuclear power plant.



Verification result for reverse estimation of released source term

Future work

- Combine forecasting and observing meteorological data to improve the forecasting accuracy.
- Integrate domestic and global system for radiation dispersion model and dose evaluation.
- Keep routine operation and maintenance.
- Strengthen graphic display .
- Extend application cases.

3-1-9 Establish the radioactivity primary standard of Mn-54

The standardization of Mn-54 radiation source is needed to a calibration source or proficiency testing source for γ spectrum in Taiwan. The end-users include Institute of Nuclear Energy Research(INER), Nuclear Power Plant, Academia Sinica, and National Tsing Hua. These units are the frontline labs of nuclides analysis for environment , radioactive wastes , and imported and exported food. The measurement accuracy is related with the public and environment radiation safety. Therefore, it is necessary to establish the radioactivity primary standard of Mn-54, and then transfer to the secondary national measurement system, as shown in Figure 1. It could provide the calibration service and enhance the radioactivity measurement accuracy.

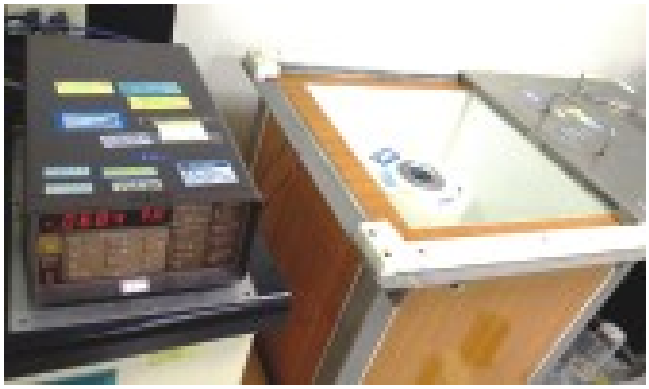


Fig. 1 the secondary national measurement system ($4\pi\ \gamma$ ionization chamber)

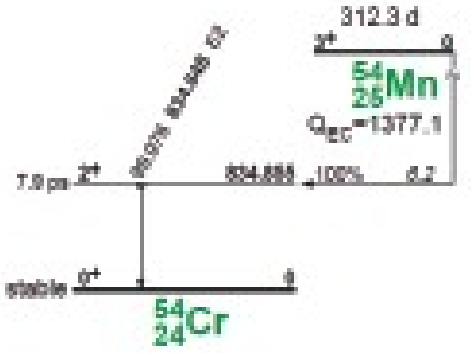


Fig. 2 Mn-54 decay scheme

Mn-54 is decayed by electron capture directly to the 835 keV excited level of Cr-54, producing γ -ray, X-ray and Auger electron, as shown in Figure 2. The absolute counting method ($4\pi\ \beta$ - γ counting system) is employed , the system is shown in Figure 3. For the β -channel, a proportional counter is usually used to measure the Auger electrons. The source sample preparation is shown in Figure 4. The counting results, based on the radionuclide's decay structure analysis and the linear extrapolation method, would lead to the derivation of activity. The radioactive source of Mn-54, after being calibrated by the absolute counting method, can serve as the national standard for $4\pi\ \gamma$ high pressure gas free chamber and be used for calibration services.

Fig. 3 $4\pi\beta$ - γ measurement system

Fig. 4 source sample preparation

The uncertainty of the primary standard of Mn-54 radioactivity measurement techniques was reduced to 0.45% from 3%. The results of the bilateral comparison with PTB/ Germany (Physikalisch-Technische Bundesanstalt, PTB) were in good agreement(INER / PTB = 0.999 ± 0.009). The comparison results with the International Bureau of Weights & Measures (BIPM) were less than the standard measurement uncertainty as shown in Figure 6. The radioactivity measurement accuracy has been greatly improved to earn a leading place in the world. The fear towards radiation is hence reduced for people.

The specific activity of Mn-54 measured by absolute counting method was 770.5 ± 3.5 KBq/g and the measurement uncertainty was 0.45% as shown in Figure 5. Then, The standard was passed to a 4πγ national standard system with a calibration factor of about 8.2 pA / MBq. As the Mn-54 activity measurement uncertainty has been lowered, through the traceability of the standard can uplift the calibration and analysis accuracy of γ spectrum analysis instrument owned by laboratories dealing with environmental radionuclide analysis, food testing and other secondary laboratories.

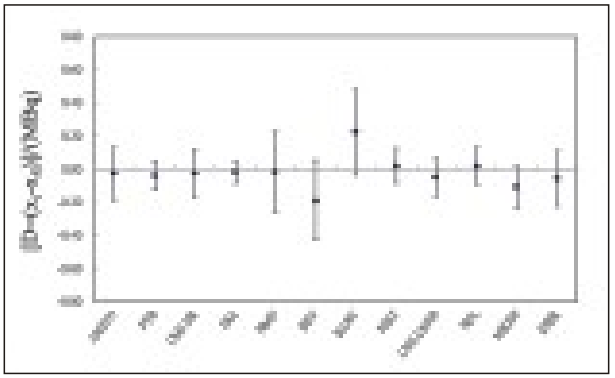


Fig. 6 in comparison with other national lab

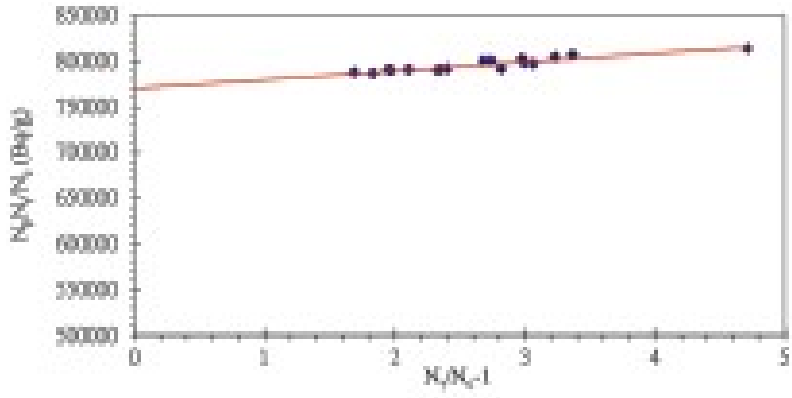


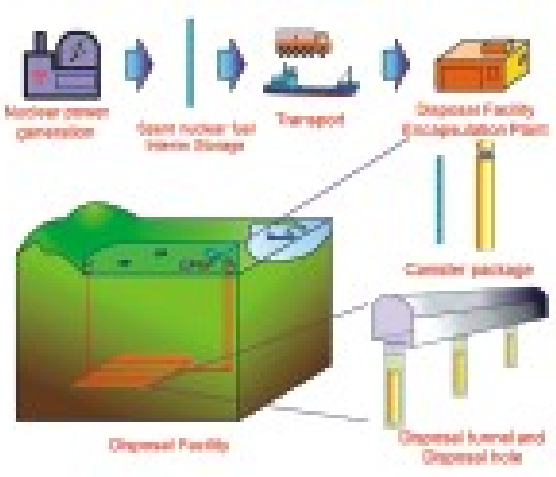
Fig. 5 4- measurement result

After completing the establishment of the Mn-54 radionuclide activity primary standard, INER can produce Mn-54 standard sources for end-users. Meanwhile, INER offers calibration services for liquid sources of different strengths by using the national standard 4πγ ionization chamber system, spectrum analyzer or liquid scintillation counter to fulfill customers' needs .

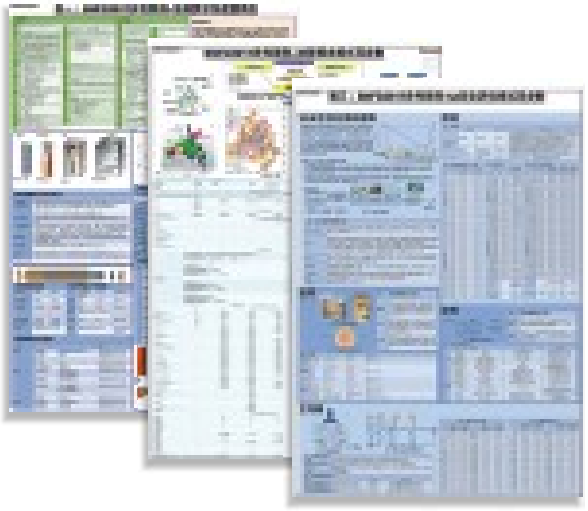
3-1-10 Technical Feasibility Assessment Report for the Spent Nuclear Fuel Final Disposal in Taiwan

Institute of Nuclear Energy Research is commissioned by the Taiwan Power Company to implement "The Spent Nuclear Fuel Final Disposal Program". In 2017, the work of "Potential Host Rock Characterization and Evaluation Stage "was accomplished. We established safety assessment technology for deep geological disposal for the spent nuclear fuel. We also completed the "Technical Feasibility Assessment Report for the Spent Nuclear Fuel Final Disposal in Taiwan (SNFD2017) "to summarize the current stage progressive results and to establish a solid foundation for the follow-up disposal tasks.

The objective of SNFD2017 is to summarize the technical feasibility assessment for current stage, and to ensure that (1) whether a scientifically suitable granite body is available in Taiwan for geological disposal; (2) whether the research teams have had enough ability of geological disposal technology; and (3) whether the research teams have established the long-term safety assessment technology for geological disposal facility.



SNFD Concept Diagram



SNFD2017 Reference Case / Parameter Table

Geological Disposal System and Safety Concept

The international community generally recognizes that deep geological disposal is the currently preferred method for high-level radioactive waste disposal. Basically the high-level radioactive waste is isolated in the deep, stable underground host rocks with multiple barriers to achieve the purpose of keeping an integrated containment over 1 million years. The radiation limit for disposal facilities is to ensure the personal radiation dose rate (for key groups) must not exceed 0.25 mSv/yr, and the personal annual risk caused by the radiation to a person in the key groups outside the facilities is not more than 1/1,000,000.

The Geological Environment of Taiwan

Based on the geological conditions of Taiwan, the assessment for scientifically suitable area for deep geological disposal should consider the geological impact factors include volcanism, faulting, earthquake, mud diapirism, uplift/subsidence/denudation, and climate change. With the comparison of the long-term stability of various potential host rocks in Taiwan, the granite rocks in the western offshore islands and the eastern part of Taiwan, have the potential to retain their long-term stability at least millions of years. These rocks are relatively with survey feasibility and characteristics predictability.

Safety assessment is a key element in constructing safe disposal system, and forming the safety case

Development of Repository Design and Engineering Technology

The calculation tools, numerical models, testing techniques and performance assessment methods were ready for this concept design stage. The research achievements were submitted to the peer-reviewed process by domestic and international experts, to verify the domestic technical competence in carrying out a final disposal program.

Development of Safety Assessment

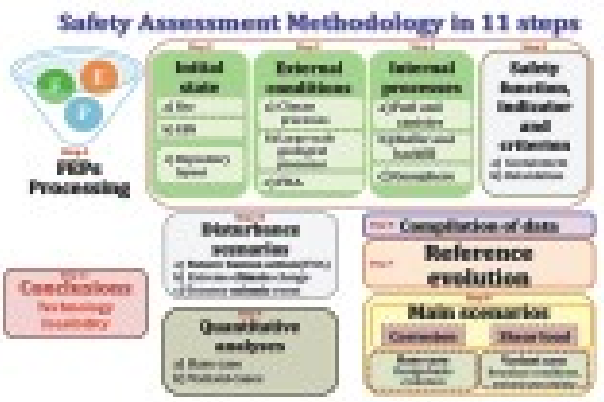
Based on the SNFD2017 Reference Case, the research team integrated Taiwan FEPs database, local deep geological information, the interaction processes of the disposal system to construct the safety function, reference evolution, and case scenario. The experiments and simulations on radionuclides migration and THMC coupling process were also performed maturely. Thus they had laid down the foundation for future research in this matter.

Safety Case and Peer Review

At current stage, the research team used the K-area as the reference case to present the repository design and engineering, and the safety assessment technologies as an important result for SNFD2017 report.

In order to verify the domestic geological disposal ability, the SNFD2017 report had been experienced six months of international peer review by OECD / NEA experts. Positive opinions were given from the perspectives of SNFD2017's maturity, human resources and capabilities. As a result, the project is encouraged to move forward to the next phase of the SNFD program.

According to the established plan of the SNFD program in Taiwan, the work of "Candidate Site Selection and Approval Stage (2018-2028) "will be continued. INER will keep improving its performance / safety assessment techniques and apply that to specific candidate regional sites demonstrate its localization technology in line with international levels.



The International Review Team (IRT)

3-2 Endeavor to Ensure the Sustainability of Ecosystems and Devote to the Development of Supportive Technologies

In response to the worldwide crucial issues including the shortage of renewable energy and risks from climate change, we have taken, as a national research institute, the assigned responsibility to extend our research to cover the technologies in energy and environment areas, and those for the application of radiation in addition the recognized focus in nuclear safety. In the development of energy and environment associated technologies, we have taken the advantage of experiences from nuclear energy research forging a strong base to support civil applications. Some achievements have been made after years of effort in this new approach helping the reach of sustainable ecosystems and could be reviewed in our annual reports.

Last year, we have had following advancements in different topics:

In the energy saving technology, INER has developed high performance heat pipes, for the industrial needs of waste heat recovery in Taiwan as well as the reduction of carbon emission. And our team has successfully developed a computer-aided program. Through this analytic tool, the users can easily understand the maximum heat capacity of heat pipes in any size. The development of this program had been presented in the 2017 TTMA Annual Meeting and won "the Best Paper Award." With this convenient tool, INER could therefore focus on the key performance factors of heat pipes, and facilitate the R&Ds progress. Currently, we have developed an innovative high-density plasma source plating system to apply electrochromic film, and improved conditions and stability in this process. Furthermore, this technology with low cost advantage has great commercial potential in the future and has transferred to private firms.

In the energy storage system technology, INER has developed key materials for Vanadium Redox Battery (VRB) and mastered key technologies for materials such as PEM, MEA, electrode materials, and bipolar plates. And our team established a research and development test platform to provide validation and testing of domestic industrial materials, effectively integrated product applications and feedback from domestic battery components or material suppliers, increased technological competitiveness and increased the proportion of domestically produced materials, and developed energy storage industry value chains to support renewable energy policies.

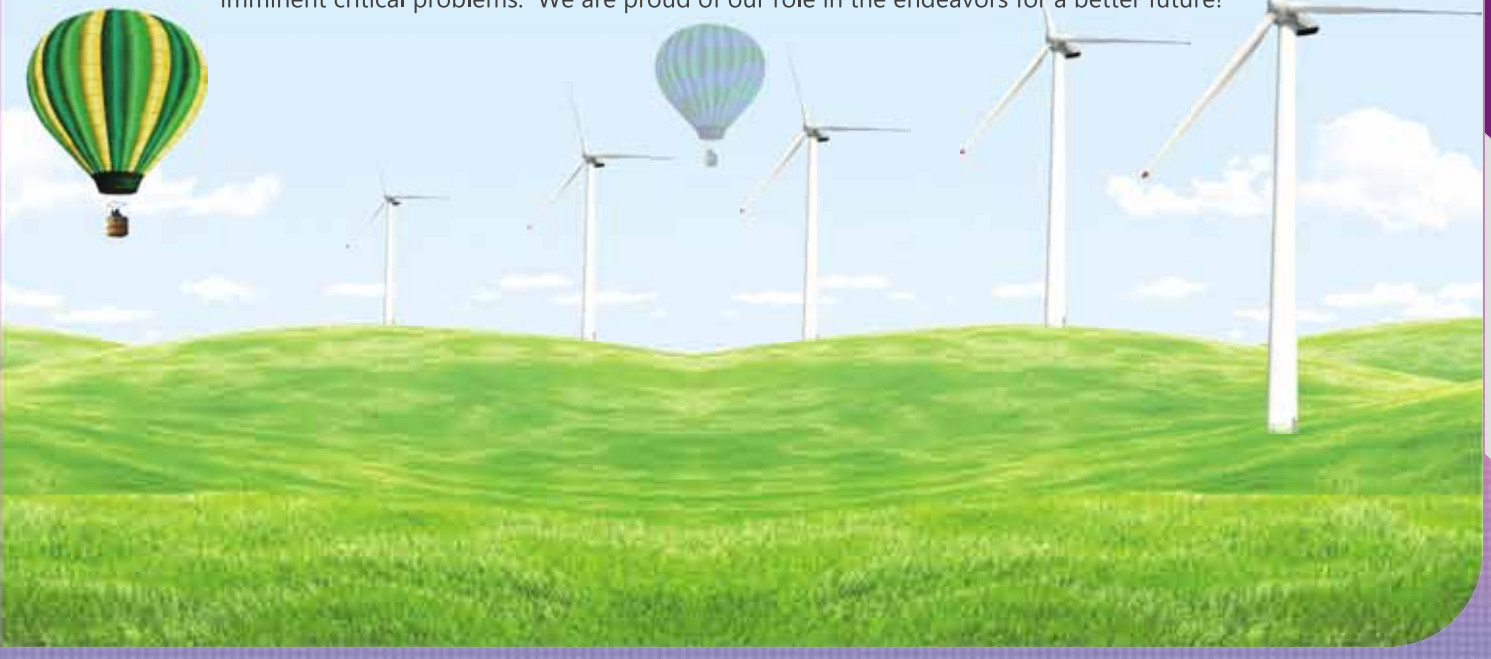
In the new energy technology, our solid oxide fuel cell (SOFC) technologies from powder to power are linked closely with domestic industries. In combination with local technical capacity, we and private businesses are jointly constructing a 3-5 kW power generating system. In terms of wind turbines, we established the dynamic load calculation procedure of the OWT to evaluate the effects of Taiwan's extreme environmental conditions on offshore wind turbines. This technology will improve the reliability of offshore wind turbine structure, promoting the policy and technologies of OWT.

Moreover, we not only promotes the technology of cellulosic ethanol to industrial development by using non-food biomass as resources, with the objective of lowering the dependence on petroleum, reducing carbon emissions and building a new low-carbon industry; but also integrates the biogas and other biomass thermoelectric technologies at the same time, to help increase the domestic contribution of green electricity and achieve the purpose of low-carbon products valorization, with the strategy of high-value by-product application.

In the aspect of developing distributed power systems and intelligent control technologies, as being supported by National Energy Program of Ministry Science and Technology, we made a successful microgrid control technology transfer to a local firm who built up the first Taiwan's high-renewable-energy penetration microgrid system in Dongji Islet of Penghu County. In March 2017, the system reached the maximum instant renewable energy penetration ratio of 92.8%, so the technology has met the international standard.

