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วิทยาศาสตร์ วิจัยและนวัตกรรม
Ministry of Higher Education, Science, Research and Innovation

สวทช NSTDA

ANNUAL REPORT
2019
National Science and Technology Development Agency

ANNUAL REPORT 2019

National Science and Technology Development Agency

This report is prepared according to the 2019 fiscal year of the Royal Thai Government, from 1 October 2018 – 30 September 2019.

Annual Report 2019

National Science and Technology Development Agency

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NATIONAL SCIENCE AND TECHNOLOGY DEVELOPMENT AGENCY (NSTDA)

The National Science and Technology Development Agency (NSTDA) was established in 1991 under the National Science and Technology Development Act 1991. The agency is affiliated to the Ministry of Higher Education, Science, Research and Innovation and reports to the NSTDA Governing Board, chaired by Minister of Higher Education, Science, Research and Innovation.

VISION

"To be a key partner for a knowledge-based society through science and technology"

MISSION

"NSTDA aims to perform research, development, design and engineering; promote the transfer of knowledge and technology to users; and support the scientific and technological human resources and infrastructure development with effective internal management to enhance national competitiveness and facilitate sustainable development."

CORE VALUES

N: Nation First

act in nation's best interest, be socially responsible and dedicated to the common goal

S: Science and Technology Excellence

committed to excellence, culminating from curiosity, initiative and creativity, in every aspect with the highest standards

T: Team Work

work cooperatively, be open to criticism and play a constructive role, subscribe to two-way communication

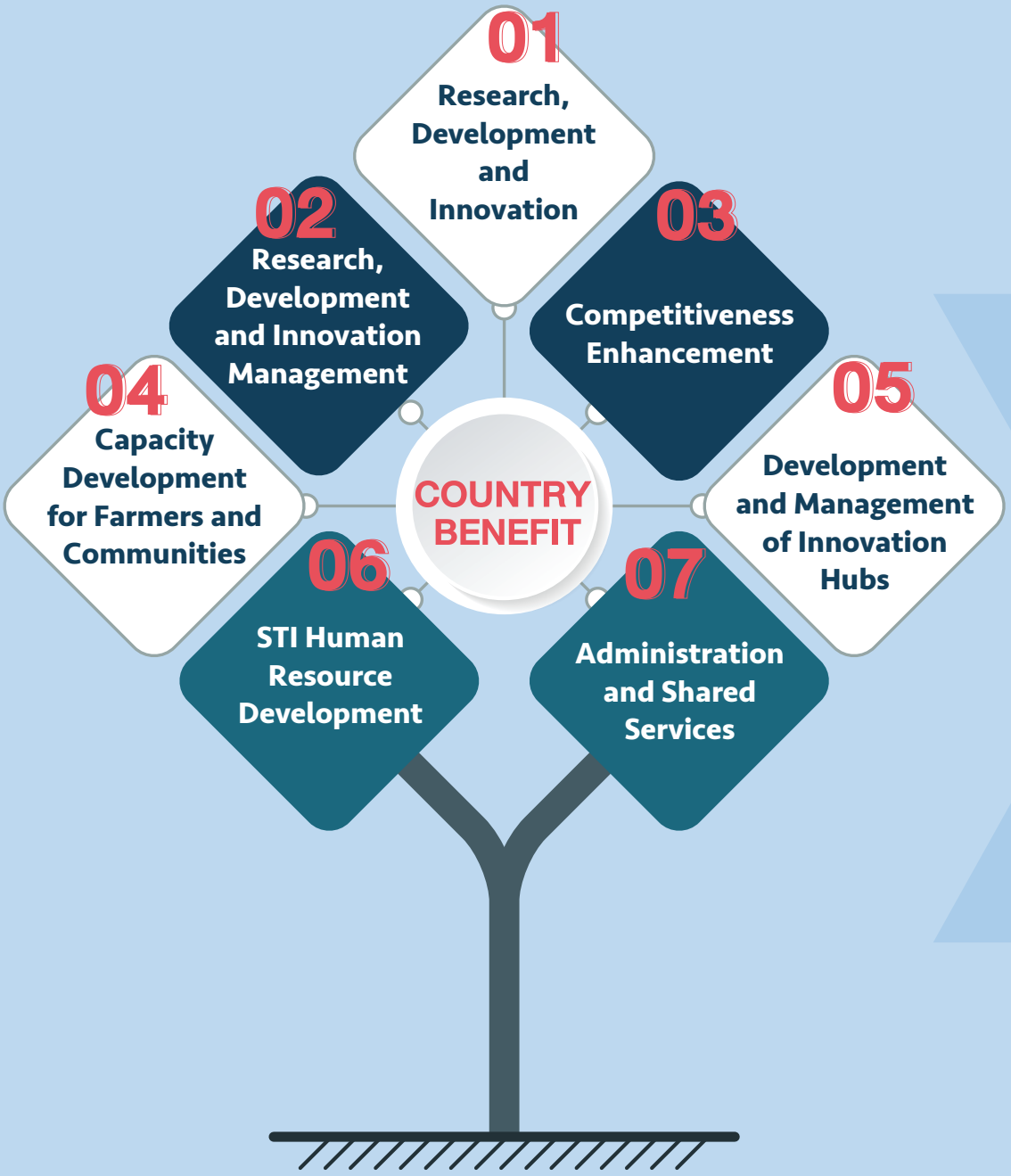
D: Deliverability

deliver quality output as promised, contribute to a stimulating and agile workplace