In addition to the technology development, we were also involved in the planning of future energy development strategy and policy. We used the Marginal Abatement Cost Curve(MACC) to explore the cost, low-carbon technology portfolio, and technical carbon contribution needed to achieve this goal. To meet the national carbon emission reduction targets and propose strategies. Since energy is a social issue, we also study the intention of the mass energy choice. The most closely related to people's lives in the energy transition is the issue of electricity prices. We have accumulated the results from 2015 to 2017. As the domestic electricity price has been controlled for a long time, people have accustomed to lower electricity price. As the result shows, in the current electricity service scenario the WTP for electricity price in the past three years fell 2.91 NTD/ kWh to 2.7 NTD/ kWh, slightly lower than the real residential electricity price of Taipower.

UN has raised Sustainable Development Goals(SDGs) to integrate the efforts from member states and organizations to deal with critical issues and challenges we are facing in upcoming years. Most of them are linked to the advanced development and use of energy to preserve a sustainable future. We are in a position taking the responsibility to catch the international focuses and trend in both energy and environment, helping our country get involved the global effort in resolving the mutual and imminent critical problems. We are proud of our role in the endeavors for a better future!



3-2-1 High Performance Heat Pipe & Its Computer-Aided Design Interface

A heat pipe is a closed two-phase heat transfer system that the heat can be transferred efficiently via phase changes (liquid-to-vapor as well as vapor-to-liquid). A heat pipe is also known as a "thermal superconductor" owing to its extremely high thermal conductivity. Heat pipes are therefore widely used in cooling, thermal management, and waste heat recovery. In view of industrial waste heat recovery, when compared with traditional heat exchangers, heat pipes have the advantage in resisting dust blocking and higher toleration to tube failure. Due to these benefits, INER develops high performance heat pipes for the industrial needs of waste heat recovery as well as the reduction in carbon emission.

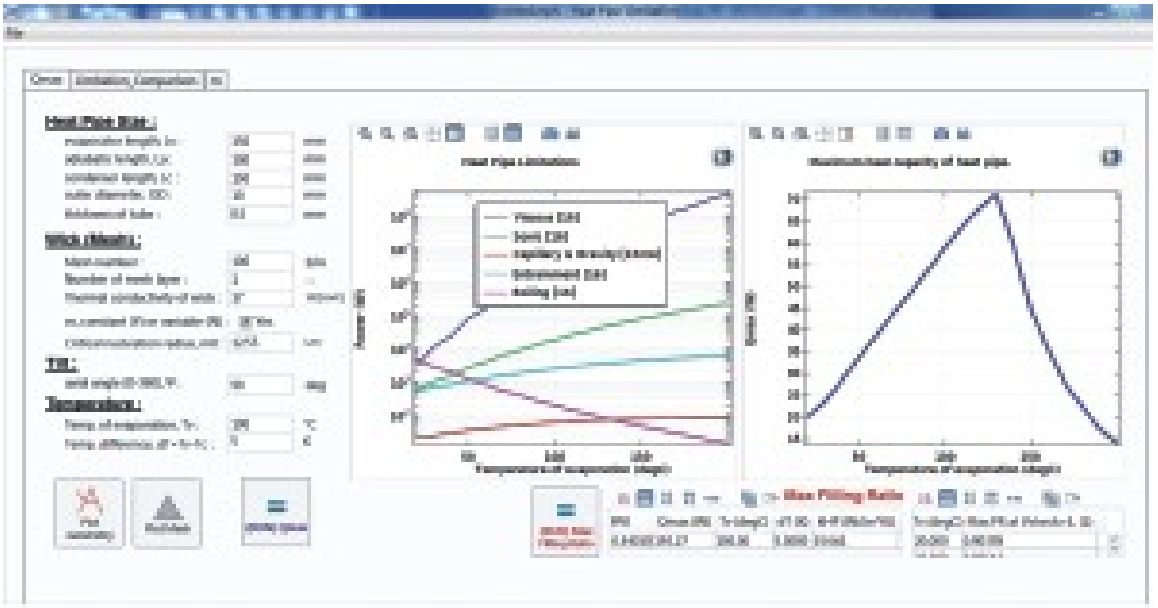
	>300°C	<300°C	50-250°C	Dew point corrosion	Dust problem	Size	Pressure drop
Low-grade heat source			V	Severe	High	Limited	As low
Shell & Tube	Yes	Yes	Yes	Severe	Low	3-5	1
Plate-type	No	Yes	Yes	Severe	High	1	2
Heat Pipe	Yes	Yes	Yes	Severe	Low	0.5-2	<1

Comparison of heat exchangers and associated technology gaps

INER has designed series of high performance heat pipes. The tube material could be SUS316L, SUS304, copper, or alumina. The working fluids can be deionized water, ethanol, ammonia, or others. On the outer surface of the tubes, anti-corrosion material is coated to enhance the anti-corrosion capability and extend their lifetime. While on the inner surface, there are nano-porous coatings to improve the capillary force as well as the boiling heat transfer of working fluids. A fast screening technique for heat pipe quality check with IR thermal image and data analysis process has also been successfully developed.

High performance heat pipes developed in INER

Currently it is still lack of a commercial package to predict the performance of heat pipes. INER has successfully developed a computer-aided program, based on the five major limitations of heat pipes and the equations from literatures and textbooks. Through this analytic tool, the users can easily understand the maximum heat capacity of heat pipes in any size. The development of this program had been presented in the 2017 TTMA Annual Meeting and won "the Best Paper Award." With this convenient tool, INER could therefore focus on the key factors of heat pipes, and facilitate the R&Ds progress.



COMSOL Multiphysics v5.3a

User-friendly interface

Developed by INER

Functions :

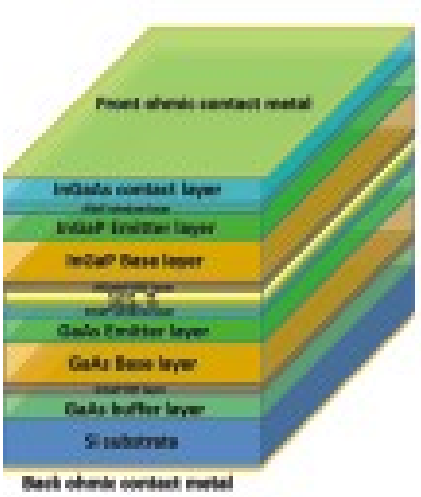
1. Qmax of any size
2. Qmax at any temperature
3. Influence of wick structure
4. The max filling ratio of working fluid

A user friendly computer-aided design interface

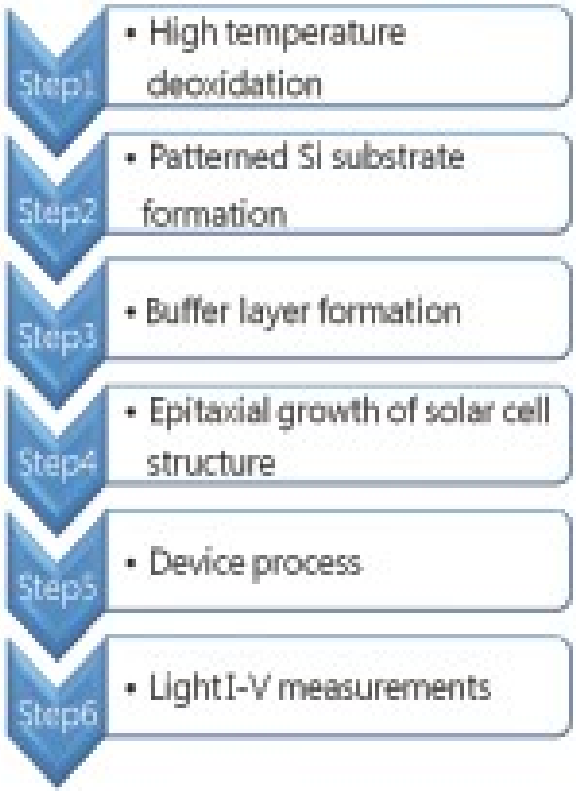
The heat pipes developed by INER have helped a local firm to improve the energy efficiency during their plastic pyrolysis process, producing chilled water by recycling the waste heat of plastic pyrolysis chamber exhausts, with a estimated payback time in less than one year. In the meantime, INER had cooperated with a kiln company for innovative energy-saving applications. INER had close cooperation with a local steel company, and provided them the heat capacity, thermal resistivity, the reliability testing, temperature limitation, and the hazard assessment analysis of heat pipes. Currently, INER is arranging the heat pipes-associated technology transfer to a technical company and a refrigeration and air-conditioning firm. A field test of a kW-level heat pipe heat exchanger has also been scheduled in 2018.

3-2-2
III-V on Si Solar Cells
New strategy of low-cost high-efficiency solar cells

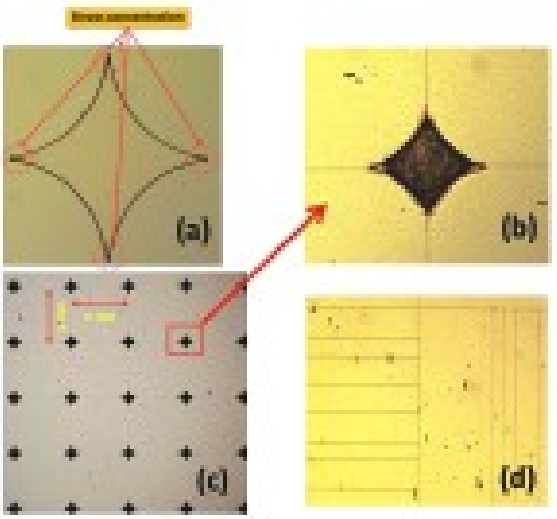
III-V multi-junction solar cell has the stunning world record efficiency of 46%. However, the cost issue causes the dominance of silicon solar cells in recent years. The significant cost contributor for III-V solar cells is from that of the starting substrate. Both GaAs and Ge substrates, typically used for the epitaxial growth of III-V multi-junction solar cells, are about ten times more expensive than Si substrate. Si wafer has then been chosen as the starting substrate in this project for the potential of high efficiency and low cost.



INER has successfully developed MOCVD hetero-epitaxial growth technology, which combines low temperature buffer layer, thermal cycle annealing (TCA) method and patterned silicon substrate formation, to mitigate the cracking issue of III-V on Si epitaxial growth. In addition, the InGaP/GaAs dual-junction solar cells on Si substrate with the best efficiency of solar cell approaching 18.6 % are also demonstrated.



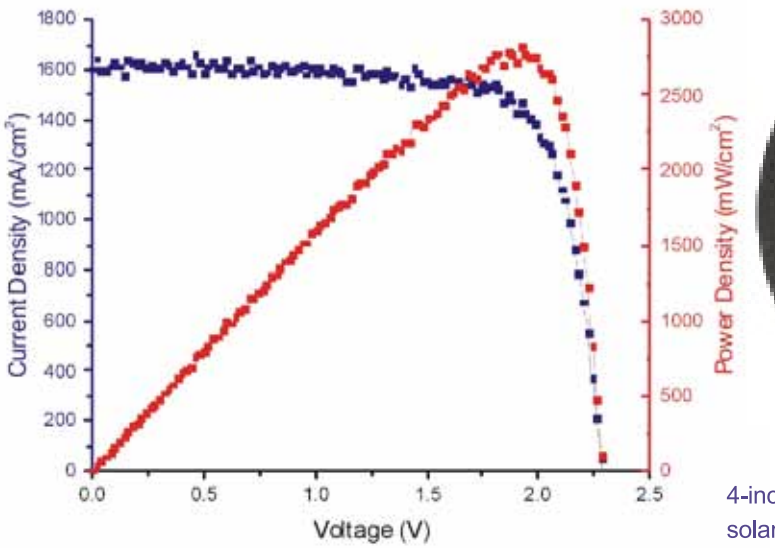
Device process flow of GaInP/GaAs on Si solar cell



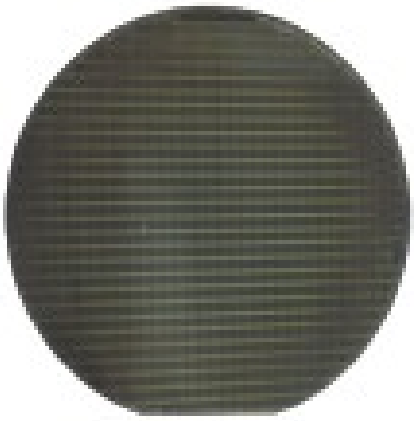
Device process flow of GaInP/GaAs on Si solar cell

Due to the lattice and thermal expansion coefficient difference between III-V material and Si substrate, stress will cause micro-crack along with the thermal process of epitaxy growth, and significantly reduce the efficiency of solar cells. Thus, patterned silicon substrate instead of the regular substrate is adopted for the III-V on Si epitaxial process to resolve the micro-crack issue.

We also demonstrate that the patterned Si substrate can make the micro-crack generate in the designed directions, and form a 1mm x 1mm crack-free region.



Light I-V characteristics of InGaP/GaAs on Si dual-junction solar cell.



4-inch InGaP/GaAs on Si dual-junction solar cell

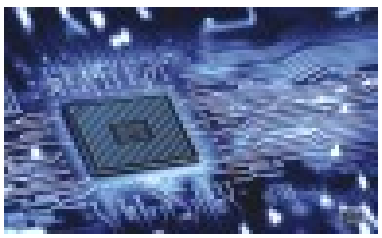
Light I-V characteristics of InGaP/GaAs on Si dual-junction solar cell	
Open circuit voltage (V)	2.3
Short circuit current density (mA/cm^2)	1626
Number of suns	152
Fill factor (%)	75.4
Efficiency (%)	18.6

To resolve the micro-crack issue, Si substrate with the desired strain-relief patterns are used in the MOCVD epitaxial growth, on which epitaxial growth of GaAs buffer layer is conducted first after the pattern formation and is followed by the TCA process. After that, the InGaP/GaAs dual-junction solar cell structure can be grown on the GaAs buffer layer.

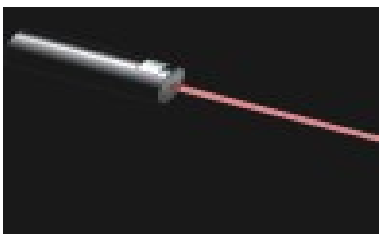
By using the patterned Si substrate to replace the conventional one, the InGaP/GaAs dual-junction solar cells on Si substrate have been fabricated successfully. The best efficiency of solar cells has reached 18.6 % at 152 suns.

The major goal of this project is to develop the manufacturing technology of III-V dual-junction solar cells on Si substrate. In addition, III-V on Si hetro-epitaxial technology could be applied in other fields such as high power electronic devices, high speed transistors and LED device, so as to make this technology more versatile and more competent in the near future.

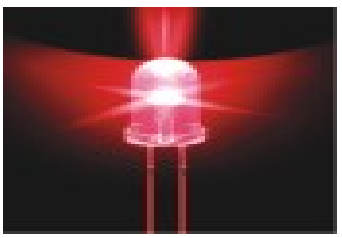
4-inch InGaP/GaAs on Si dual-junction solar cell



High Speed IC



Laser

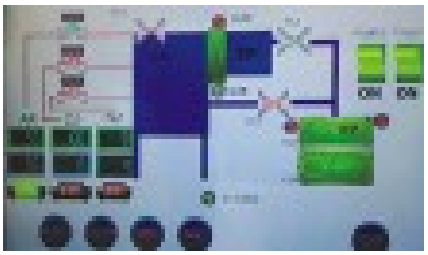


LED

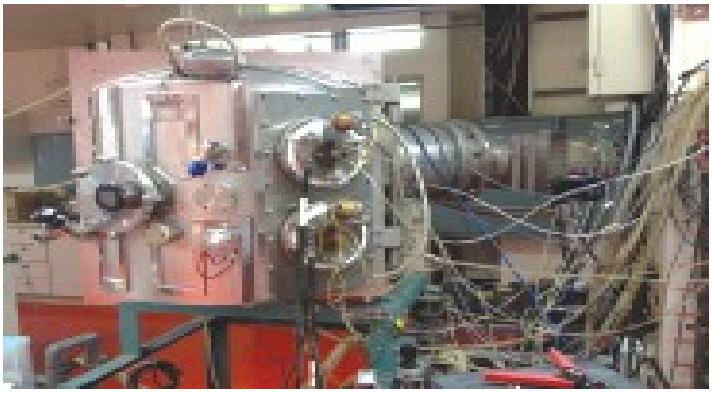
3-2-3 High-density plasma coating technology applied to commercial electrochromic device

According to nanomarket firm statistics, the global electrochromic smart window is expected in the market in 2020 there will be 5.6 billion in the scale of business opportunities. Electrochromic smart window related products have great commercial potential in the green building city development for the future. The large-scale electrochromic devices are mainly fabrication by magnetron sputtering. However, most of the key factor of electrochromic materials are high melting point materials, which has a low deposition rate by magnetron sputtering and the coating equipment expenditures. The technology of magnetron sputtering is still not widely used in ordinary home and commercial buildings. Currently, we have developed an innovative high-density plasma source plating system to apply electrochromic film, and condition and stability in this process. Furthermore, this technology with low cost advantage has great commercial potential in the future.

Electrochromic device



Man-Machine Interface



Development of high-density plasma

High-Density Plasma Source

Using high-density plasma source equipment with excellent characteristics: (1) high deposition rate (2) with a high ionization rate of the plasma (3) good adhesion, and (4) wide range of process parameters, INER has effectively increased the plating rate by 7 times than that of the magnetron sputtering, with higher potential to commercialize.

Traditional of the high-density plasma source cannot be directly applied to the nano-scale electrochromic film (single layer thickness of 100~300nm), the use of high-density plasma generated particle size is too large (particle size of about 10um). INER improved of high-density plasma source performance with reduced the size of micro-particles to less than one order of magnitude, and enhanced of causing rapid coloring/bleaching phenomenon (transmittance variation 50% is taken with 10 sec), faster than the traditional method (magnetron sputtering). This innovative high-density plasma plating system can be applied in porous electrochromic film with superb stability during the process.

Cross section view of electrochromic film

Porosity is synthesized by High-density plasma source

The comparison of costs and fabricated methods among different electrochromic devices

Fabricating Methods	Thermal Evaporation Deposition	Sputtering Deposition	Sol-gel Deposition	Highdensity Plasma Deposition
Fabricating Cost	MediumHigh	High	Low	MediumLow
Materials	WO_3、NiO、TiO_2	V_2O_5、WO_3、NiO、TiO_2、Ta_2O_5	Prussianblue、Butylviologen	WO_3、NiO、TiO_2、Ta_2O_5
Response times	> 3min	> 1min	>5 sec	> 10 sec
Applied Company	SAGE、View Inc (USA). SaintGoain (Fran.). EcontrolGlas (Germ.).	SAGE、View Inc(USA). France:SaintGoain(Fran). EcontrolGlas(Germ.). Nicon(Jap.). TinTable、ChungHsing Chin-Teng (Taiw.).	Gentex、PPG、AshwinUshas(USA). Simen(Germ.). ETRI (Kor.). News(Jap). Licon(Taiw).	INER

The technology reduces the size of micro-particles by an order of magnitude

The innovative technology has embedded two patents and the third one is still in the application process for the US patent. An award has been granted in the 2017 Taipei International Invention Exhibition. The agreement with local firm to provide technical service in 2017 has been signed. We are endeavoring to transfer technology helping manufacturers to mass produce large-scale electrochromic film and in the development of qualified equipment.