A: Accountability and Integrity

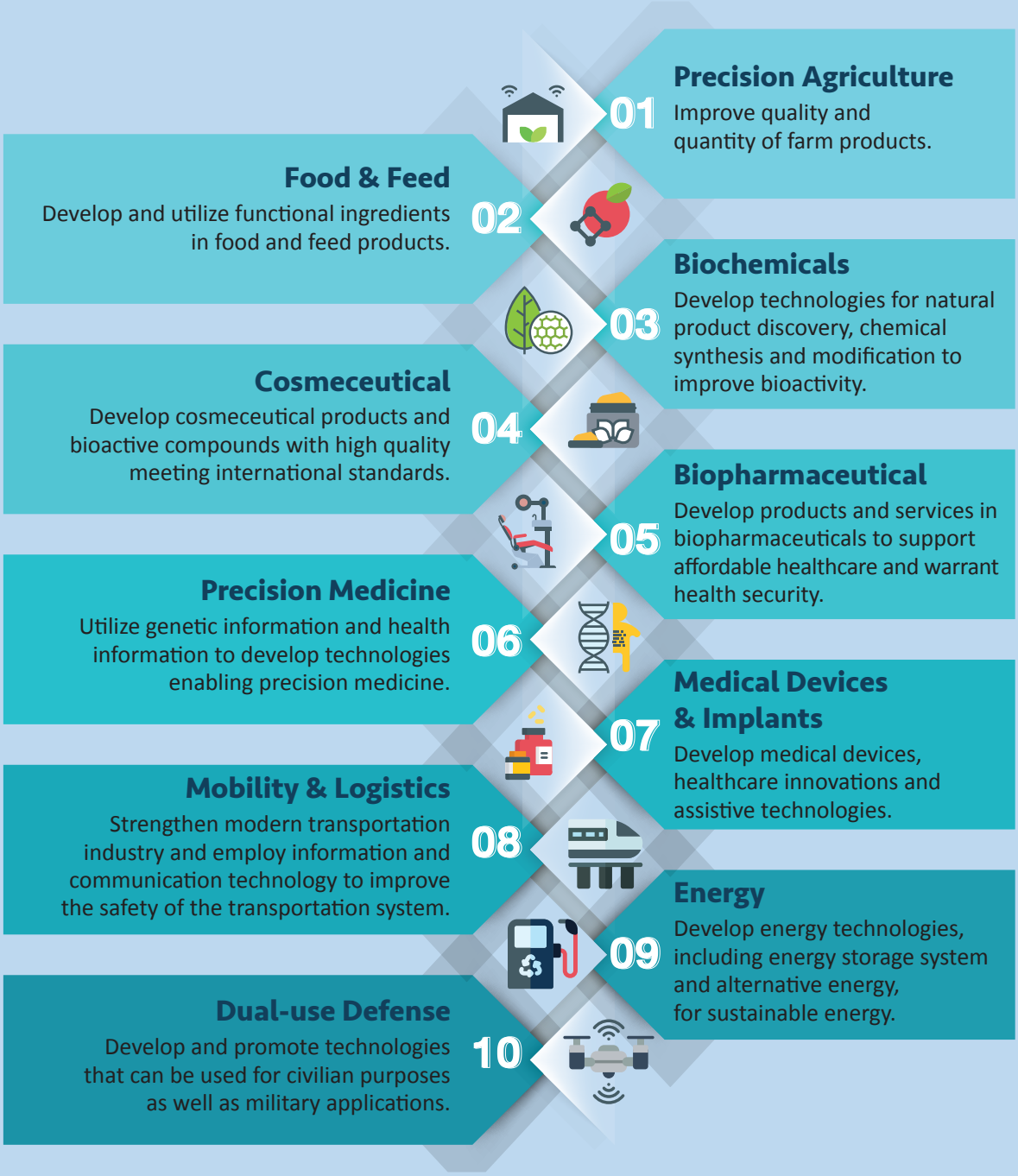
adhere to morality, ethics and transparency; stand up for a good cause

7 Functional Groups



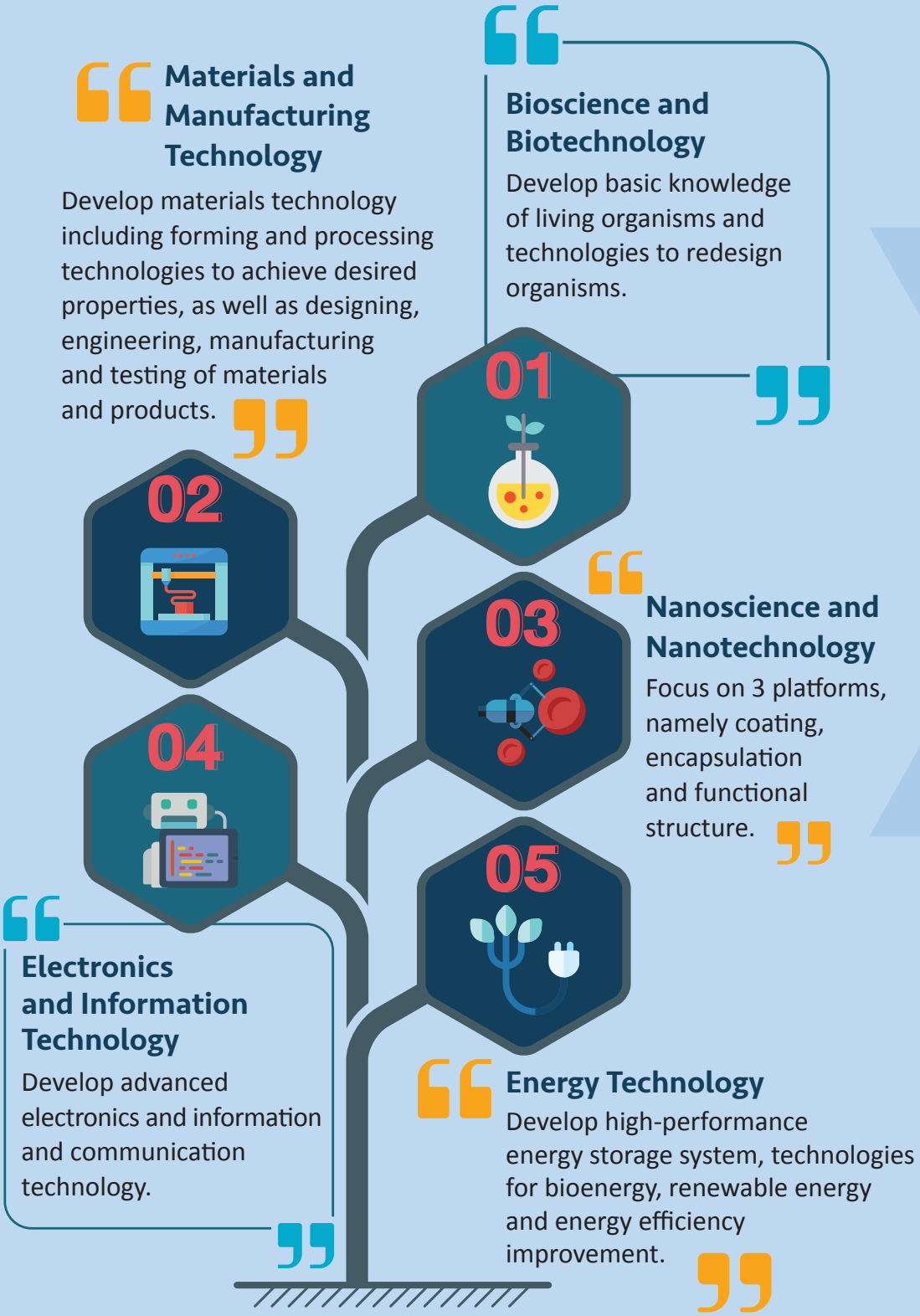
10 Technology Development Groups (TDGs)

TDGs aim at integrating and framing the direction of research pillars, focusing on the translation of research to real-world applications in order to realize tangible socio-economic impact.