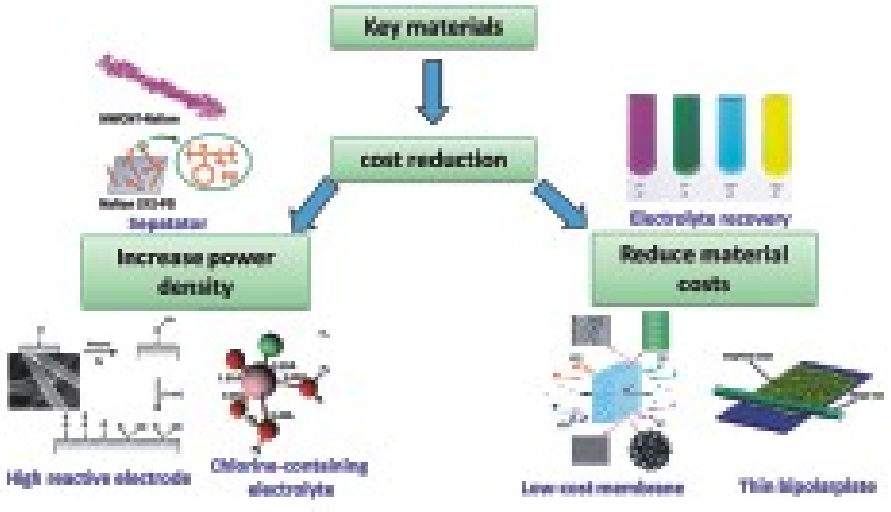
Planning of the product development and its applications in the future

3-2-4 INER made decentralized flow battery energy storage system key materials

Our government has set the goal to expand installations of renewable energy by 2025 and promotes four major strategies in energy saving, energy conservation, energy storage and smart integration to increase the portion of autonomous energy sources. The energy storage provides stable output for regulating and plays a key role in the renewable energy system that is crucial to support efficient operation. Flow batteries have the advantage in safety, life, and recycled materials with the benefits of environment-friendly to fulfil sustainable development. Their power/energy can be independently designed and will be one of the options to support future power grid energy storage system.

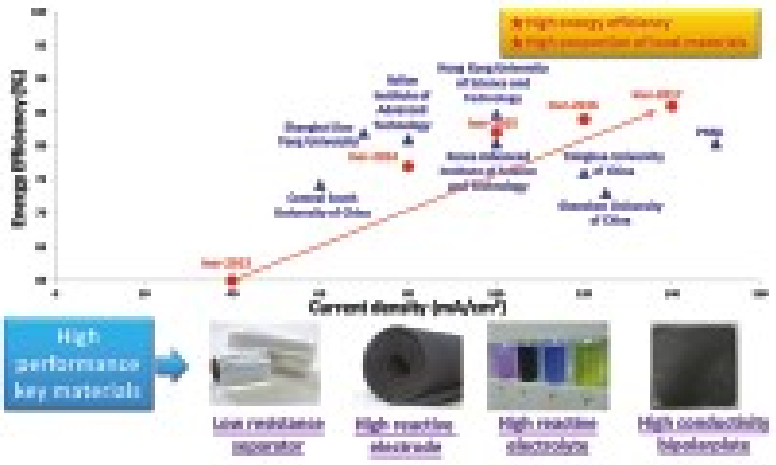
Development of Vanadium Redox Flow Battery at INER

Our R&D of key technologies for the materials used in Vanadium flow batteries include the assessment of material selections, simulation of flow field designs, development of stack assembly procedures and exploration of stack leak detection technologies. A removable battery module research platform with high durability and excellent performance has also been developed.

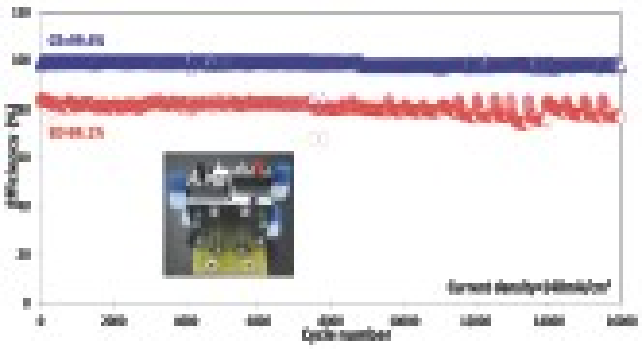


Evaluation of key material R&D strategies of Vanadium flow batteries

By screening and testing modified electrode materials, electrolytes and membranes, the single-cell (carbon felt electrode, 25 cm^2) VRFB with an efficiency of 84% at 140 mA/cm^2 has been developed. In addition, analysis technologies for charactering related cell properties have been established to clarify the relationship between mechanism and efficiency to improve the battery design.



Development of high-quality key materials with excellent performance

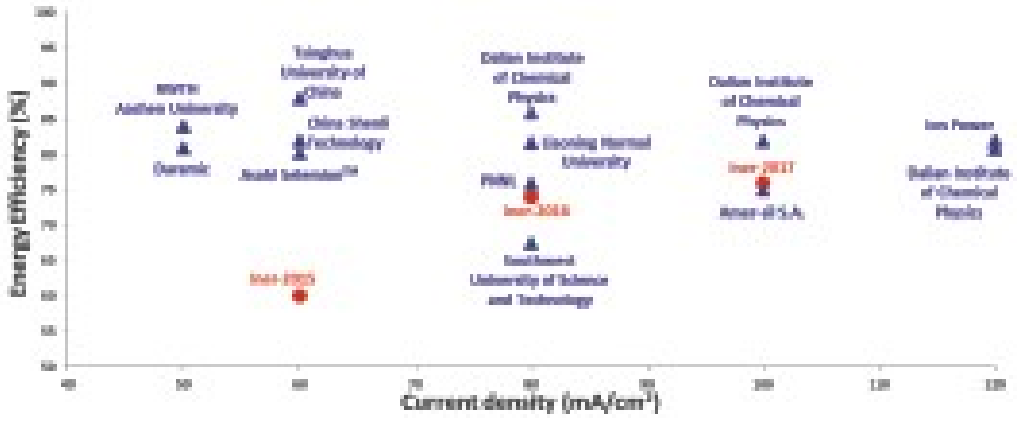


Long-term stability test of high performance and high quality key materials

The R&D in key materials for flow batteries has not only improved the performance but also reduced their costs. The higher the number of discharge cycles in stable operations, the lower the storage cost in average. The left figure shows that at a high current density of 140mA/cm^2, the energy efficiency remains in a level of more than 80% after 16,000 cycles charge-discharge tests.

Membrane is one of the most important key materials for flow batteries. The development of innovative local membrane material would help the development of domestic industry, and also enhance the competitiveness of domestic flow battery energy storage system.

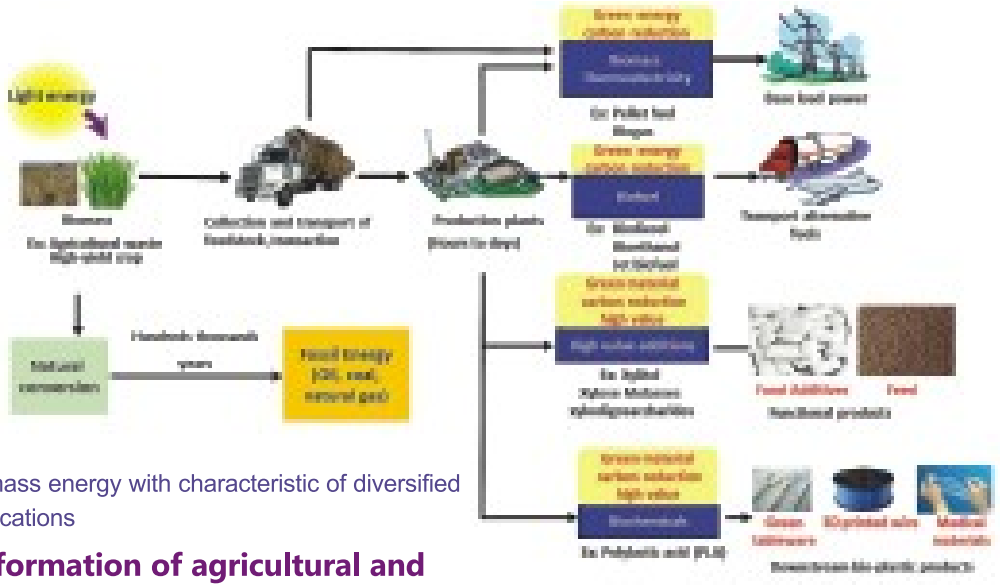
During the cooperation with domestic fuel cell manufacturers, our team has magnified the accumulated experience in developing porous membranes to improve the materials that were previously unable to complete charge-discharge cycles so that the modified membranes can be charged and discharged and enhance their electric current density and energy efficiency.



Development of low-cost membrane materials for flow batteries

3-2-5 Eco-Friendly Economic Revitalization- Versatile Bioenergy Triggers New Circular Economy Models

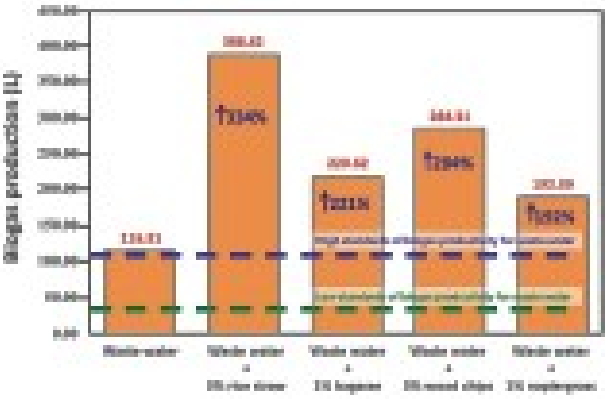
With the depletion of petrochemical resources coupled with the rising awareness of sustainable development in the international community, the way to utilize resources has been gradually transformed from the one-way consumption model to circular economy. Its core value of environmental sustainability has become the mainstream of the recent international industry and economy, and the application of renewable biomass in bioenergy is in line with the spirit of the circular economy. Our institute has not only promoted the technology of cellulosic ethanol to industrial development by using non-food biomass as resources but also integrated the biogas and other biomass thermoelectric technologies to help increase the domestic contribution of green electricity and achieve the purpose of low-carbon products valorization, with the strategy of high-value by-product application.



Biomass energy with characteristic of diversified applications

Transformation of agricultural and livestock waste makes the waste-to-energy real

Based on the technology of biomass depolymerization for biogas production and mass production technology in biorefinery, we have maximized and diversified the application of biomass energy. By using depolymerized lignocellulosic biomass directly for biogas production or mixing it appropriately with livestock or industrial wastewater, we increase the original biogas production and accelerate the productivity. So the agricultural and livestock waste can generate commercial benefits through the utilization for biogas production, resulting in a business model of the circular economy.



Biogas production comparison for depolymerized lignocellulosic biomass mixed with wastewater

The research achievement of biological resources development was affirmed by the nation

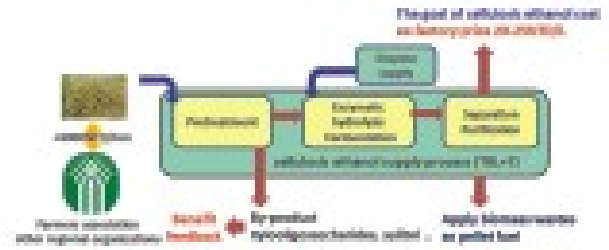
Developing core technology of polylactic acid(PLA) is a key for bio-based materials promotion

In order to mitigate the negative impact of petrochemical plastics toward environmental sustainability, our team has developed PLA bioplastics with excellent processability and biodegradability, using lignocellulosic biomass as feedstock. In the future, waste PLA products will be reused for biogas production and power generation, which upgrades the value of PLA bioplastics.

Research achievements of INER in the field of bioresources and fermentation have been recognized by the national award so many times. Over the years, numbers of self-developed microbial strains and processes have been promoted to industries through technology transfer and services. By integration of core technologies, our team now is going to produce bio-chemicals meeting market demand through trial production and validation, which will help stimulate the development of the circular material industry and extend the application of PLA technology.

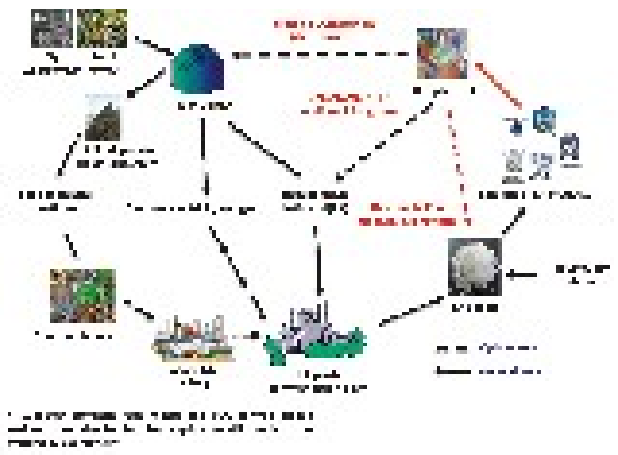
Combination of agriculture and energy drives bio-economic growth

Reasonable profit can be created when producing high values byproducts from depolymerized biomass, which increases market competitiveness. The strategy of high values products from biomass can be implemented by cooperating with local rural organizations or Farmers' association to establish a new operating platform. This "agro-energy combination" model not only can be integrated with the developed issue in the current national "bio-economy" policy but also display derivative value from the emerging low-carbon industry, which builds a bioenergy model with site-specific characteristics.



Combination of agriculture and energy builds operation model of high value products

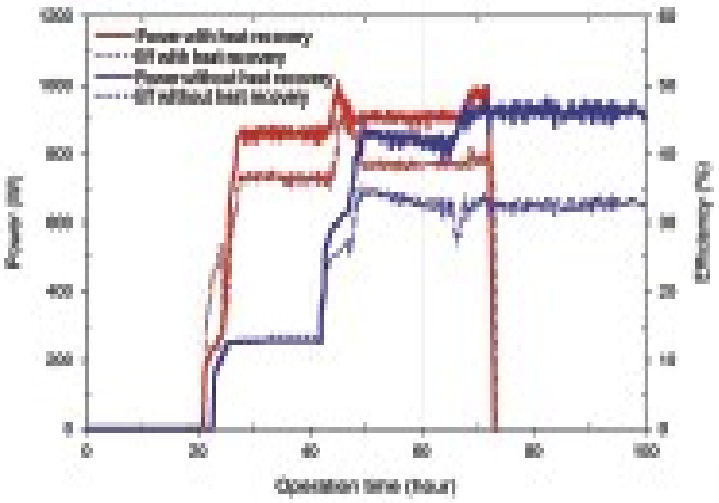
Overall, the circular economy is no longer just resource utilization and energy conservation but is able to elevate the economic value and efficiency. In the situation of resources depletion, biomass is viewed as the most significant alternative energy, its diversified energy and circular economy application are the potential models balancing energy, environmental protection, and economy. Reutilization instead of discards can enhance the added value of Taiwan industry, thus further demonstrating the benefits of low carbon, eco-friendly, and high added value.



Vision of Bio-plastic recycling

3-2-6 INER has developed entirely indigenous SOFC technologies

Solid oxide fuel cell (SOFC) technologies developed at INER are linked closely with domestic firms. To combine with local technology capabilities, we worked together with domestic firms and have developed a 3-5 kW power generating system. INER was in charge of system design, components assembling and integration of basic elements, key parts and sub-systems manufactured by local companies. System verification and validation tests are proposed to be performed in the industry. Moreover, INER has been constantly assisting the technology transferred companies to mass produce ceramic-supported cells at a small scale. The technology of stack assembling has also been transferred. Our team encouraged companies to sharpen their assembling skills, set up stack performance testing facilities, and develop an auto-assembling process. Based on the technology licensing for metal-supported cell manufacturing, we are consulting a company to establish the powder granulation process. Technologies of protective coating on metallic interconnect and nano-catalyst for fuel reforming will be transferred to domestic firms. We expect the project could help, in some levels, uplift the technology capability of our industry and strengthen the competence to play a role in the global market.



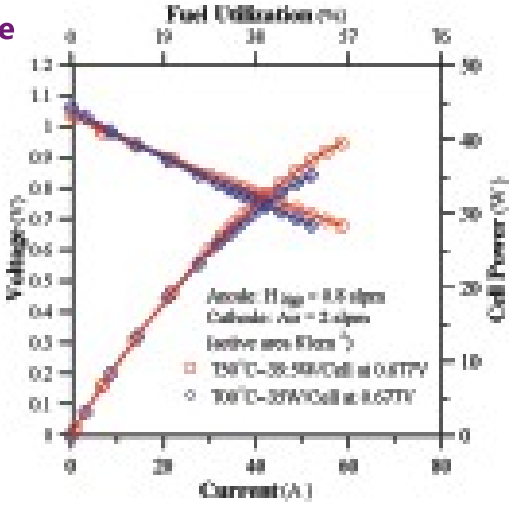
SOFC system with heat recovery

SOFC power system with recovery of thermal energy

INER is currently developing a SOFC power system with the benefit of thermal energy recovery. The cathode air is heated by fuel gas with an integrated balance of plant and a heat exchanger, independent of electrical device. Experiment results show that the cathode air temperature increases from 70°C to 430°C, and the fuel flow rate reduces from 4.76 to 4.2 lpm. The system power is around 993 W with the electrical efficiency around 40 %.

Plasma sprayed metal-supported solid oxide fuel cell:

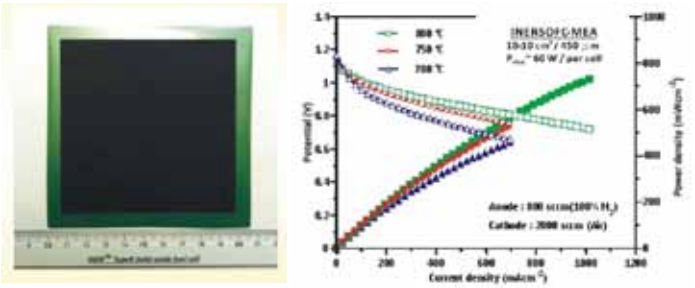
Flexible metal-supported solid oxide fuel cells with 250 μm in thickness and 10x10 cm^2 in size are designed and installed. The single cell stack can deliver about 35 and 39.5 W at the cell voltage of 0.68 V for test temperatures of 700 and 750°C, respectively. This cell shows a superb low degradation rate around 0.93%/khr.



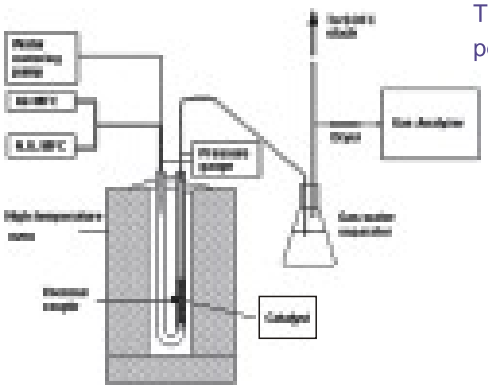
Performance of the single cell stack containing a flexible MSC

Ceramic-supported solid oxide fuel cells:

Performance of commercially available cells (10x10 cm^2 / 450 μm) has been promoted with multiplication of gas-permeation paths in anode and improvement of the catalytic property in cathode. The power can approach 60 W (~ 740 mW/cm^2 @ 800°C/0.7 V).



The ceramic-supported solid oxide fuel cell and the enhanced performance characteristics



Nano-catalyst for fuel-reforming:

(1)High space velocity honeycomb catalyst

(2)Low temperature (550°C) particle catalyst

(3)High temperature (800°C) particle catalyst

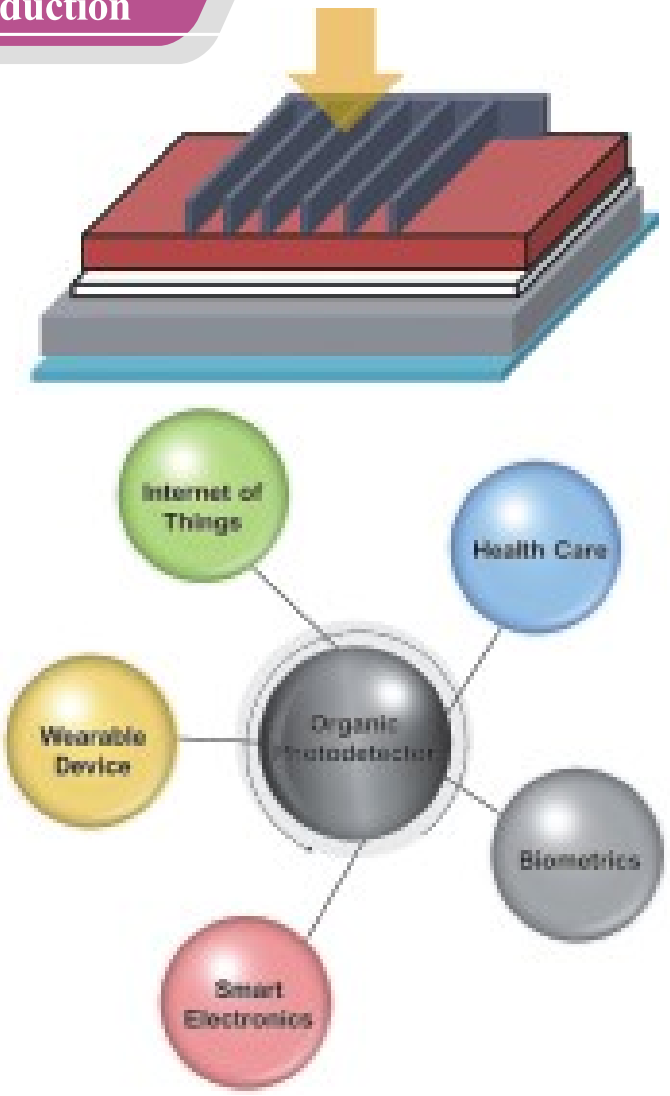
Awards:

2017 Taipei International Invention Show & Technomart

- **Gold medal awards:**
  1.Integration fabrication process with lamination and sintering of tape casting optimization for improving SOFC-MEA output power density
  2.Manufacturing methods of permeable metal substrate, metal-supported solid oxide fuel cell
- **Bronze medal award:**
  A composite material type oxygen transmission film and its preparation method

3-2-7 Solution coating of large-area organic photodetector for mass production

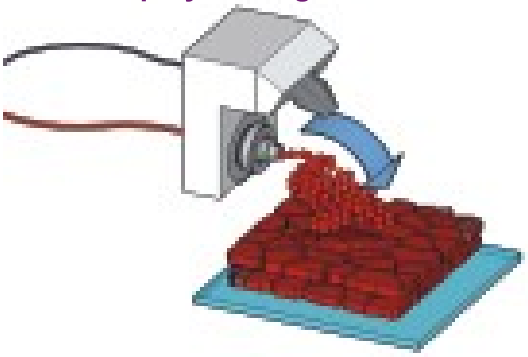
Recently, Internet of Things (IOT) largely progressed and had extensive applications in the fields of smart home, smart industry and health care, demonstrating the high commercial values. Sensing device or sensor plays an important role in linking IOT and environmental change, like perception organ. Photodetector is one of the wide-used sensors. Compared to the conventional semiconductor-based photodetector, the organic photo-detectors (OPDs) have the unique and promising advantages, such as low cost, non-vacuum solution printing, flexible and low weight etc., demonstrating the higher cost-performance value. The current status of OPDs development is mainly in laboratory scale. INER develops the large-area printing technique of OPDs toward commercial mass production, establishing the layout of core patents and new market.



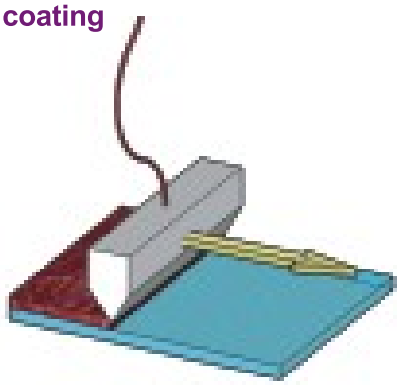
Diverse application of OPDs

Large-area solution coating of OPDs for mass production has the characteristics of low carbon, low energy and fast printing. Development strategy of OPD mass manufacture of INER is focused on (1) ultrasonic spray coating and (2) slot-die coating. The former has the advantage of easily patterning. The latter has the nature of fast and mass production. Manufacturer can select one according to the customer requirement. INER is collaborating with the domestic company for developing the mass production technique of OPD coating toward commercialization.

Ultrasonic spray coating



Slot-die coating

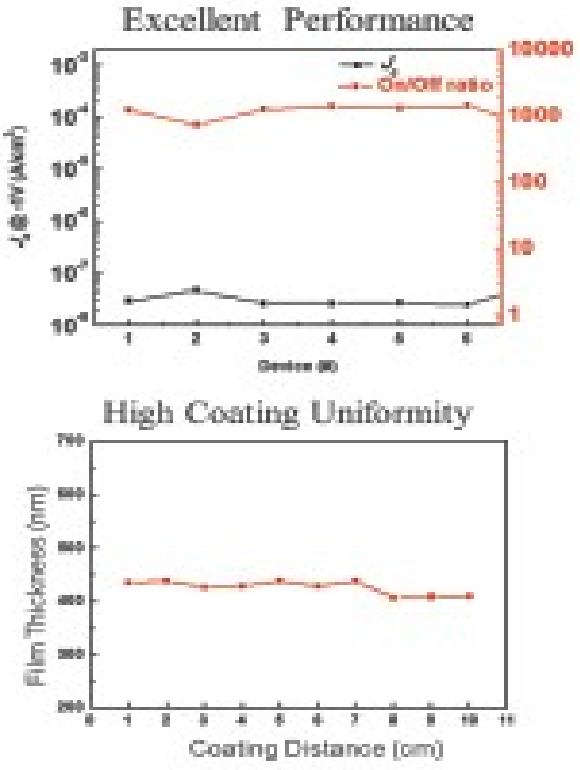


Development of large-area coating for mass production

The results of large-area coating technique of OPD developed by INER were submitted to journal and patent application. According to IDTechEx report (2017),the market of printable and flexible OPDs in 2020 is estimated to ~70 billion. INER is improving the performance of OPDs and evaluating the potential techniques for OPD mass production for timely entering the markets.

Research team of OPD

The performance of OPD is determined by low dark current and high on/off ratio. Compared to the laboratory-scale spin-coated OPD, the large-area coated OPD suffers more difficulties from the uniformity and defects etc., leading to reduction in performance. The performance of both spray- and slot-die- coated OPDs developed by INER achieves the level of commercialization (dark current < $5x10^{-8}$ A/cm^2 ; on/off ratio >1000)。The uniformity of large-area coating (area= 10x10 cm^2) is within 10%. These large-area printed OPDs result is better than the reported world record of OPDs prepared by the similar process, demonstrating the large-area coated OPD technique of INER is close to the international level.



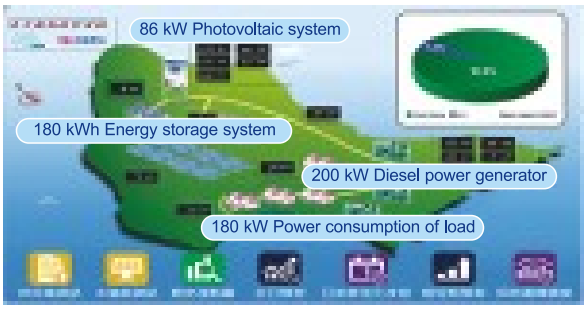
Performance of large-area coated OPD

INER focusing on the solution-printing and mass production technique is the only institute of intermediate role linking the academic society (including universities) and the domestic industries. INER not only published the academic papers of the frontier research but also developed the commercially core technique for the industries. The mission of INER is to accelerate the commercialization and application of the prospective research.

Role of INER linking the academy and industry

3-2-8 The Green Energy Technologies for Isolated Islands - Implementation of Microgrid in a Renewable Energy System in Dongji Islet

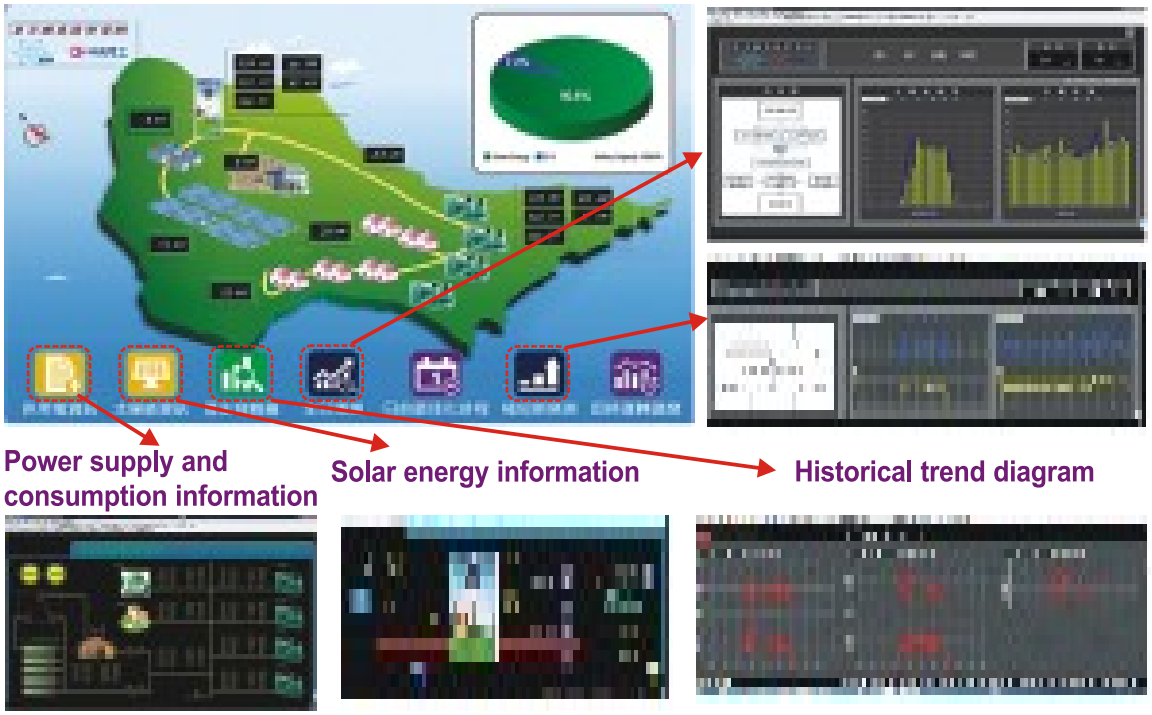
Current Offshore Island Power Generation Problems and Implementation of Renewable-Energy Microgrid System of Penghu Dongji Islet



Penghu Dongji Islet Microgrid Power Supply System

Dongji Islet is one of the islands of Pescadores of Taiwan. The offshore island power generation has high fuel transportation cost. Since Dongji Islet is not covered by any electrical grid system installed by major utilities, the local government is responsible for the power generation that results in high costs with deep concerns to maintain the stability. To save more fuel, the local government plans to provide power generation by renewable energy. However, since the renewable energy has the inherent property of intermittence, the floating voltage will be incurred when the transmission of a large amount of renewable energy is relied on the a small grid system on an island that will impact the stability of the power supply.

The microgrid has functions to stabilize voltage and frequency and effectively increase the availability of the renewable energy if integrated with the energy forecasting and scheduling management system. The average cost per unit power can then be reduced with the benefit of low carbon emission.

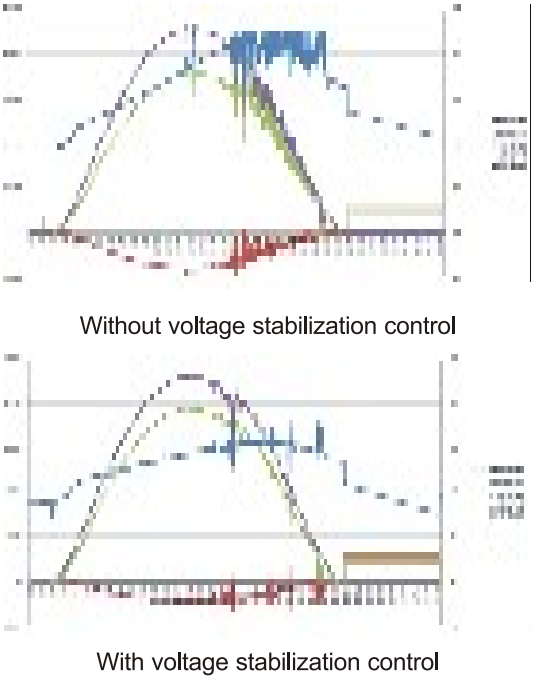


Advanced Micro Energy Management System (μEMS)

Installation and Size of the Microgrid Power Supply System on Dongji Islet

Being sponsored from the National Energy Program led by the Ministry of Science and Technology (MOST), we have made a successful transfer of the microgrid control technology to a local firm helping the installation of the first high renewable energy penetration microgrid system in Dongji Islet of Penghu County. Three steps were taken to approach the target of installation and described in brief as follows:

(1)Setup the grid connection between the diesel power generators and the currently existing photovoltaic system; (2)Install the intelligent inverters and introduce the basic electricity management system with the function of wireless remote monitoring; and (3)Implement the advanced micro energy management system (μEMS) developed by our institute together with the grid connection between the system, the renewable energy power generation and load forecasting technology to appropriately control the energy storage system. Such management can therefore perform optimized deployment in energy input/output and increase the instant renewable energy penetration up to 92.8%. In addition, the developed power regulation for the energy storage system and the voltage stabilization program can effectively suppress the DC-link voltage oscillation of the system and maintain a stable charging status so as to extend the its life. Currently, the microgrid system on Dongji Islet consists of a 86kW solar power generation system, 180kWh energy storage batteries, a 200kW diesel power generator, and three power load feeders.



Power regulation and voltage stabilization control of power storage system of Penghu Dongji Islet

Award honors and economic efficiency

Dongji Islet microgrid system was commercialized in March 2017 and has approached the maximum instant renewable energy penetration ratio of 92.8%, a milestone to mark the competence of technologies. Our team attended the "Best Practices Awards of the Energy Smart Communities Initiative (ESCI)" of 2017 Asia-Pacific Economic Cooperation (APEC), and won the silver award among 197 competitive practices from 21 countries; The award was granted to us on April 24.

According to the statistics data from March to the end of the year in 2017, the power integrated from the solar energy was around 65,200kWh after the renewable energy and energy storage system were effectively operated, and about NTD$1.43 million of the cost for power generation from diesel generators was saved (the power generation cost of Dongji Islet was NTD$22/kWh from the data of Taiwan Institute of Economic Research). Meanwhile, it is estimated that this microgrid power supply system can reduce the CO_2 emission by about 58 tons over the whole year.

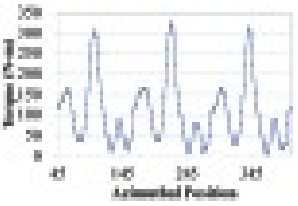
Create New Southbound Green Power Opportunity

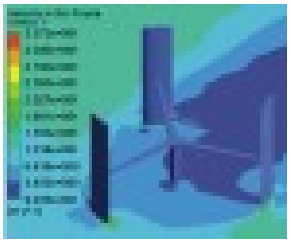
According to the statistics data to the end of 2nd quarter in 2017 from the research report of Navigant Research, there were 135 countries in total engaging in the establishment of the microgrid system; there were 1,842 sites in total, and the total device capacity was about 19,279 MW. Furthermore, about 126 new sites were established across 39 countries, and the device capacity was about 772MW where 95% were in North America and Asian-Pacific. The most important part is the power-distribution level microgrid system owned by power utilities. Besides, the major growth driving force in Asian-Pacific is the installation of microgrid on remote islands.

Looking ahead, INER will cooperate with the domestic relevant firms coping the southbound policies of the government to promote our microgrid technologies, and apply them to the islands with urgent demand so as to improve the international cooperation, promote the economic and trade development, and find more opportunity for green power.

3-2-9 Development of urban suitable technologies of small-and-medium wind turbine

During past decade, the research and development of wind energy at INER has been primarily focused on developing small wind turbines, such as 400W, 25kW to 150kW. INER is a national laboratory, specialized in design and integration of the wind turbine system. To support the development of domestic industry in the field of small wind turbine system, key technologies have been proposed and will be developed in a small-and-medium wind turbine project to fill the technical gap. In the future, the effort for wind power generation will be shifted to the medium-and-large turbine that will further reinforce the competitiveness of local firms.