5 Research Pillars

NSTDA aims at developing technology platforms and building capability in five key areas.



Bioscience and Biotechnology

Develop basic knowledge of living organisms and technologies to redesign organisms.

Materials and Manufacturing Technology

Develop materials technology including forming and processing technologies to achieve desired properties, as well as designing, engineering, manufacturing and testing of materials and products.

Nanoscience and Nanotechnology

Focus on 3 platforms, namely coating, encapsulation and functional structure.

Electronics and Information Technology

Develop advanced electronics and information and communication technology.

Energy Technology

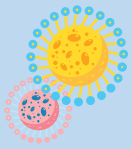
Develop high-performance energy storage system, technologies for bioenergy, renewable energy and energy efficiency improvement.

6 Frontier Research Areas

Six areas of frontier research are fostered in order to build the strong foundation for future development.

1. Quantum Engineering
For data storage and processing

2. Terahertz
For ultrahigh-speed wireless communication



3. Artificial Photosynthesis
Enable energy production by replicating the natural process of photosynthesis

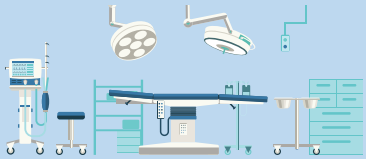
4. DNA Data Storage
Convert data and encode to DNA sequences

5. Exoskeleton
Wearable machines with useful applications in physical rehabilitation, sports and military

6. Nanorobotics
Nanoscale devices and robots to perform assigned tasks

3 Focus Centers

Focus centers aims to deliver innovations in selected fields of industry.



1. Assistive Technology and Medical Devices Center (A-MED)
Medical devices, healthcare innovations, signal processing device, biomedical applications, rehabilitation technology and technologies to support a medical hub initiative.

2. National Security and Dual-Use Technology Center (NSD)
IT system supporting authentication, system for protection from threats caused by unmanned aerial vehicles and wireless technology, power supply stability control system, air filtration system and sensors for air quality analysis.

3. Rail and Modern Transports Research Center (RMT)
Technologies for testing, inspecting and maintaining; design and development of parts and vehicle assembly; as well as manpower development and international partnership formation.

5 National Science and Technology Infrastructure (NSTI) Centers

National Science and Technology Infrastructure aims at building national S&T capability through fully-equipped advanced research facility, skilled researchers and network of domestic and international partners.

01

National Biobank of Thailand (NBT)

An infrastructure for storing and conserving biological resources which include plants, microorganisms and their data as well as human genome database to enhance capacity in conservation and sustainable utilization of bioresources in compliance with applicable regulations and standards.

02

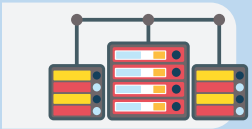
National Omics Center (NOC)

An infrastructure for developing cutting-edge genomic, transcriptomic, proteomic and metabolomic tools to support the development of innovations for agriculture and industrial sectors.

03

Center for Cyber-Physical Systems (CPS)

An infrastructure for supporting research, services and technology transfer in the field of cyber-physical systems to upgrade Thai industry to achieve Thailand 4.0 vision.



04

NSTDA Supercomputer Center (ThaiSC)

A high-performance computing infrastructure for supporting Thai research community on issues of national interest and S&T advancement.

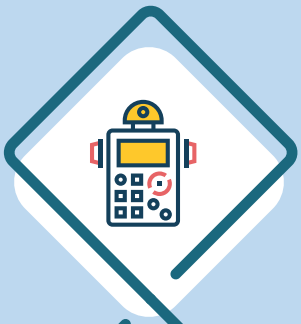
05

Technology and Informatics Institute for Sustainability (TIIS)

An infrastructure for supporting life cycle thinking (LCT) to promote circular economy and sustainable growth, as well as enhance the nation's competitiveness.

4 National Quality Infrastructure (NQI) Centers

National Quality Infrastructure offers services in design, testing, calibration and certification to enable Thai industry to develop high quality products meeting international standards.



Electrical and Electronic Products Testing Center (PTEC)

Provides testing services to support electronic, electrical and medical device industries.

NSTDA Characterization and Testing Service Center (NCTC)

Provides a wide range of analytical services with advanced scientific instruments and ISO/IEC 17025 certified laboratories.

Design & Engineering Consulting Service Center (DECC)

Offers services in product and process design by employing computer software to perform engineering analysis.

Industrial Ceramic and Houseware Product Testing Center (CTEC)

Provides services for testing and evaluation of tableware, tiles, sanitary ware and building materials in compliance with national and international standards.

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MESSAGE FROM NSTDA BOARD CHAIRMAN

Ministry of Higher Education, Science, Research and Innovation (MHESI) is a main driver to build a strong foundation for the future development with the goal for Thailand to become a nation of smart citizen, value-based economy and innovation. This goal is realized through 4 platforms: 1) Manpower and Knowledge Development by building a cohesive force of academic and research agencies and fostering a research and innovation ecosystem to attract and nurture local and international talents; 2) Social Inequality Reduction and Poverty Alleviation by applying technology and innovation to enable targeted poverty alleviation; 3) Competitiveness Enhancement with advanced technologies and concepts such as artificial intelligence (AI), creative economy, and sharing economy; and 4) Solutions to Grand Challenges with frontier research such as zero waste technology and the management of PM2.5 air pollution. The implementation will be driven according to the motto "ministry of opportunity, wisdom and the future".

NSTDA is tasked with an important mission to develop and employ science, technology and innovation to drive economic and social development. NSTDA's numerous achievements serve as a testament to its commitment to enhance the nation's competitiveness, apply research and innovation to all sectors including the agricultural and industrial sectors and local communities, as well as support S&T manpower and infrastructure development to underpin long-term competitiveness and sustainability.

On behalf of NSTDA Governing Board, I would like to congratulate NSTDA on its continuous success in developing Thailand's science and technology, and hope that NSTDA will continue to lead the nation through crises and achieve the sustainable development goals, following MHESI's vision to build and develop manpower, knowledge and innovation to transform Thailand into the 21st century and become a developed country.

Dr. Suvit Maesincee
Minister of Higher Education, Science, Research and Innovation
Chairman of NSTDA Governing Board

MESSAGE FROM NSTDA PRESIDENT

NSTDA is committed to support the Thai Government's policy to transition the country to an innovation-driven economy and prepare Thai people into the 21st century by performing research, development, design and engineering to arrive at outputs which can be transferred to users in the public and private domains, supporting manpower and infrastructure development, and strengthening STI capacity in all fields and sectors.

In FY 2019, NSTDA revised its strategy to better address changes that have taken place. The agency now places great emphasis on applying its competence in core technologies to develop innovations, as well as building technological capability in the fields essential to the national development and responsive to future technological trends. This revised strategy enables NSTDA to drive the agenda of Bio-Circular-Green Economic Model (BCG) - a new economic model introduced by the government to promote the growth of new S-curve industries – through the following mechanisms: research management, competitiveness enhancement, capacity development for farmers and communities, development and management of innovation hubs and STI human resource development, as well as change agility. Furthermore, new National S&T Infrastructure (NSTI) centers were established to build national S&T capacity and National Quality Infrastructure (NQI) centers were set up to enable Thai industry to improve quality of products and services, therefore enhancing competitiveness on a national scale.

It is our commitment to perform high quality research and development and collaborate with all sectors to bring innovations to real-world applications, enabling Thailand to escape the middle-income trap and be on the path to stability, prosperity and sustainability. I wish to express my appreciation to all NSTDA staff for their hard work and tenacity to constantly make an improvement to reach the success.

Mr. Narong Sirilertworakul
President
National Science and Technology Development Agency

EXECUTIVE SUMMARY

The National Science and Technology Development Agency (NSTDA) is a research and development organization affiliated to the Ministry of Higher Education, Science, Research and Innovation. The agency is committed to develop capability in science and technology and employ innovation to improve people's quality of life, drive the economy, enhance the competitiveness of target industries, prepare Thai people for the 21st century and lead the nation to attain Thailand 4.0 vision.

Year 2019 marked a major change in S&T governance. Two ministries were merged to form the Ministry of Higher Education, Science, Research and Innovation to serve as a vehicle to transition Thailand to a developed country. In response to this development, NSTDA revised its strategy to better address emerging challenges. The organization was re-structured into seven functional groups corresponding to the policy and national strategic plan. NSTDA also intensified its activities to build up scientific and technological capability to meet the demand of industry and respond to an ever-changing world. Current research strategy focuses on five platform technologies and six frontier research areas. Ten Technology Development Groups (TDGs) were introduced in order to integrate expertise in various technologies and focus on the translation of research to real-world applications in order to drive the economy and benefit the society. Three new focus centers were established to address the national agenda. These focus centers are Assistive Technology and Medical Devices Center, National Security and Dual-Use Technology Center and Rail and Modern Transports Research Center.

To lay down a firm foundation for research and development, NSTDA established National Science and Technology Infrastructure (NSTI) centers. Five new NSTI centers are: National Biobank of Thailand to preserve and provide services on biological resources including plants, microorganisms and human genome database; National Omics Center to develop and utilize cutting-edge omics technology to study living organisms; Center for Cyber-Physical Systems to serve as a regional hub for exchanging

and disseminating knowledge and applications of cyber-physical systems; NSTDA Supercomputer Center to provide high-performance computing (HPC) resources to support research on issues of national interest; and Technology and Informatics Institute for Sustainability to support life cycle thinking (LCT) for circular economy and sustainable growth.

National Quality Infrastructure (NQI) centers were set up to act as catalysts for improving quality of products and services offered by Thai industry, therefore enhancing competitiveness on a national scale. NQI centers provide services such as product design, testing, calibration, conformity assessment, inspection and certification. Innovation hubs offering infrastructure and supporting innovation ecosystem are essential for transitioning to an innovation-driven economy. Food Innopolis and the Eastern Economic Corridor of Innovation (EECi) are among innovation hubs managed by NSTDA. Food Innopolis aims at supporting food and food-related industry, whereas EECi will promote new growth engines under the Bio-Circular-Green Economic Model (BCG) for economic sustainability.

In FY 2019, a number of research, technology and innovation have been developed to enhance Thailand's competitiveness and people's quality of life across 4 key industries. LOMAR is an example of innovation in food and agriculture sector. LOMAR is an innovative ultra low ammonia natural rubber latex designed for mixing with asphalt cement for road construction. With superior quality compared to commercial concentrated latex, LOMAR was used in 1,800 km. of road construction, creating a 1.2 billion THB socio-economic impact. DentiiScan 2.0 – a cone-beam CT scanner for dental and maxillofacial imaging - represents a fine invention in the medical and wellness sector. The machine has been installed in 60 public hospitals and performed over 7,000 scans. In bioenergy and biomaterial sector, bio-compostable plastic bags were invented with a special feature of complete decomposition within 3-4 months. The invention was debuted to a success at the Annual Red Cross Fair 2019. To support tourism and creative economy, NSTDA helps promote wildlife tourism at Khao Dinsor, a prime site to observe migratory raptors in Chumphon Province, with a research project employing satellite tracking to study raptors' flyways. In addition, NSTDA's work on big data such as "AI for Thai" supports a wide range of industries. AI for Thai is a platform that enables Thai manufacturing and service industries to employ artificial intelligence (AI) and machine learning tools to improve their products and services. The platform has garnered more than 1,700 users since its launch in September 2019.

To strengthen communities and the farming sector, NSTDA carried out the transfer of knowledge and technologies to more than 10,000 farmers and 1,000 business operators in 500 communities located in 53 provinces. Among 36 available technologies are smart farming, seed production and agricultural and food processing.

Recognizing the importance of competent and skilled manpower in driving forward science and technology in Thailand, NSTDA implements a range of human resource development programs. To inspire children to pursue S&T education, projects such as "Coding at School with KidBright" and "Fabrication Lab" were created for kids to unleash their creativity to build innovations, thus

supporting Thailand to become a Makers Nation. A total of 5,800 children participated in these projects. To build critical mass of S&T students and professionals, NSTDA provided a total of 521 scholarships, and welcomed 437 Thai and foreign students and non-NSTDA researchers to work on collaborative projects in NSTDA laboratories.

These are just some examples of our work derived from collaborative effort of NSTDA staff and our partner organizations in 2019 to serve the goals which are to develop innovations for economic and social applications, support the national strategy to become an innovation-driven economy, prepare Thai people for the 21st century, create visibility at the national, regional and global levels, and make an impact to people, economy and society.