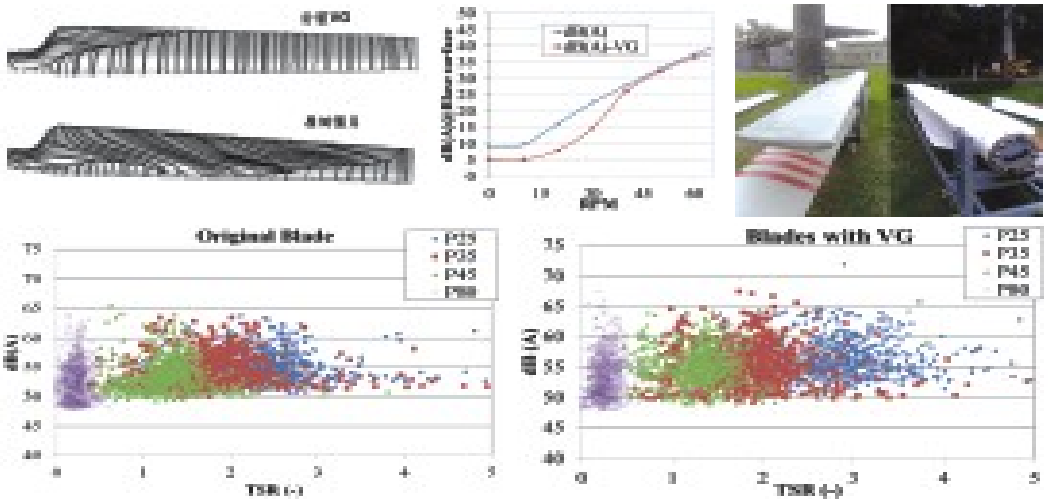




Modified 5 kW wind turbine mechanism (left), performance test (middle), and results (right)

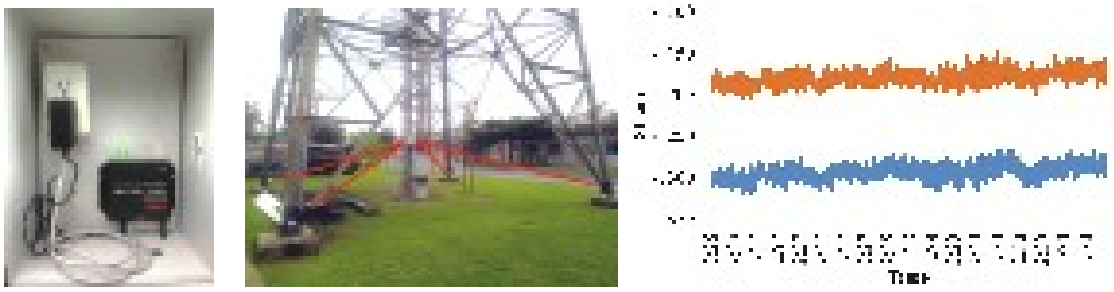
The performance tests for mechanical improvement have been conducted for the 5 kW wind turbine system. Results show that larger starting torque and over-speed protection have been achieved and activated with +5 degrees of blade pitch angle during the operational test, making it more suitable for low wind speed in urban area.

Noise measurement for wind turbine has been conducted as the baseline to verify the effect of noise reduction technology. The performance of the designed vortex generator (VG) has been also investigated by numerical simulation. Numerical results showed that the noise on the blade surface was reduced about 4 to 10 dB(A) with the proposed VG. Experimental results showed that the aerodynamic performance could be improved with VG, and the average rotational speed increased about 15%. Therefore, the rated-power can be achieved with slower rotation speed with lower noise.



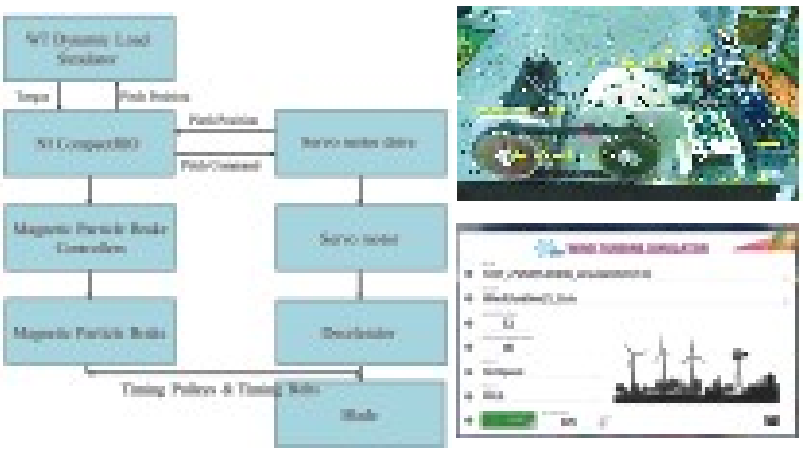
Analysis of noise reduction technique, the installation of VG (top) and experimental results (bottom)

A load measurement system for the 150 kW wind turbine tower has also been developed. Data collection and calibration were also conducted. Comparison with analytical models will be done to improve the load models.



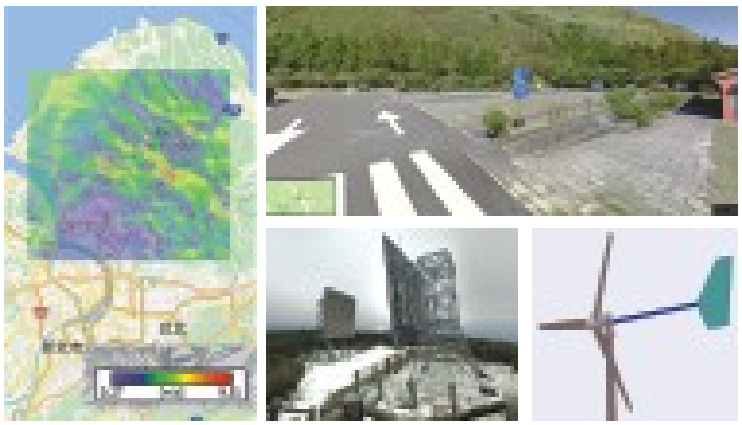
Load measurement system and data collection

The simulation platform for wind turbine in our lab has been developed. The key components include servo motors, magnetic powder brakes, a control system and related electrical powers. This platform will serve the test and verification of developed control logic and algorithm for the supervisory control and data acquisition (SCADA) system of wind turbine.



System configuration of ground simulation platform (left, top right), and user interface (bottom right)

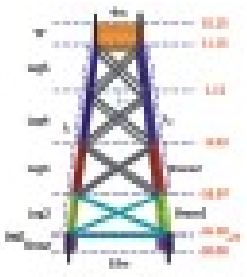
An evaluation technology for assessing annual electricity production (AEP) from wind power has been developed with a proposed high-resolution wind atlas. In the case study of Beitou district in Taipei, the Dream Lake and Siangtian Mountain were identified better regions for wind power. The AEP could be up to 9 MWh with the installation of 5 kW horizontal axial wind turbines in these regions.



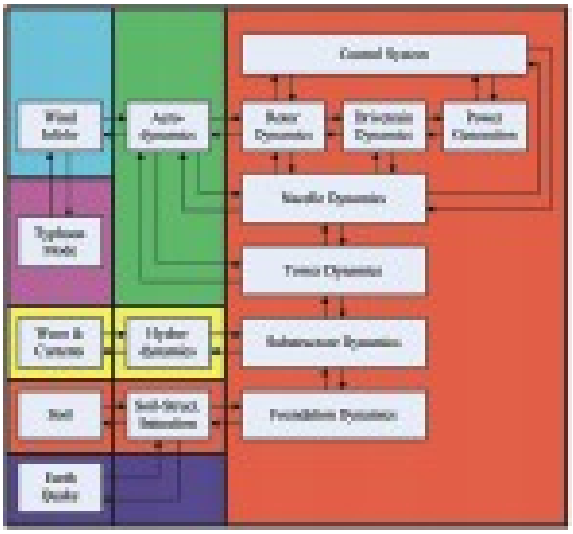
Wind resources assessment-Beitou district

To adapt to the conditions in urban areas including low wind speed and noise prohibition, performances of low-speed activation and noise reduction have been confirmed on a modified 5 kW wind turbine system. Further test and modification will be conducted in the future. Technology transfer to the firms will also be proceeded. Load measurement technology will be used to improve the load calculation model. Simulation platform will be released to academic and research institutions to conduct the test and verification of developed control logic and algorithms for the SCADA system of wind turbines. Wind field assessment technology can be also help to search for suitable locations in Taiwan for the installation of wind turbine.

3-2-10 Safety assessment of offshore wind turbine with the environmental conditions of Taiwan



The first two offshore wind turbines of Formosa-I demonstration offshore wind farm have been successfully commissioned in April of 2017. The offshore wind turbine (OWT) need to be certified by the international standards and the support structure need to be designed to the specific environmental conditions of Taiwan. In recent years, the onshore wind turbines were occasionally damaged by typhoons. Nevertheless, the design requirements of extreme environmental conditions, such as typhoon and earthquake, etc. are not included in current International standards. Therefore, INER established the dynamic load calculation procedure of the OWT to evaluate the effects of Taiwan extreme environmental conditions on offshore wind turbines . This technique will improve the reliability of offshore wind turbine structure, promoting the policy and technologies of OWT.



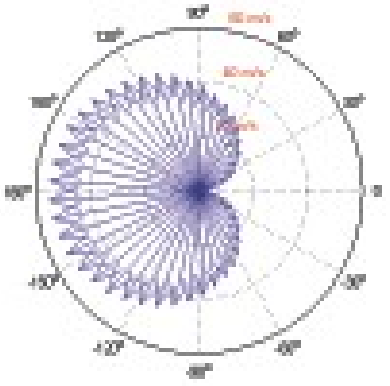
Offshore wind turbine dynamic load calculation procedure

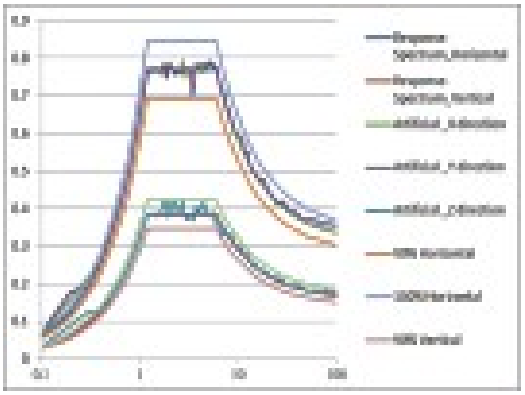
Design load cases of typhoon

Design load cases of earthquake

Design load cases of extreme conditions

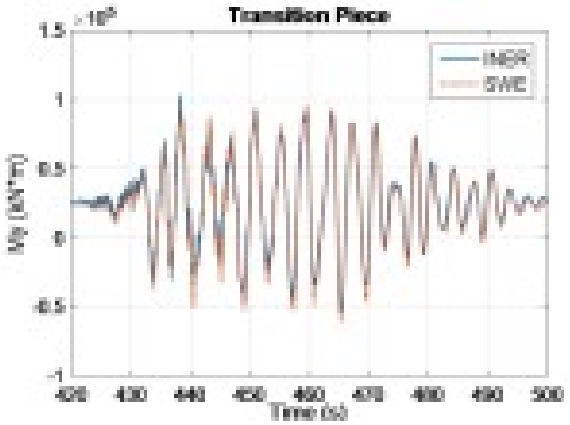
The proposed design and analysis procedures mainly referred to the international design standard-IEC 61400-3, and the load cases for earthquake and typhoon were also included. The input parameter of environmental conditions were specified based on the design requirements in earthquake and the extreme wind speed in 50-year return period.





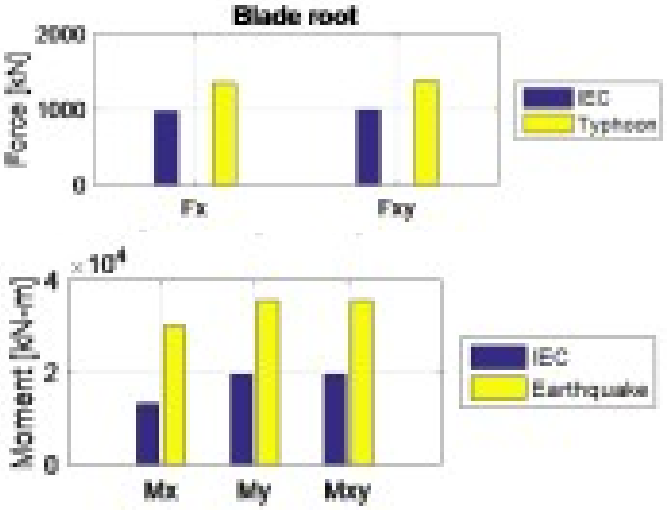
Taiwan domestic specific extreme conditions

Through international collaboration with Stuttgart Wind Energy (SWE), Stuttgart University in Germany, the capability building of OWT technology of INER were completed and verified. Excellent achievements and agreements have been obtained by the comparison with SWE, validating the proposed dynamic load calculation for safety assessment of the OWT.



Technical collaboration with Prof. Po Wen Cheng, Stuttgart Wind Energy (SWE)

A series of dynamic load calculation for the scenarios of earthquake and typhoon were conducted. Comparing with the IEC Standard, the results on the impact of extreme loads of typhoon and earthquake were significant. Increase of extreme load on tower top due to earthquake effect was observed to be approximately 70 % and increase of extreme load on blade root due to typhoon was approximately 30 %.



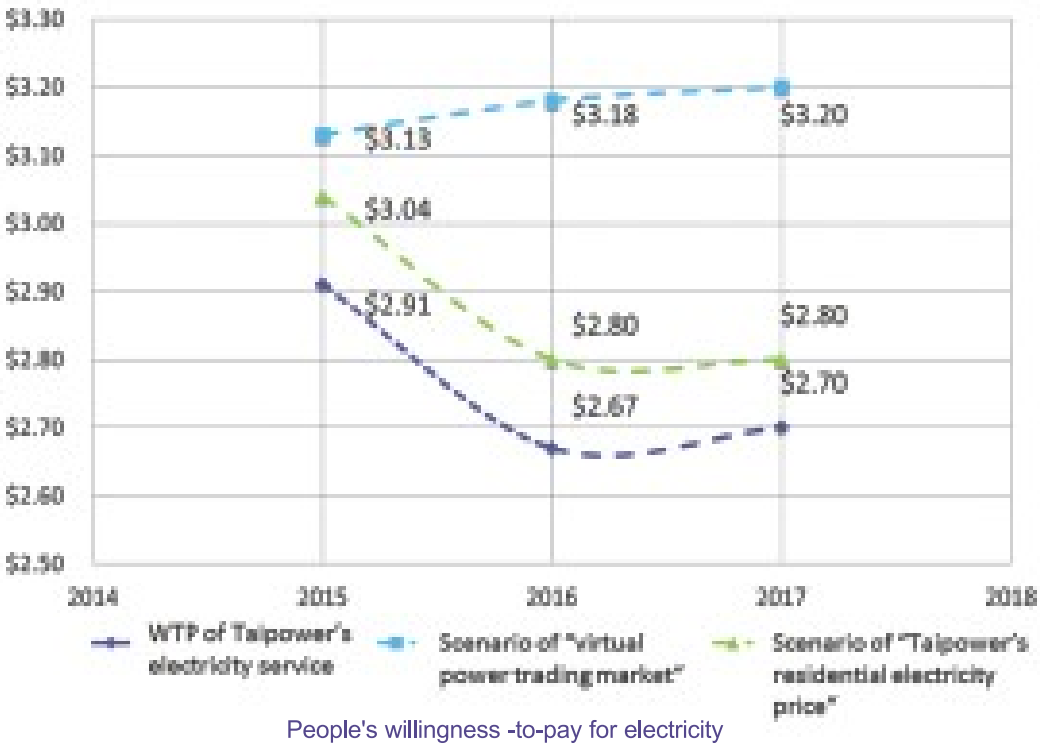
The influence of earthquake and typhoon on dynamic loads

The development of OWT in Taiwan is still in the preliminary stage. In the future, the floating support structure will be possibly employed for the wind farm in deeper sea. Floating OWT technology will also be one of the primary research hotspots at INER in the near future.

The different types of offshore wind turbine support structure

3-2-11 How much are you willing to pay? A survey of acceptable prices to pay for electricity

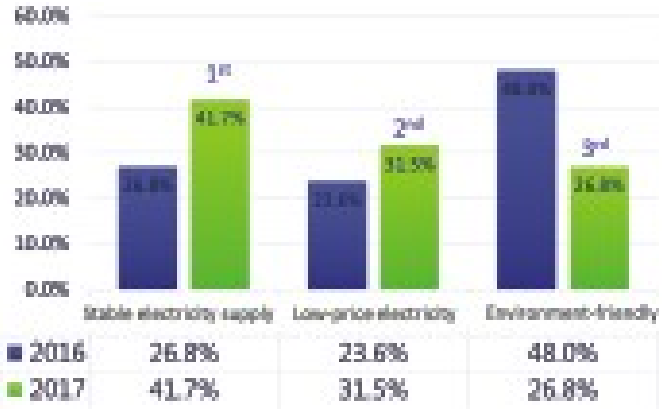
In the process of our nation's energy transition, many possible risks may appear one after another. Among them, the most closely related to people's livelihood is electricity price. In view of the fact that electricity strategy planning in the past has always focused on technical feasibility, however this study aims to introduce the social survey at the front end of the strategy planning. By exploring the social intent and willingness-to-pay(WTP) for electricity, this study measures the gap between social expectation and strategy planning. The data base has accumulated the data from 2015 to 2017. As the domestic electricity price has been regulated for a long time, people have accustomed to lower electricity price. As the result shows, in the current electricity service scenario the WTP for electricity price in the past three years fell 2.91 NTD/ kWh to 2.7 NTD/ kWh, slightly lower than the real residential electricity price of Taipower Company.



People's willingness -to-pay for electricity

Learning from advanced developed countries' experience on dealing with social risk of technology, such as UK, US, Netherlands and Denmark, these countries enhance the governance efficiency especially by electronic participation. Thus, this study emphasizes the concepts of the new media spirit of "openness, interaction and simplicity".