2019 Statistics

3009 Staff in total

- **69%** research and scientific staff
- **31%** operation and management
- **22%** doctoral degree
- **44%** master's degree
- **34%** bachelor's degree and below

66 Awards

Socio-economic impact of NSTDA outputs

48.743 BILLION THB

STI investment contributed by NSTDA partners

12.179 BILLION THB

500 COMMUNITIES
53 PROVINCES
10,786 PEOPLE benefited from

Capacity development program for farmers and communities

258 PROJECTS/AGREEMENTS executed

316 ORGANIZATIONS participated in

Technology transfer and licensing program

544 **Publications in international journals**

358 **IP applications**

1,791 SMEs benefited from

Innovation Technology Assistance Program (ITAP)

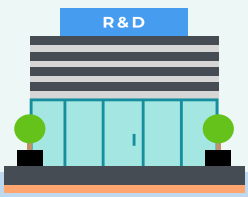
81,477 TESTS AND SERVICES performed

2,270 CLIENTS served by **NQI centers**

521 SCHOLARSHIP RECIPIENTS

5,800 CHILDREN benefited from

STI human resource development program



149 COMPANIES establishing R&D facilities/activities in **Innovation hubs**

RESEARCH, DEVELOPMENT AND INNOVATION

NSTDA designed a 6-6-10 research strategy to serve as a framework for building its capacity in research, development and innovation in order to drive the economy under Thailand 4.0 policy. The 6-6-10 strategy comprises 6 research pillars - based on five core technologies, namely Bioscience and Biotechnology, Nanoscience and Nanotechnology, Electronics and Information Technology, Material and Manufacturing Technology and Energy Technology and a concept of focus center – 6 frontier research areas and 10 Technology Development Groups (TDGs).

Agriculture and Food

LOMAR: Ultra Low Ammonia Natural Rubber Latex for Road Construction

LOMAR is a new type of concentrated natural rubber latex that has a very low ammonia content and high thermal stability. Designed for mixing with asphalt cement for road construction, it has an ammonia content below 0.15% by weight – whereas commercial concentrated latex has an ammonia content of 0.6-0.7% by weight - and a mechanical stability time of above 1,500 seconds. Due to its high thermal stability, LOMAR can be processed at 140-160 °C. It can be used immediately within 1-2 days after the production date- whereas commercial ones require 21 days for aging - and has a shelf life of over 6 months.

Current Status

- LOMAR is now commercially manufactured by Thai Eastern Rubber Company Limited.
- Tipco Asphalt Public Company Limited uses LOMAR in the production of para-asphalt concrete (PARA AC).
- LOMAR-PARA AC products are commercially available for road construction businesses.

ParaFIT: Concentrated Latex for the Production of Pillows and Mattresses

ParaFIT is a concentrated latex containing less than 0.2% ammonia by weight – whereas a commercial concentrated latex contains 0.3-0.7% ammonia - and therefore does not require an extra ammonia removal step prior to processing into pillows and mattresses. ParaFIT also contains 30% less amount of zinc oxide (ZnO) and tetramethylthiuram disulphide (TMTD) than commercial LA and MA concentrated latex, thus reducing the amount of toxic chemicals used in the production of concentrated latex. While commercial concentrated latex normally requires a 21-day incubation, ParaFIT can be used immediately within 1-3 days after the production date, enabling business operators to reduce their cash flow for purchasing fresh latex and save investment capital in constructing latex storage facilities. ParaFIT has a shelf life of over 6 months.

Current Status

- ParaFIT is now manufactured at an industrial scale.
- ParaFIT has been used for the commercial production of latex foam pillows and mattresses.
- Implementation plan to expand ParaFIT utilization in community enterprises and industry is in progress.

Medical and Wellness

DentiiScan 2.0: Cone-beam CT Scanner for Dental and Maxillofacial Imaging

DentiiScan 2.0 provides 3D internal anatomy images of dental and maxillofacial structures, without distortion and superposition of anatomic structures. It emits smaller dose of radiation than other CT scanners commonly used for medical purposes. The machine takes 18 seconds to complete a 360-degree rotation to provide a high-quality 3D image that enables accurate diagnosis and safe treatment planning. DentiiScan 2.0 supports medical procedures such as dental implant, wisdom tooth extraction, oral and maxillofacial surgery as well as sinus abnormality assessment. The machine is small in size and can accommodate users in the sitting and standing positions. Developed by Thai research team, DentiiScan 2.0 is manufactured in Thailand, thus making the CT scan procedure more accessible and affordable to Thai people.

60 machines have already been installed in hospitals and performed over 7,000 scans.

270 million THB has been saved from importing CT scanners.

Current Status

- The technology has been transferred to Pixamed Company Limited.
- 60 machines have already been installed in government hospitals throughout Thailand.

M-Bone: Bone Graft Substitute

M-Bone is a synthetic hydroxyapatite and tricalcium phosphate bone graft. Its high porosity of 80% and rough surface allow for new bone to form rapidly and provide strong bone anchorage. New bone cells are able to form and grow in the pore space in just 16 weeks after the implant. M-Bone passed all the tests prescribed by ISO 10993, including cytotoxicity, irritation, material-mediated pyrogenicity, as well as side effects on tissues. Furthermore, R&D and prototype manufacturing processes of M-Bone are complied with ISO 13485 standard for medical devices.

M-Bone has already been used
at Kasetsart University Veterinary Teaching Hospital,
making a 30 million THB impact.

Current Status

The technology has been transferred to Oss Hydroxy Company Limited for commercial production of dental implants for humans and animals.

Bioenergy, Biomaterial and Biochemical

Bio-compostable Plastic Bag for Food Waste

This bio-compostable plastic bag is based on the bioplastic compound innovation for industrial production. It marks the first time that the production of bio-compostable plastic bag can be achieved at an industrial scale in Thailand. The bioplastic compound contains tapioca starch, one of Thailand's economically important commodities. The bio-compostable plastic bag takes 3-4 months to be fully decomposed by microorganisms. The decomposition can be faster in landfills due to high temperature. This bio-compostable plastic innovation is NSTDA's answer to Bio-Circular-Green Economic (BCG) Model by creating additional value to local agricultural commodity and offering an alternative green solution to the society.

Bio-compostable plastic bag innovation made its debut at the Annual Red Cross Fair 2019.

Current Status

Bio-compostable plastic bags were used for collecting organic waste at the Annual Red Cross Fair 2019 held during 15 - 24 November 2019, at Lumpini Park, Bangkok.

Aluminum Minibus

Model C Bus is the first aluminum-bodied minibus designed and manufactured in Thailand under the partnership of NSTDA and Sakun C Innovation Company Limited. Advanced technology was utilized in the development and manufacturing of this aluminum minibus. Computer technology was employed to assist with the design and strength analysis of aluminum body, whereas the assembly was done by robots. Its outstanding features include lightweightness, excellent fuel efficiency, durability, safety, rustproofing and low maintenance requirement. The design of this aluminum minibus also supports the modification to an electric minibus in the future.

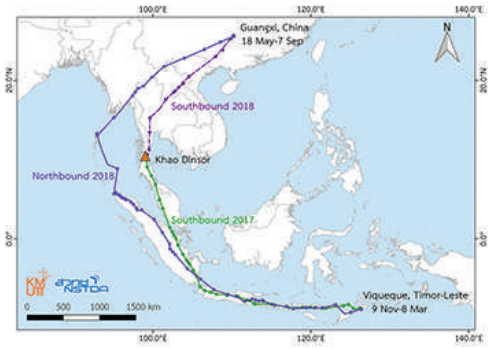
Current Status

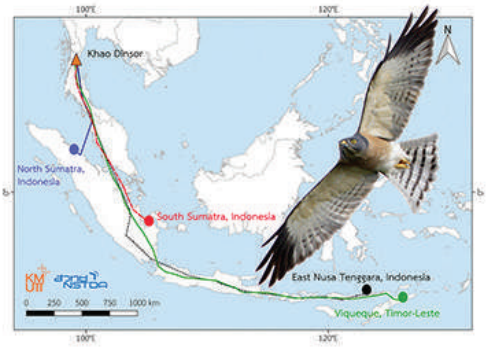
This aluminum-bodied minibus was unveiled at the 16th Commercial and Special Purpose Vehicle Exposition (BUS & TRUCK ’19) in Bangkok and 370 orders have been placed.

Tourism and Creative Economy

Development of Tourist Attraction in Secondary City

Khao Dinsor (Dinsor Hill) in Chumphon Province is among the world's top 5 sites to observe migratory raptors. Every year around September - November, raptor watchers from all over the world gather at Khao Dinsor to catch the sight of hundreds of thousands of raptors migrating from breeding grounds in Russia and China to wintering grounds in Southeast Asia. NSTDA in collaboration with partner organizations employed satellite tracking to study raptors' flyways. The solar-powered satellite tracking devices, weighing less than 4% of the raptor's weight, were attached to Chinese Sparrowhawks (*Accipiter soloensis*) and Japanese Sparrowhawks (*Accipiter gularis*) to find out where they travel to and stop. The paths and locations can be monitored via a website or a mobile application.





Current Status

- Knowledge obtained from the study can be applied to a raptor conservation program and support Khao Dinsor's wildlife tourism.
- Data on migration routes can be accessed through http://www.argos-system.org/ or CLS View application on a mobile device.

NAVANURAK: e-Culture Open Data Platform

e-Culture involves an application of digital technologies in the field of cultural heritage. Cultural data are systematically archived and can be easily accessed for historical investigations. As e-Culture enables virtual observation and investigation, it can help preserve cultural heritage by reducing risks of damaging and deteriorating artifacts.

NAVANURAK is a digital platform for archiving Thai cultural heritage. It was designed to systematically archive cultural data. NAVANURAK follows the concept of open data - allowing public to freely access the information - and can be linked to museum libraries worldwide.

Current Status

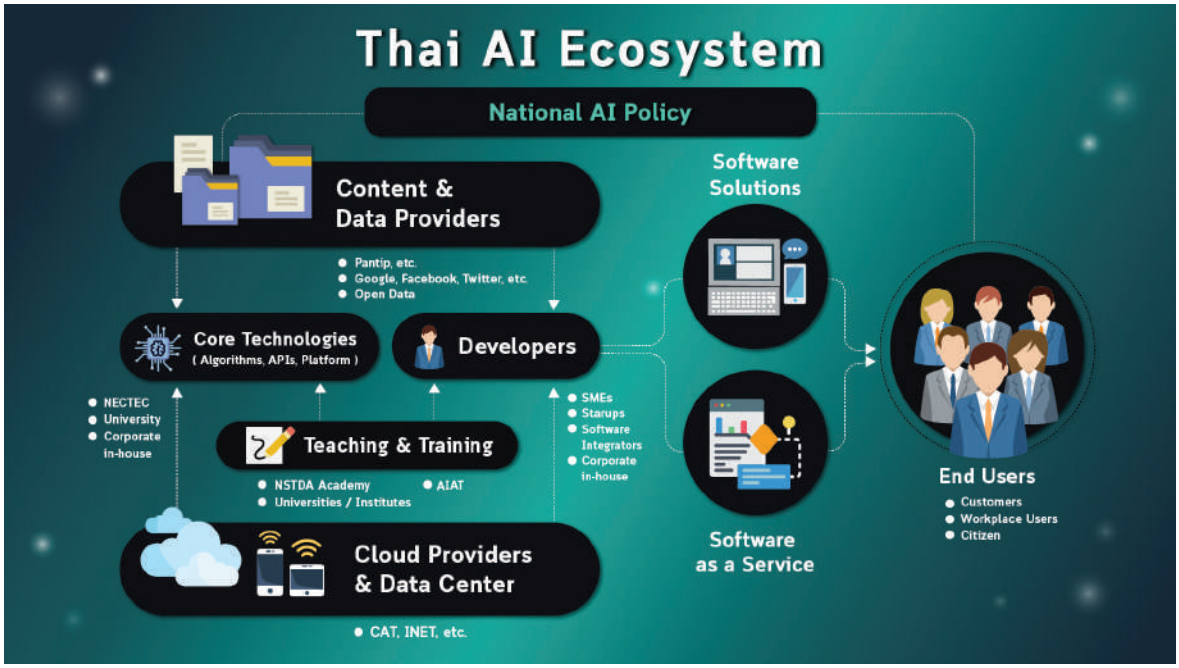
- NAVANURAK can be accessed through http://www.navanurak.in.th.
- Over 70 organizations have applied to use the platform.
- The platform enables effective management of cultural heritage data for preservation and tourism purposes.