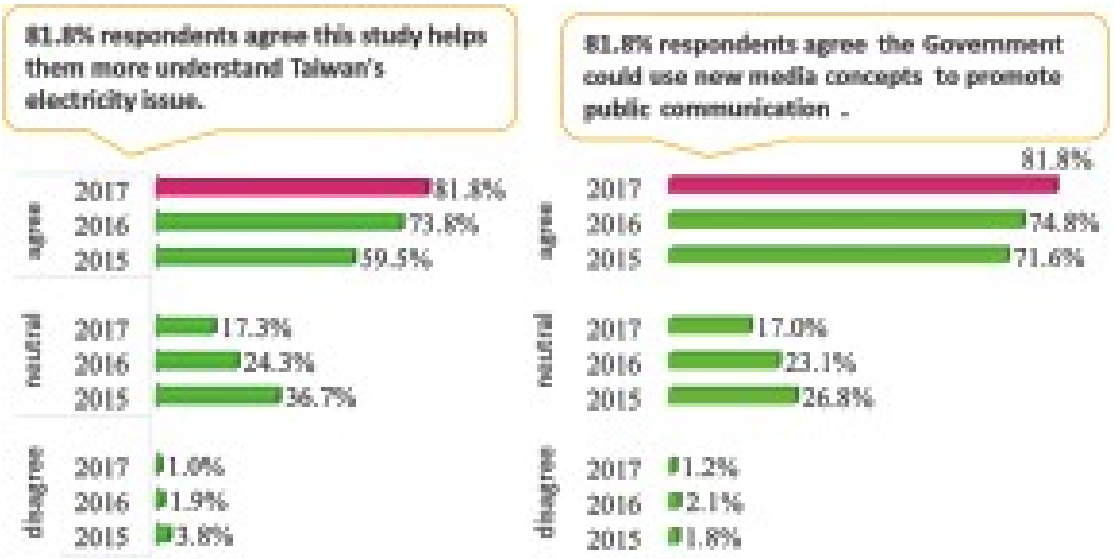
The survey platform is developed by INER. The first highlights is the responsive information disclosure called "power supply station", in which various electricity generation technologies were transformed into personification to enhance the readability of energy information. Second, the "virtual power trading market" comprises a interactive power calculator with information completely disclosure, respondents can be free to determine the power generation portfolios and WTP for electricity in the well-informed situation. As the result shows, in the "virtual power trading market" scenario the WTP is about 3.13 NTD/ kWh to 3.20 NTD/ kWh , which shows that people can raise the WTP for electricity price when they have power purchase options.



People's decision basis of electricity consumption

In some investigations, it is reported that people are most concerned about the "climate change" (86.1%), "the air pollution caused by fossil fuels (85.1%)", followed by "the impact of power rationing" (85%), and "the safety of nuclear waste disposal (82.1%)". In practical, the survey shows that although people pay great importance to environmental issues emotionally, the "electricity supply stability" and "burden of electricity price" are still the primary considerations in the actual electricity consumption decision.

To further explore people's decision basis of electricity consumption, the results of the 2016 survey showed that the people are most concerned about "environment-friendly" and prefer low-carbon electricity. Nevertheless, because the 2017 survey period experienced power shortages and the 815 power outage event, people would pay more attention to "stable electricity supply" (as figure2). It illustrates people's electricity consumption decision is still based on the power supply stability, and the pursuit of environment-friendly electricity without seriously affecting the comfort of life.



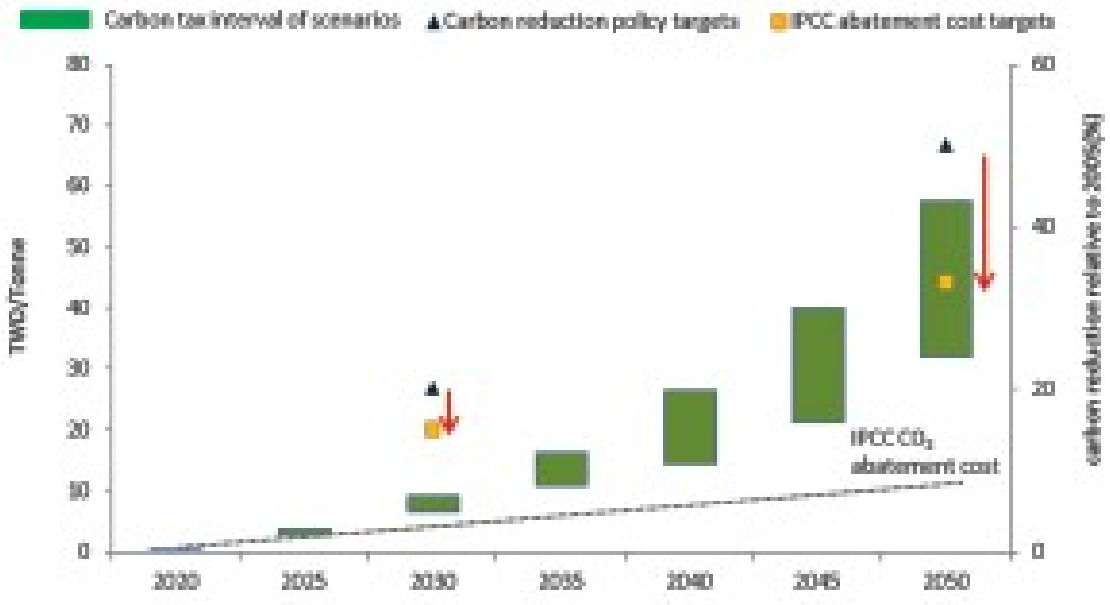
Feedback of the survey platform from respondents

There are some policy implications to promote the energy transition strategies and to reduce the possible social protest events. This study recommends the Government should speed up the electric industry reform, enhance people's reasonable cognition of electricity price through information disclosure. In addition, based on about 80% of the people recognizing the content and form of energy information delivered during the survey process,this study could improve the Government's energy policy promotion much more suitable and feasible.

3-2-12 Assessment of the Strategy of Carbon Reduction Policy and New and Renewable Energy Technologies in Taiwan

In facing the climate change issue in the world, there are two main greenhouse gas reduction policies in Taiwan, INDC (Intended Nationally Determined Contribution) and Greenhouse Gas Reduction Act. The two polices aim to reduce 20% and 50% of greenhouse emissions of the year 2005 in 2030 and 2050, respectively. Besides, some suitable supporting measures are needed to reduce the impact of climate change policy. As such, a careful assessment of the new and renewable technology strategy in facing the climate change mitigation policy is necessary before the decision of relative energy development is made. The aim of this research is to employ a computable general equilibrium model, GEMEET (General Equilibrium Model for Energy Economic and Technology Analysis) model, to analyze the new and renewable energy development under the carbon reduction policy. Suggestions to develop the new and renewable energy technologies will also be derived based on the analysis results and be provided to the related agencies for formulating suitable policy measures.

For the conclusion in this research, the targets stipulated by INDC and Greenhouse Gas Reduction Act policy are too high to be implemented, especially under the nuclear-free homeland policy and limited renewable energy resource in Taiwan. Consequently, the targets should be adjusted to a acceptable level. According to the CO2 abatement cost of IPCC, the reasonable targets might be the reduction by 15% and 33% of greenhouse emissions of the year 2005 in 2030 and 2050 respectively. Otherwise, more new and renewable energy are necessary to mitigate the impact of climate change policy.



The comparison of carbon reduction policy and IPCC abatement cost

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3-3 Research and Development of Radiation Applications

There has been a long history in nuclear medicine and image device research and development in INER. After so many years research, INER had succeed in commercializing at least more than 10 drugs. Even the imaging device and relative software is also already under clinical try. Recently, following the developing of cancer radiotherapy and diagnosis all over the world, nuclear medicine and imaging devices have developed into a new generation, such as PET, SPECT combines with MRI, CT and with 3D tomographic technology. These develops can help doctor look inside the patient's sick foci clearly, and help doctor's micro surgery and precise therapy much easily.

In nuclear medicine, from top research to bottom commercialization, INER has owned a unique complete chain. It is composed of drugs discovery laboratory, optimization of lead compounds laboratory, preclinical study, clinical trials (IND), registration (NDA), PIC/S GMP manufacturing production facility (including raw materials and drugs), commercialization of products and technologies transfer etc. INER also has the experience in PET, SPECT and X-ray and CT. With the recent development of precise therapy and personalize medicine, INER chooses nuclear medicine and imaging technology as a priority research and developing items.

INER TRODAT-1 Kit was approved by Taiwan Department of Health in 2005. Over these years, INER TRODAT-1 Kit has reached the pharmaceutical industry PIC/S GMP level. INER TRODAT-1 Kit has also owns the spot light and internationally renowned by supplying to academic and medical field for research. It was license-out in 2016. In 2017 this drug had entered into the highly competitive global biomedical market through industrial worldwide marketing channel.

INER iodine-123 MIBG is the best example of a new use of an old drug developed in INER. In 2015, Taiwan Food and Drug Administration had agreed the registration trial wavier of iodine-123-MIBG on the diagnosis of neurogenic tumor and cardiac sympathetic nerve function. We hope to get the medicinal license ASAP in 2018 and transfer this medicine to local industry for clinical application.

In 2016 the global market of medical imaging devices had reached 800 million US Dollars (about 24 billion New Taiwan Dollars). In research and development of medical imaging devices, INER are focusing on improving the quality of medical imaging and decreasing absorbing dose as well as enhancing the measurement sharpness. There is one report in this annual report as "High-Performance X-ray Tomosynthesis Software Technology". This report described some unique points of this software. Hopefully, this system can be transferred to local private company later very soon. There is another report as "Feasibility study of applying an NM gamma camera to image radioactive hot spot in a nuclear facility". It is a very interesting research about the waste reutilization for the old animal PET device. It also can help the radioisotope contamination detection and clearance in the decommissioning of INERs old reactor (TRR).

In nuclear medicine, INER also begin a lot of new drugs research items. There are several related nuclear pharmaceutical research introductions in this annual report, such as "The Development and Applications of Multivalent Glucose Conjugate for PET Cancer Imaging" and "Bioactivity evaluation of ^{188}Re-human serum albumin microspheres via intra-arterial route in an orthotropic hepatoma model". In biodosimetry, this annual report also had a research, "Accidental radiation exposure to personnel assessment by ISO17025 biodosimetry laboratory". These topics will be the major research and development items for INER in the near future.

With the developing of domestic pharmaceutical biotechnology and nuclear medicine industry, INER is trying to integration the energy of academy, research center and medical units through co-operation to achieve the industrialization and commercialization purpose, to make a global high-competitive biomedical market distribution. To achieve Taiwan's nuclear medicine and imaging medicine to be one of the best pharmaceutical in the world, INER will like to create and fulfill these radiation medical applications, and make them as INERs sustainable development object.

3-3-1 The Development and Applications of Multivalent Glucose Conjugate for PET Cancer Imaging

The incidence of cancer rises dramatically worldwide. According to the data from newest report of World Health Organization (WHO) in 2012, the global incidence of cancer has risen 11% in four years. The new cancer incidence is up to 14,100 thousand people. In addiction, Union for International Cancer Control (UICC) points out that, in the next 20 years, the global number of deaths from cancer will reach 24 million every year, that is, deaths from cancer will be three times more in 2035. On the other hand, the results statistic report of death causes from Ministry of Health and Welfare indicated that cancer is still the top 1 cause in 2016, number of death is 47,760 (27.7%). So development of effective cancer diagnosis and treatment methods should brook no delay.

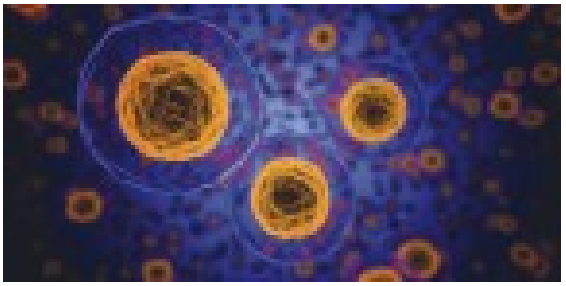


Figure 1. Animal magnetic resonance imaging (MRI) scanner at INER for rats and mice. This is an imaging machine with high resolution for soft tissues.

Figure 2. Animal positron emission tomography/computed tomography (PET/CT) scanner at INER. Fusion of PET and CT images can combine anatomical and functional images, and can increase the accuracy of cancer diagnosis.

There are many medical imaging technologies developed for understanding human structures and functions, such as computed tomography (CT), magnetic resonance imaging (MRI), ultrasound (US), single photon emission computed tomography (SPECT), positron emission tomography (PET). Every imaging technology owns their advantages and limitations. CT and MRI has high resolution for anatomical structure, but low detection sensitivity of early and small lesions. This limitation can be ameliorated by PET/SPECT functional and molecular imaging, they provide biologic information on tumor cell metabolism, proliferation rates, and receptor densities, etc. One of the important features of malignancy is its uncontrolled energy needs. In order to proliferate and to divide, cancer cells need a lot of energy to maintain their growth and metabolism, while the main source of energy in the human body is glucose. Accurate energy metabolism information can helps us to evaluate the tumor malignancy and the treatment results.

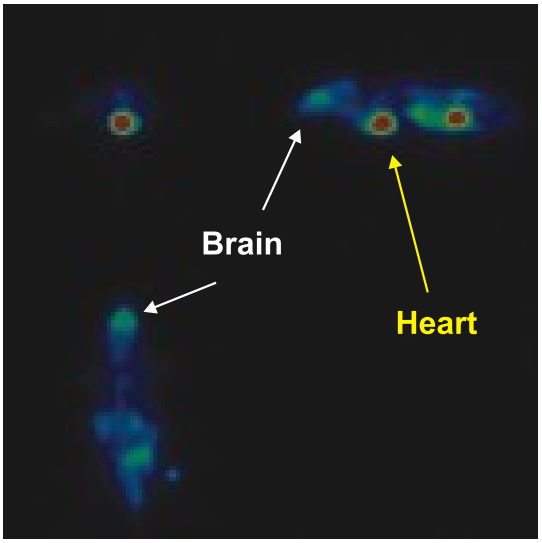


Figure 3. PET/CT images in mice injected with ^{18}F-FDG.

Molecular imaging technology combined with cellular energy metabolism contrast agents can provide valuable information for tumor detection and therapeutic evaluation. The radio-labeled glucose analogue ^{18}F-FDG combined with nuclear medicine tomography has been very common, can help clinical detection of tumor lesions. However, ^{18}F-FDG has its drawbacks, such as obvious uptake in normal brain and heart (Figure 3), resulting in reduced contrast in tumor at these sites and may result in low detection rate of small or low-uptake tumors.

The purpose of this study was to evaluate the potential of ^{68}Ga-NOTA-G3 as a tumor imaging probe in animal models of lung cancer using a novel radioactive multi-linked glucose cancer PET contrast agent (Figure 4). We performed synthesis of NOTA-G3 (precursor of ^{68}Ga-NOTA-G3), radiolabeling of ^{68}Ga-NOTA-G3, and PET/CT imaging in mice with NCI-H292 lung cancer. The results of the ^{68}Ga-NOTA-G3 labeling study showed radiochemical purity bigger than 95%. PET/CT images showed significant accumulation of ^{68}Ga-NOTA-G3 in the tumor with a tumor/muscle ratio of 5.1 at 2 hours after drug injection (Figure 5). The results of present study indicated that ^{68}Ga-NOTA-G3 is a potential tumor imaging agent. Since the ^{68}Ga can be milking daily with a generator, it is much faster and easier to synthesize ^{68}Ga labeled drugs, when compared to cumbersome labeling and purification steps of ^{18}F labeled compounds.

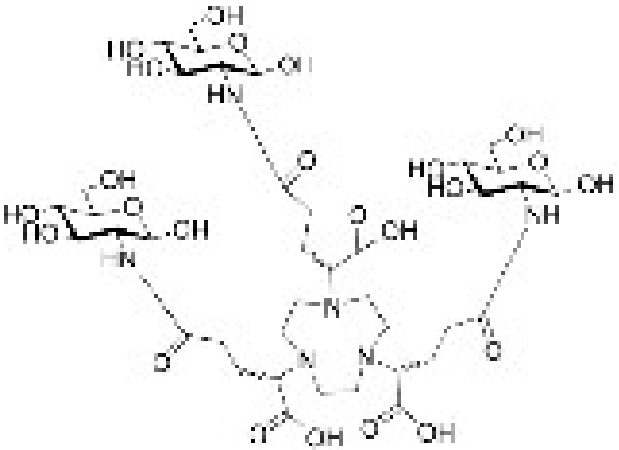


Figure 4. Chemical structure of ^{68}Ga-NOTA-G3，NOTA can chelate ^{68}Ga and conjugate 3 glucose molecules.

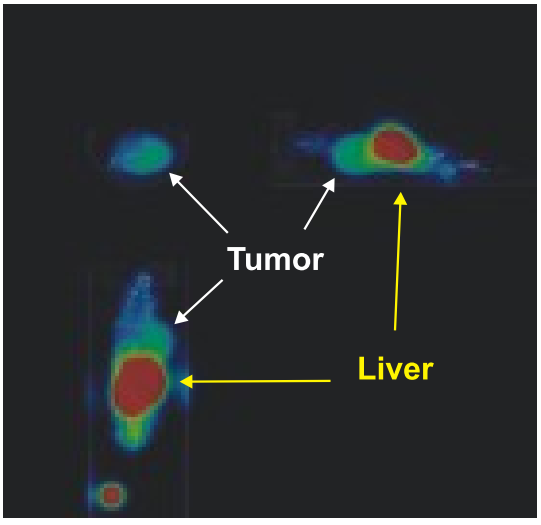
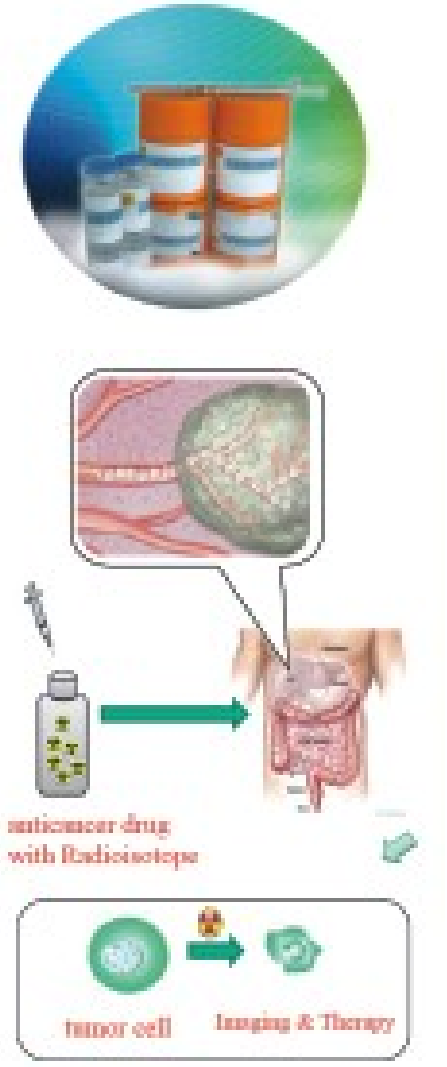


Figure 5. PET/CT images in NCI-H292 tumor-bearing mice injected with ^{68}Ga-NOTA-G3.