Big Data

AI for Thai: Thai AI Service Platform

AI for Thai is a platform providing artificial intelligence (AI) services to users in the manufacturing and service industries. The platform helps promote research and development in AI and machine learning and enables Thai industry to employ AI and machine learning tools to improve their products and services. Example of AI applications are as follows:

- Retail: Chatbots are used to replace human customer service.
- Logistics: Facial recognition is used for detecting truck driver fatigue, thus reducing fatigue-related accidents.
- Healthcare: AI is used for predicting risk of an individual patient or performing X-ray diagnosis.
- Tourism: AI is used for language translation and analyzing photos of food and tourist attractions.

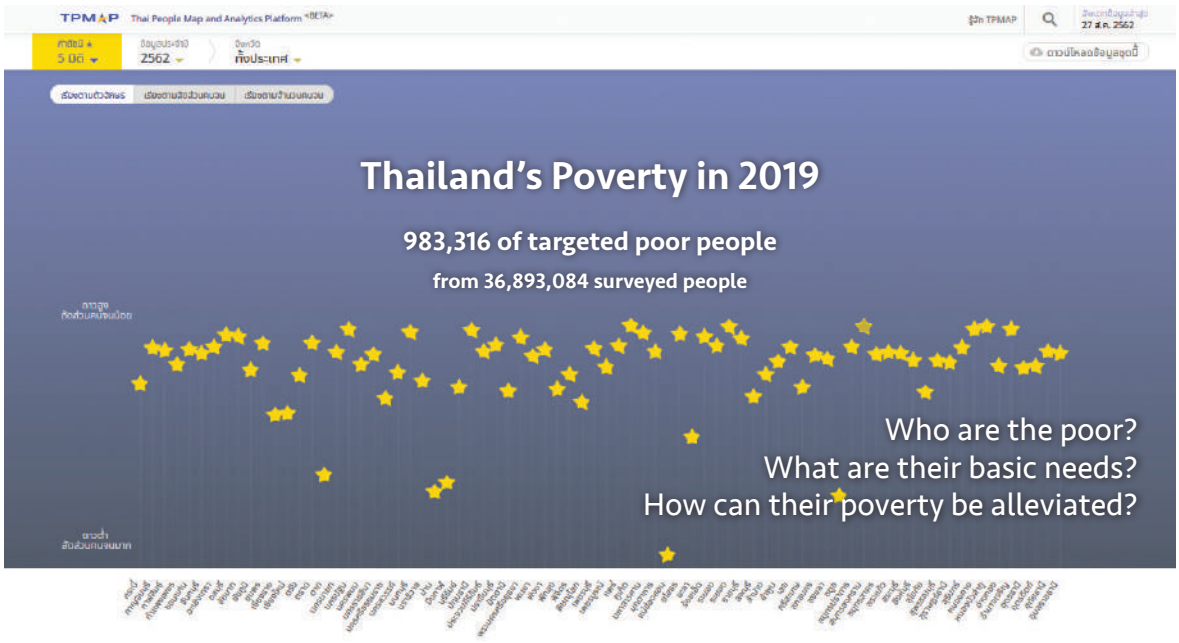


Current Status

- AI for Thai is now available at www.aiforthai.in.th.
- The platform gained more than 1,700 users over a 3-month period, from 9 September - 4 December 2019.

TPMAP: Thai People Map and Analytics Platform

Thai People Map and Analytics Platform is a government big data system that creates accurate poverty maps based on integrated datasets from two sources, the census-based Basic Minimum Needs (BMN) data from the Interior Ministry's Community Development Department and registration records of the Government Welfare Program from the Finance Ministry. Multidimensional Poverty Index (MPI) approach is used to analyze poverty in 5 key areas: healthcare, education, income, standard of living, and access to public services. TPMAP enables policy makers and government agencies to design precise poverty alleviation policy and strategy.



Current Status

- TPMAP is available at https://www.tpmap.in.th.
- 17 provinces have requested detailed information from TPMAP. These provinces are Samut Songkhram, Pathum Thani, Chiang Mai, Mukdahan, Nakhon Phanom, Phra Nakhon Si Ayutthaya, Sakon Nakhon, Udon Thani, Tak, Lopburi, Yala, Ubon Ratchathani, Nonthaburi, Chanthaburi, Nakhon Pathom, Roi Et and Uthai Thani.
- Samut Songkhram has launched a TPMAP-based poverty alleviation pilot project. In 2019, 50 households showed improvement in standard of living.

National S&T Infrastructure (NSTI)

National S&T Infrastructure aims at building national S&T capacity through fully-equipped advanced research facility, skilled researchers and network of domestic and international partners.

National Biobank of Thailand (NBT)

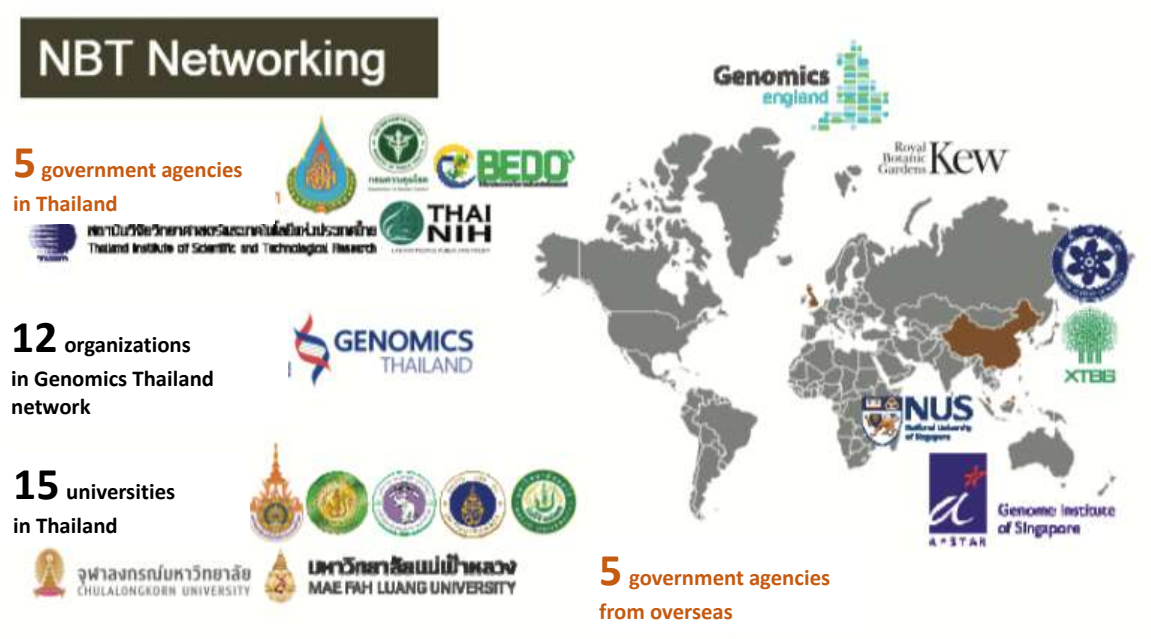
NBT serves as an infrastructure for storing and conserving biological resources which include plants, microorganisms and their data as well as human genome database to support research communities. In addition, NBT forms alliances with strategic partners to enhance capacity in conservation and sustainable utilization of bioresources in compliance with applicable regulations and standards.