As seen from Figure 5, although ^{68}Ga-NOTA-G3 is significantly accumulated in the tumor, the liver also has a high uptake of the drug, mainly due to the drug structure and in vivo metabolic properties. Therefore, in order to solve these problems, modification of the drug structure and functional groups will be improved in the future to optimize the metabolism and pharmacokinetics of the drug in the body, become a cancer diagnostic probe with low background and high sensitivity for tumor detection. On the other hand, if ^{68}Ga is replaced by a radionuclide that emits beta particle, such as lutetium-177 (^{177}Lu) or yttrium-90 (^{90}Y), NOTA-G3 is able to become a cancer radiotherapy agent and a theranostic drug, which is a important part of precision medicine.

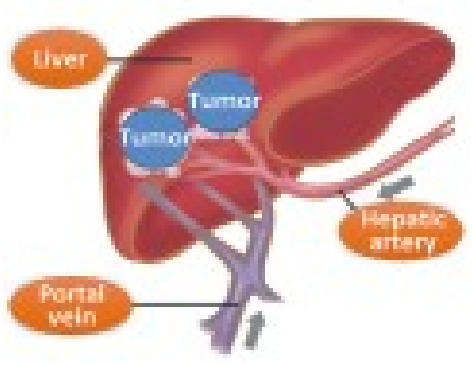
3-3-2 Bioactivity evaluation of ^{188}Re-human serum albumin microspheres via intraarterial route in an orthotopic hepatoma model

In liver cancer therapy, chemotherapy drugs are used to treat in liver cancer patients. However, the combination therapy of doxorubicin, 5-FU and cisplatin has the low therapeutic effects . The chemotherapy has only 10-20% therapeutic response and serious side effects in patients. They have limited in clinical use. Major advances have been achieved in the filed of target therapy in the past years. Compared to chemotherapy, target therapy has fewer side effects and well tolerated by patients. Therefore, it become more important for that target therapy drugs are combined with traditional chemotherapy. In this study, we used biodegradable materials to develop internal radio-therapeutic drug (^{188}Re-human serum albumin microsphere). The course of treatment by using ^{188}Re-human serum albumin microsphere are fewer than chemotherapy drugs. The biodegradable materials also decrease the risk of microsphere drugs in human body and improving patient quality of life.

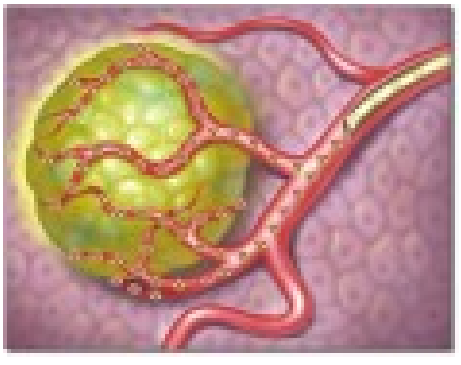


The application of ^{188}Re-human serum albumin microsphere

Normal liver tissue receives about 75% of the blood through the portal vein, while liver tumors receive approximately 80-100% of blood from the hepatic artery. In this study, we used hepatic arterial catheter to deliver ^{188}Re-human serum albumin microsphere (^{188}Re-HSAM) into the hepatic artery which provide nutrient to liver tumor and microspheres are trapped in the capillary bed of the tumor. The liver tumor were killed by β radiation released from ^{188}Re-HSAM. The dosimetry of ^{188}Re-HSAM can be evaluate by the biodistribution of ^{188}Re-HSAM in normal and tumor tissue. According to lung shunt fraction and tumor size, the optimal dose could be set up. ^{188}Re-HSAM can also used to treat patients with orthotopic or metastatic liver tumor.



The blood supply of liver tumor

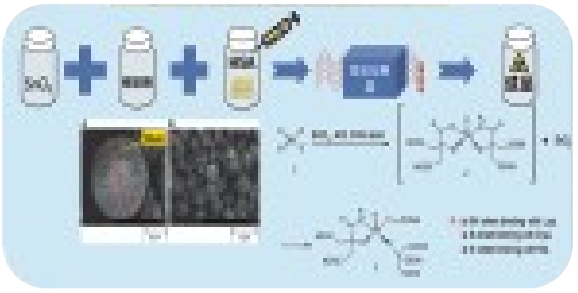


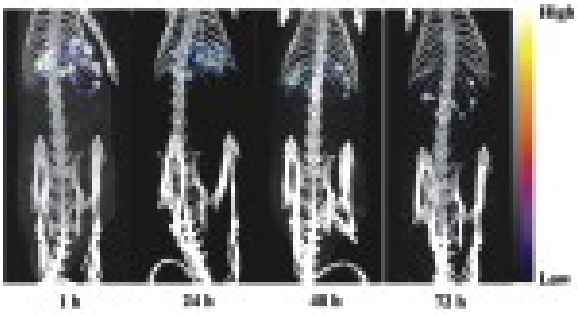
Mechanism of ^{188}Re-human serum albumin microsphere

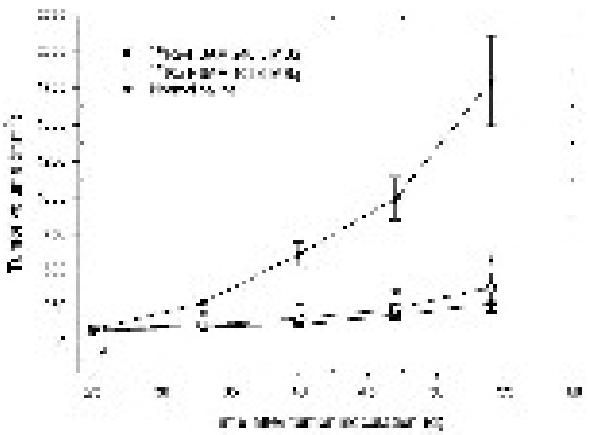
Liver cancer is a very popular disease in Asia. The aim of this study is to develop ^{188}Re-HSAM and provides new option for liver patient treatment. We have obtained 4 patents (3 TW and 1 US) and received the Taipei International Invention Show & Technomart bronze medal award.

Taiwan and US patent; 2017 Taipei International Invention Show & Technomart bronze medal award

This project utilizes home-made kit, which contains the self-synthesized serum albumin microspheres (15-60 μm). It can be prepared by reacting with radioactive isotope rhenium-188 for 1-10 minutes at high temperature. Labeling efficiency was more than 90 % after 1 to 48 hours in saline. The administration is to use catheter to deliver the drug into the tumor site. The microspheres were trapped in the capillary bed of the tumor and achieved treatment effect by irradiated to the tumor lesion. Animal experiments confirmed that the drug accumulated in the tumor site significantly, and had a good therapeutic effect to inhibit tumor growth.







General external irradiation therapy is limited by the number and volume of tumors. The ^{188}Re-HSAM developed by this project is delivered directly via the hepatic artery. At the blood supply site, the radiation can be released into the tumor to kill the tumor cells. Patients with large tumors, diffuse dissemination or metastasis to the hepatic portal vein can still be treated, and most patients have only one course of treatment. Compared to non-degradable ^{90}Y-microsphere, ^{188}Re-HSAM has biodegradable properties to reduce the risk of permanent retention in patient's body. Compared to expensive ^{90}Y isotope, single-use drug cost up to 0.3-0.4 million, ^{188}Re-HSAM can effectively reduce the cost on patients for the benefit of more patients with liver cancer.

^{188}Re-HSAM labeling method, SPECT/CT imaging and efficacy study

The aim of ^{188}Re-HSAM development is to provide molecular imaging diagnosis in low dose and radiation therapy in high dose. Thus, ^{188}Re-HSAM is a theranostic agent for cancer patients and is importantly for radioembolization drug. In future, ^{188}Re-HSAM can be used to treat patients with orthotopic or metastatic liver cancer. ^{188}Re-HSAM can be an optional anti-cancer drug for medicine care and personalize medicine.

3-3-3 Personnel assessment of accidental radiation exposure by ISO17025 biodosimetry laboratory

人員生物劑量實驗室
Biodosimetry Lab

When radiation exposure accidents occur, biodosimetry assessment is essential for estimating personal absorbed doses, and as a reference to take medical treatment for safety of radiation workers and normal populations. This project is to setup world-class level of the techniques for evaluation of personal biodosimetry. It can be helpful to set up accidental exposure procedures and develop an international biodosimetry laboratory.

In the object, INER wants to assist the radiation exposure biodosimetry procedures and regulations establishment, and continues to promote the research of biodosimetry techniques. Through the establishment of biological samples and dose-response curve, INER will establish and maintain the national level radiation biodosimetry laboratory. Wish the biodosimetry laboratory can reconstruct the radiation exposure level of people in radiation accidents.

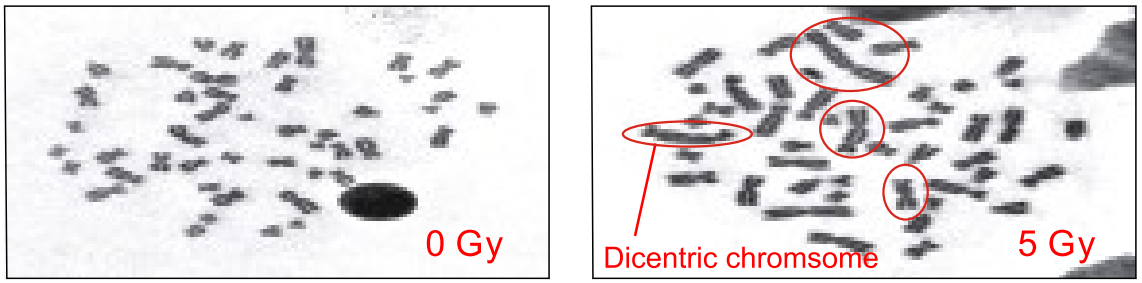


Fig.1 Radiation-induced chromosomal instability of human lymphocytes (dicentrics), which is internationally standard for biological dosimeters, is used to assess acute radiation exposure

INER has reconstructed the biological dose laboratory and developed capabilities since 2011. INER also devotes to building a professional bio-dose assessment laboratory and enhancing its quality. This professional national laboratory has already gotten ISO17025 certification for analysis of biodosimetry (Fig. 2 and 3).

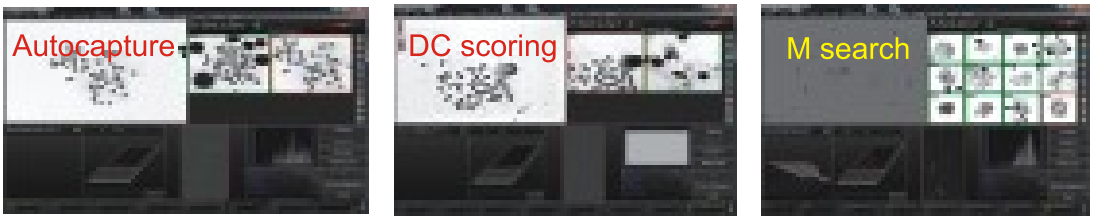


Fig.2 Biodosimetry laboratory computer automated capture image data

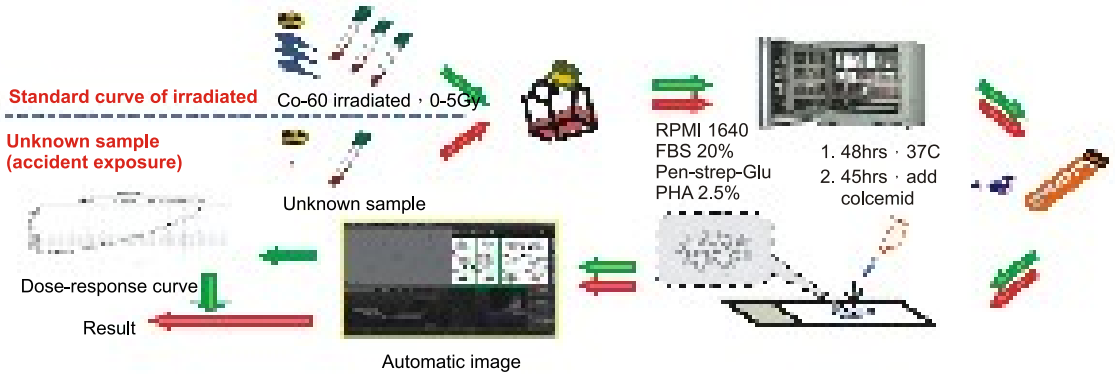


Fig.3 Establishment of irradiated reaction curve and accidental exposure process

In the event of an accidental radiation exposure, INER processed the biodosimetry to assess the dose received and as a reference for medical care. It can safeguard the health and safety of staff.

In May 3rd, 2017, INER received the first case of an emergency exposure in Taiwan announced from Atomic Energy Council (AEC). Since the staff did not wear personal dose film badge, INER was asked to help assessing the radiation exposure by dicentric chromosome aberration analysis. In radiation exposure accidental, INER had setup the standard operation procedure as figure 4.

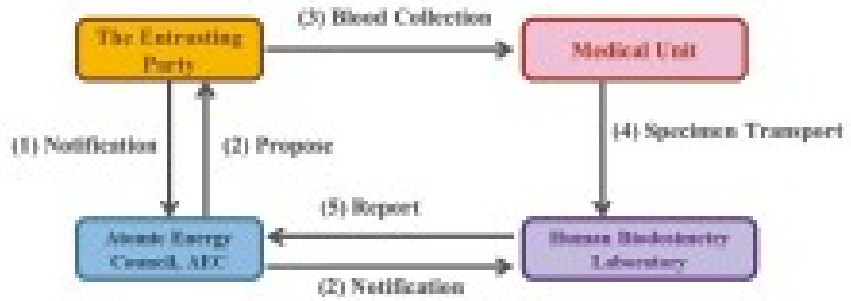


Fig.4 Accidental exposure process

According to ISO 17025 documents: when analyze the emergency case, in each analyst needs to measure at least 50 cells/case, and until the number of dicentric chromosomes observed up to 30, the observing then can be stopped.

Therefore, three analyst each analyzed of 50 cells (total count of 150 cells), and double checked to ensure the correctness of the analysis results.

Finally, in counting total of 132 cells observed, there were no dicentric chromosome was found. After the radiation dose-estimate software calculation, the exposure dose was 0 Gy and upper/lower limits of 0~0.287Gy (with uncertainty of 95%, Fig. 5).

Fig.5 Accidental exposure analy sis rep ort

This emergency exposure was due to the engineer in a radioactive equipment without personal dose film badge and stayed about 40 seconds after taking an emergency collision. To estimate the exposure dose afterwards, the dose is about 0.1Gy and is still in the acceptable range of the radiation worker dose. But for the safety reason, this event still should be reported to AEC and will be commissioned by biodosimetry laboratory analysis.

In this case, This laboratory had completed the acute radiation exposure analysis with sample preparation, image analysis and report double check within 15 working days, and successfully replied the dose.

When an accidental radiation exposure occurs, a biodosimetry laboratory would immediately assess the acute exposure dose and provides a reference for future medical care to health protect radiation workers and the general public. INER laboratory has obtained the TAF ISO17025 certification, but this technology has not yet been published for application test. Wish in the future, this technology can benefit the people and observe the damaged chromosomes.

3-3-4 High-Performance X-ray Tomosynthesis Software Technology

The R&D team at Institute of Nuclear Energy Research(INER) independently developed the tomosynthesis imaging system of Taiwan TomoDR with a 3D imaging and lower radiation dose than traditional computed tomography(CT). Taiwan TomoDR is in line with the international trend of reducing medical radiation exposure. Tomosynthesis mainly uses multi-axial X-ray and limited angle range imaging. The most important technique in 3D imaging is image reconstruction, which converts the projection data into 3D images. The R&D team of INER specially tailors the high-performance X-ray tomosynthesis software for Taiwan TomoDR to reconstruct high-precision and fast 3D images with clinical diagnosis and application value.

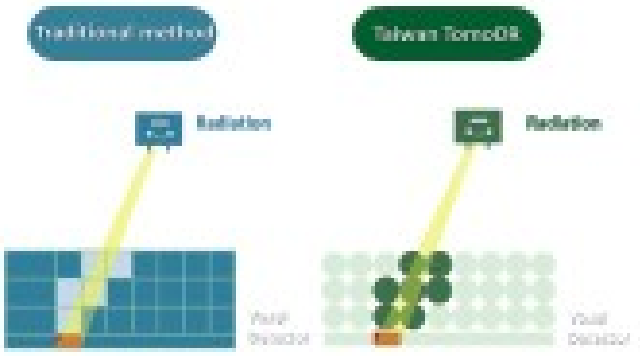


Figure 1 - simplify the core of innovative computing technology

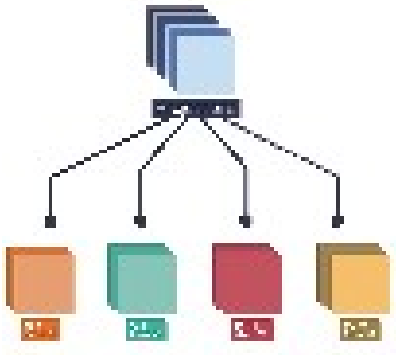


Figure 2 - simplified parallelization of computing technology

High-performance X-ray tomosynthesis has two major characteristics, namely, high-precision imaging and high-efficiency computing. Using statistical iterative algorithms, repeated iterative operations to obtain a more accurate 3D images. But, repeated computing causes low computing performance. The traditional computing method takes about 5 hours, R&D team to simplify the computing core will shortened the computing time to about 50 minutes. Then, to reduce the complexity of computing through graphics processing unit(GPU) parallel computing method, the computing time is reduced to 2 minutes. The performance of results make innovative R&D technology to both imaging accuracy and computing performance, and has the clinical value of diagnosis and application.

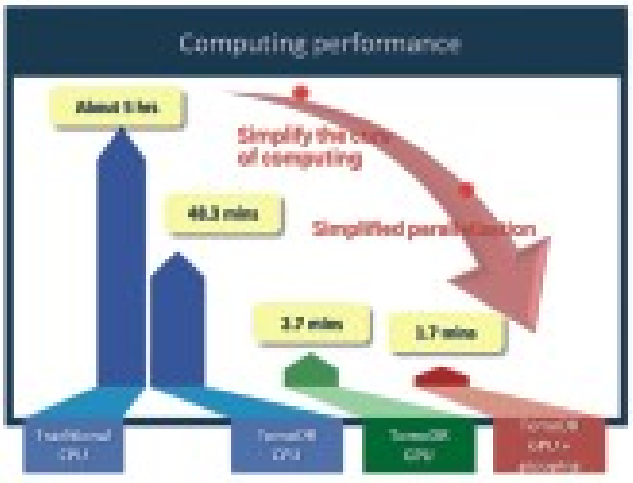


Figure 3 - image reconstruction technology performance computing

High-performance X-ray tomosynthesis software technology with technological innovation, until to 2017, It had been patented by Republic of China, Japan, European Union and United States. This patent also participated in the "2017 Taipei INST" invention competition and won the gold medal award. Its technical results confirmed by domestic and foreign experts.

Figure 4 - multi-national patent and 2017 INST winner

INER developed universal type imaging device, is suitable for any part of the body. Take chest image as an example to compare with commercial image. From the results, it can be seen that the image of INER is clear and less distorted. The main organs and details can be clearly identified. For example, the outline of descending aorta is clear and the direction of slight trachea is clear. Clinical image has image distortion, such as edge artifacts and ghosting artifacts. These distortions may result in the diagnosis of false-negative or false-positive ratio increased. "High Performance X-ray Tomography Software Technology" provides fast and accurate 3D images of clinical imaging medicine.

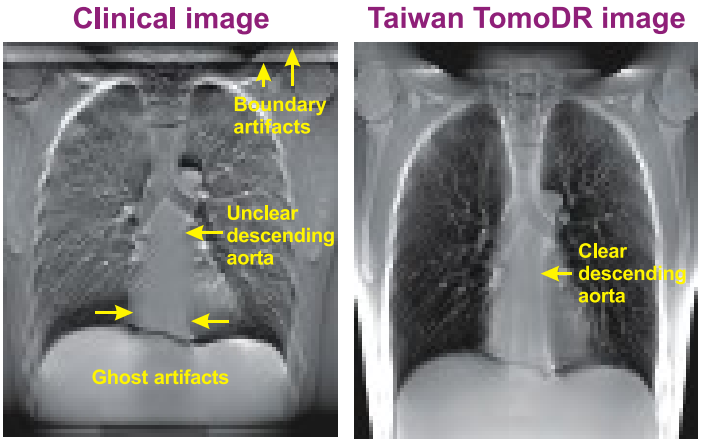


Figure 5-comparison of clinical commercial device image and INER developed device image

Tomosynthesis imaging is a limited range imaging process, prone to image distortion caused by image artifacts. The future will be for ripple artifact and metal artifact reduction algorithm, reduce image distortion and enhance the diagnostic value. In order to make the imaging system more suitable for clinical use, follow-up will promote clinical trials and repeatedly revise the imaging software technology. Expecting the tomosynthesis imaging system developed by INER can successfully enter the healthcare system and benefit the public with low radiation dose.

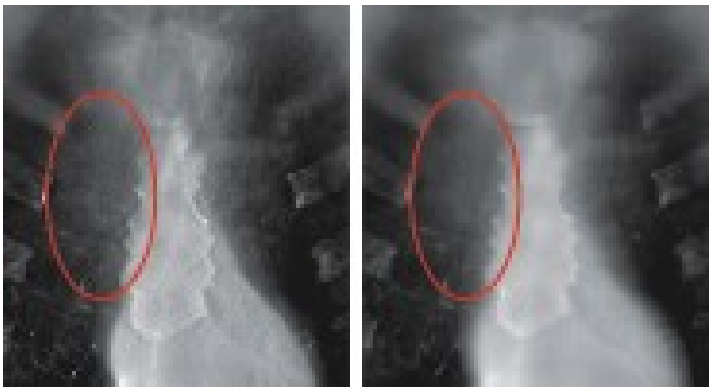


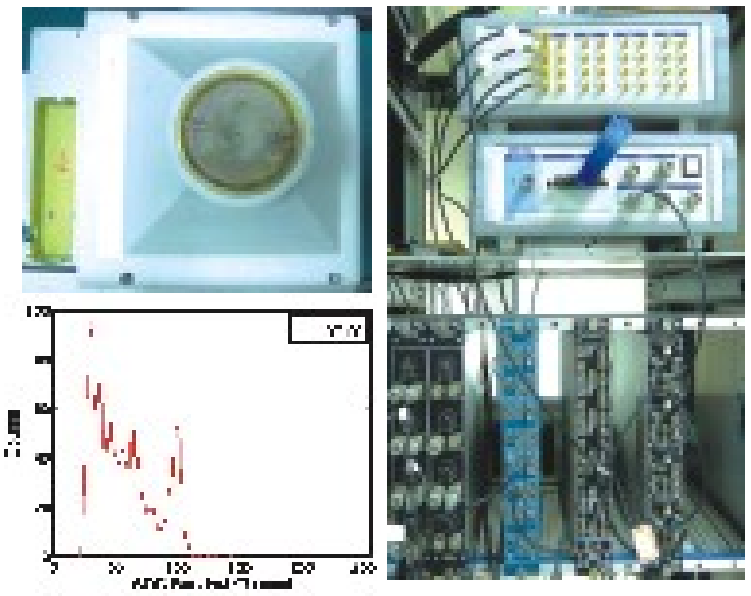
Figure 6 - tomosynthesis imaging unique artifacts - the development of ripple artifact reduction algorithm

3-3-5 Feasibility study of applying an NM gamma camera to image radioactive hot spot in a nuclear facility

The decommissioning process of TRR (Taiwan research reactor) has been proceeding in INER. A difficulty of pollution hot spots searching was encountered during the work of dismantling spent fuel pool. Due to storage of some ruptured spent fuel bundles, the pool was highly polluted with fission products, mainly the Ce-137. The contamination distribution on the surface of pool side wall and bottom is complicated and unaware. It makes traditional hot-spot finding approach, manually scan by using survey meter, unreliable due to high background interference, and thus makes dismantling difficulty and human radiation dose increase. A gamma camera with shielding and collimator pointing is a reasonable solution. In this research, an obsolete camera for nuclear medicine imaging use is restored and tuned, and then its feasibility to image Ce-137 contamination distribution is evaluated.

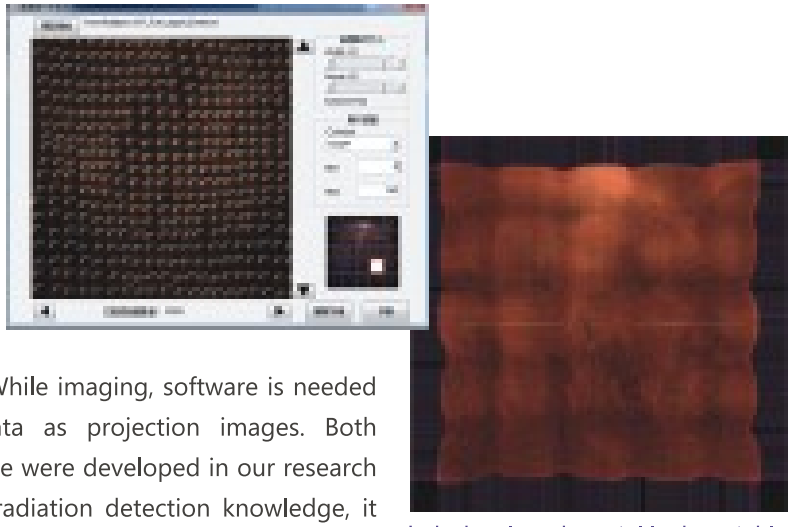
The obsolete animal imaging instrument X-SPECT(left) and one of its gamma camera components (right).

The camera mentioned above is designed to image low energy (<350 keV) gamma rays, therefore it is necessary to tune the camera to detect higher energy gammas (662 keV) from Ce-137. With examination of the camera sensing layer, it was found that all elements are intact. After repairing the readout electronics and restoring its power supply, functional signals were observed. For processing these signals, a dedicated DAQ system was built. Signal processing parameters such as PMT bias, amplification gain, and trigger threshold, were adjusted to make the camera fit in with detecting Ce-137. The figure on the right shows the repaired camera, its DAQ electronics, and a Cs-137 gamma energy spectrum from one crystal of the camera. A typical 662-keV energy spectrum observing indicates the camera works for detecting Cs-137.



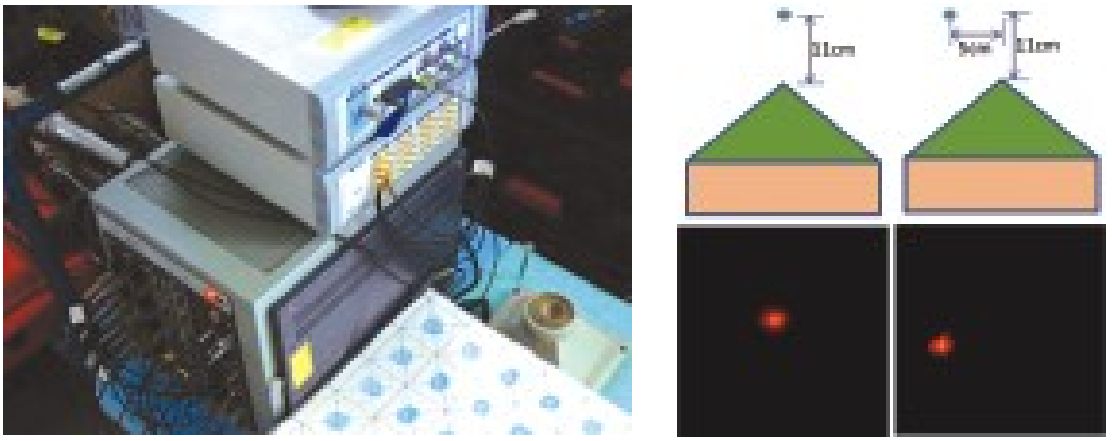
The repaired camera (upper left), its DAQ electronics (right), and a Cs-137 gamma energy spectrum from one crystal of the camera (lower left).

The sensing layer is composed of multiple, 6724 pcs actually, tiny crystals. These crystals are arranged as a square array. Therefore calibrations, which includes building a crystal look-up table and an energy look-up table, are needed for every single crystal before imaging. While imaging, software is needed to interpret the acquired data as projection images. Both calibration and imaging software were developed in our research group. Due to highly rely on radiation detection knowledge, it took another four months after the software tool implementation to manually establish calibration tables.



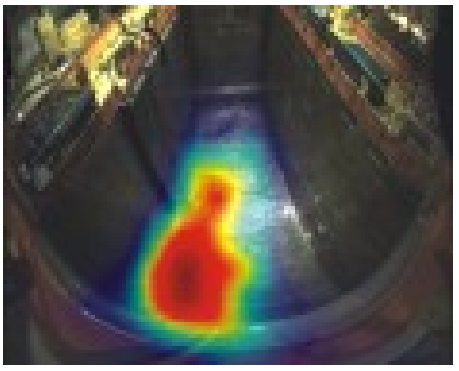
Lab-developed crystal look-up table (cLUT) building tool (left) and the resultant cLUT (right).

After the hardware restoration and the software establishment, the camera was ready for imaging. A 3.9 μC Cs-137 point source was imaged at two different positions. Both resultant images showed qualitatively correct response. In the quantitative analysis, both activity estimations from the images showed errors smaller than 2% to the real source activity. These promising test results indicate that the presented camera, which is used to image nuclear medicines, is capable of being applied to locate and image Cs-137 contamination in a nuclear facility.



The system setup for point source imaging test (upper left) and two resultant images with their relative source positions (bottom right).

In this work we successfully restored a gamma camera used to image nuclear medicine injected animals, and tuned to fit Cs-137 contamination detection. Preliminary results showed that the above mentioned object has been achieved. However to the end user, which is the spent fuel pool of TRR, there are still many engineering issues needed to face to properly use the camera, such as hanging carrier, remote control mechanism, and background measurement. Therefore, it is necessary to cooperate with the dismantle team in the future, trying to solve the engineering issues to make the presented camera work functionally in the nuclear facility decommission job.



Contamination imaging in a nuclear facility of a commercial gamma camera demonstration

4. 2017 highlighted events and memorabilia

4 2017 highlighted events and memorabilia

1.On January 13, 2017, the signing ceremony and the press conference for the INER's "Plasma Melting Fly Ash technology document" transferring to Sustainable Development Co., Ltd. were held jointly at AEC (Atomic Energy Council). The press conference was presided by Vice Minister Tsai. This research result demonstrates INER's R&D achievements in environmental protection.

2.In 2017, INER made a successful microgrid control technology transferring to Chung-Hsin Electric & Machinery Mfg. Corp., building up Taiwan's first high-renewable-energy-penetration microgrid system at Dongji Islet of Penghu county. This microgrid system went into commercial operation in March 2017 and reached the maximum instant renewable energy penetration ratio of 92.8%. In April, the research team participated in the 2017 APEC Energy Smart Communities Initiative Best Practices Awards Program. Among 197 competition practices from 21 countries, INER's microgrid control technology and its practice won the Silver Award.

3.On March 17, 2017, the "2017 Real-Time Police Drills on Prevention of Violent Major Dangerous Events" was held at INER by Special Police sixth headquarters. The situation exercises were conducted with 170 participants and attendee.

4.International Atomic Energy Agency (IAEA) inspector came to INER's material balance area TWL- in March 23-24 for nuclear facility design information verification and to perform physical inventory verification. It shows no abnormality.

5.Assistant Researcher Lai,Wun-Ci of INER won the honor of "Executive Yuan's 2017 Excellent Project Control Staff". Mr. Lai received the award at National Yunlin University of Science and Technology on May 23, 2017.

6.In June 2017, INER re-built and established ROC's first food-specific radioactivity testing laboratory and obtained the first domestic TAF food radioactivity testing ISO / IEC 17025 certification.

7.The 30th Taiwan-Japan Nuclear Safety Seminar was held in Japan during July 17-21, 2017. The seminar focused on "nuclear facilities decommissioning", at which INER delegation presented four special reports.

8.The application of the "Renewable Energy Storage System Wearing out Each and Every Individual Battery Units for Maximized System Utilization and Minimized Overall Carbon Footprint" for the 2017 Global 100 Technology R&D Awards was elected for final run competetion of IT/Electronics field by the independent review committee on August 11, 2017.

9.On August 18, 2017 INER celebrated its 49th anniversary together with parent-child activities and the general celebration assembly. Those celebration activities also include open-house visit to the offices, research results show, family fun activities, parent-child marketplaces and movie appreciation, etc. Participants include all the employees and their families. Meanwhile, the retirees were also invited back to their offices having a reunion.

10.On August 5 and 18, 2017, INER arranged staff and related equipment, carried out the venue inspection and detection drill of the 2017 Summer Universiade. INER also took part in the detection mission of the opening ceremony on August 19 and used the mobile SPARCS to carry out motion detection and inspection around the venue. The mission as well as successful conclusion of the 2017 Summer Universiade were achieved.

11.On September 15, 2017, INER held the "M&D Center Technology Seminar", in which a total of 14 units including Taiwan Power Research Institute and 63 experts participated the seminar.

12.2017 Taipei Int'l Invention Show & Technomart was held on September 28-30 in Taipei. In the event, INER won 18 awards, including one platinum award, six gold medals, four silver medals and seven bronze medals. The prize winning rate is higher than 85%.

13.Voted by the evaluation committee of the National Energy Program (NEP-II) on October 19, 2017, the project "Development and Application of High-Penetration Renewable Energy System Technology for Island Microgrid" conducted by INER and applied at Penghu Dongji islet won the second place award as an excellent project.

14.The 6th East Asia Forum on Radwaste Management Conference (2017EAFORM) was held in Osaka, Japan during November 27-29, 2017. The radioactive waste experts from Taiwan, Japan, South Korea and the United States participated in the conference for technical exchange. INER delegation, leaded by Dr. Wei, Cong-Yang, delivered 4 papers at the conference.

15.During December 5-6, 2017, the "2017 Highly-radioactive Waste Workshop and Annual NUMO / TPC Geological Disposal Conference" was held by INER. Dr. He Xiji and six other experts from Japan were invited. There were about 120 technicians participated in the discussion of "Taiwan-and-Japan's high-level radioactive waste disposal of basic policies and technology development" issue.

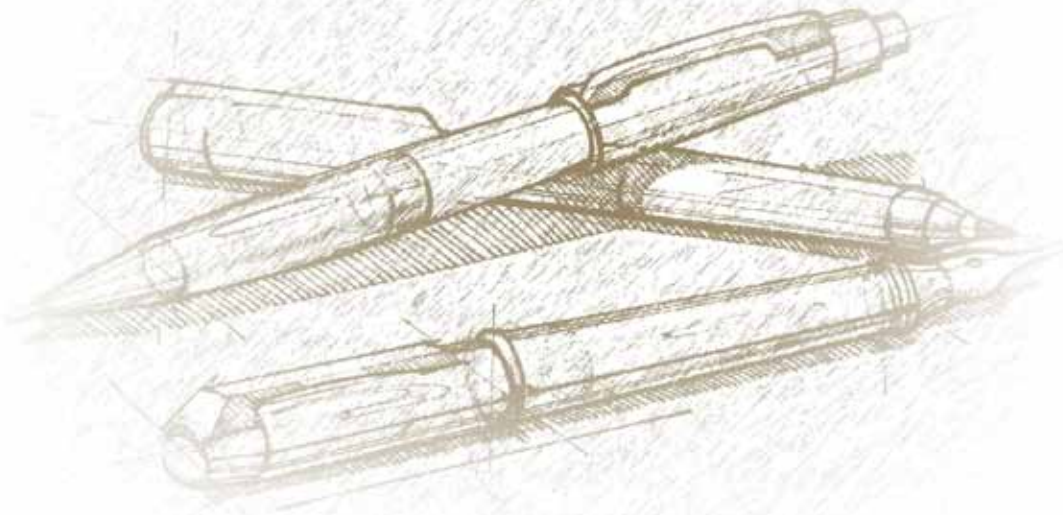
16.On December 9, 2017, INER was awarded from the "14th National Innovation Awards" by the Institute for Biotechnology and Medicine Industry. Two items, the "Ge-68/Ga-68 Radioisotope Generator and Innovate Method of Construction Thereof" and the "Innovative Mass Production Technology of Hi-end Solar Control Films", were awarded.

17.The 2017 TECRO-AIT JSCCNC annual meeting was held in Kaohsiung during December 12-14, 2017 with a total of nearly 90 participants. Colleagues from INER participated in the discussion of the working groups.

18.On December 15, 2017, "The 6th Meeting of the 15th Ionizing Radiation Safety Consultation Conference" was held in INER and co-chaired by Commissioner Chen, Fu-Dou and Director Liou,Wun-Si of AEC Radiation Protection Department. After the meeting, the delegation visited National Radiation Standards Laboratory (NRSL) and other facilities.

19.On December 25, 2017, INER was awarded from the "2017 Excellence Award of Atomic Energy Safety" by AEC. Respectively, the group award goes to the team of "Radioactive detection in Food" and the individual award goes to Deputy Director LIN,JIA-DE.

20.On December 25, 2017, INER was awarded from the "2017 Secure Operation and Excellent R&D of Nuclear Materials and Radioactive Waste" by AEC. Two research groups and two individuals were awarded.



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