In 2019, the following achievements have been made:

- **Plant Collection:** 430 plant seed specimens (chili, tomato, pumpkin, cucurbit, rice and wild plants), 159 tissue cultures of herbal plants, 150 dry plant specimens, and 200 genomic DNAs of herbal plants
- **Microbial Collection:** 2,360 microbial samples, 2,400 fungal samples, 9,167 genomic DNAs of microorganisms, and 244 microbial species with utilization information
- **Biological and Genetic Information:** DNA barcodes of 688 herbal plant samples, 305 rice genomes, 6 ecological datasets, DNA barcodes of 798 microbial species, 855 microbial species published on culture collection catalog, and genomic sequences (WGS, WES and SNP) of 2,395 Thai people
- **Online Databases:** An online system is being designed to house databases of plants, microbes, ecology and human genome to serve as a reference of Thailand's genetic diversity.
- **Analytical Platforms:** Platforms to perform genotyping-phenotyping correlation analysis and population analysis are being developed to facilitate genetic marker design for plant breeding. Development of an analytical platform for metagenomics of human and environmental microbiomes is also in progress.

In addition, discovery of new fungal species and new partnerships have been made as illustrated below:

Novel species	Sources
Hermatomyces trangenesis sp. nov.	Isolated from sugar palm in Trang province
Tamhinispora saraburiensis	Isolated from bamboo in Saraburi province
Daldinia subvernicosa	Ban Hua Thung community forest, Chiang Mai province
Tretoheliocephala cylindrospora sp. nov.	Isolated from a decaying twig of an unidentified plant, Chaiyaphum province


NBT Networking
5 government agencies in Thailand
Thailand Institute of Scientific and Technological Research
THAI NIH
BEDO
12 organizations in Genomics Thailand network
GENOMICS THAILAND
15 universities in Thailand
จุฬาลงกรณ์มหาวิทยาลัย
CHULALONGKORN UNIVERSITY
มหาวิทยาลัยแม่ฟ้าหลวง
MAE FAH LUANG UNIVERSITY
Genomics england
Royal Botanic Gardens Kew
XTBG
NUS
A*STAR
Genome Institute of Singapore
5 government agencies from overseas

National Omics Center (NOC)

NOC aims at building capacity in omics technologies as well as developing cutting-edge genomic, transcriptomic, proteomic and metabolomic tools that enable biologists analyze omics data for a better understanding of biological systems and eventually the development of successful innovations for agriculture and industrial sectors.

Noc
Provides Solutions

In 2019, the follow progress has been made:

DNA Barcode and Fingerprint

- **Establishment of DNA fingerprint database of tigers in Thailand.** DNA fingerprinting of all (2,362) captive tigers in Thailand has been performed and a web-based database is being constructed. Co-developed with the Department of National Park, Wildlife and Plant Conservation, this database enables an identification of individual tigers in Thailand and helps prevent tiger trafficking.
- **Establishment of DNA barcodes of living organisms in Thailand.** DNA barcoding of 50 algal samples and 2,000 microbial samples has been performed, as well as genotyping of the following organisms: 200 gotu kola (Centella asiatica) samples, 40 turmeric samples, 100 rice blast fungal isolates (Magnaporthe), 130 maize samples, 200 rice samples, 200 black mungbean samples in the germplasm collection and samples of cucumber, bitter gourd, watermelon, chili and tomato.
- **SNP markers for identification of economic crops and F1 verification for cucurbit.** 8,000 cucurbit samples have been genotyped. An improvement was made on the high throughput identification, improving the efficiency by 10 folds, from 100 samples to 1,000 samples per day.

Genetic Improvement

- **Development of RNA sequence gene expression analysis method.** The method enables several investigations such as the study of thermal stress response in coral and drought stress response in sugarcane.
- **Development of high throughput SNP genotyping method based on the MassARRAY system.** The method has been used in identifying starch-synthesis related genes for corn breeding program.
- **Development of high throughput SSR genotyping method.** The method has been used for analyzing drought tolerant genes in 230 sugarcane clones.

Peptide Barcode and Bioactive Peptide

- **Development of bioactive peptide analysis method.** The test has been used in discovering 2 antimicrobial peptides against pathogens causing chicken respiratory disease, and 9 antimicrobial peptides against pathogens causing gastrointestinal tract infections in chickens.
- **Development of peptide barcode identification method.** The test has enabled an isolation of pathogens causing gastrointestinal tract infections in chickens.
- **Establishment of peptide barcode database.** Targets of 100 peptide barcodes specific to chicken pathogens and 43 peptide barcodes specific to plant pathogens have been achieved.

Center for Cyber-Physical Systems (CPS)

CPS aims to serve as a regional hub for exchanging and disseminating knowledge and applications of cyber-physical systems. It is a fully-equipped laboratory and testbed facility staffed with specialists to develop innovations and provide consultancy services and technology transfer in the field of cyber-physical systems to upgrade Thai industry to achieve Thailand 4.0 vision.

In 2019, the follow progress has been achieved:

- **Consultancy service and technology transfer.** CPS has serviced 10 public and private organizations in retrieving live data from a physical system and processing them in the cyber space. These organizations include Charoen Pokphand Foods Public Company Limited, Wangmanao Kasetpan Company Limited, Kongkiat Textile Company Limited, Wuttisak Aesthetic Care Company Limited, PMCO1999 Company Limited, Thai President Foods Public Company Limited, Quality Construction Products Public Company Limited, Navita Farm Company Limited, Nakhon Pathom Agriculture Office and Chulalongkorn Center of Excellence for Parkinson's Disease & Related Disorders.
- **Testbed facility.** Testbed facility is being constructed at NECTEC Pilot Plant building at Thailand Science Park. The facility will enable testing of new solutions in cyber-physical systems and Internet of Things (IoT).
- **Knowledge and innovation.** Three articles on applications of IoT and IIoT (Industrial Internet of Things) have been written and posted on https://www.nectec.or.th/news/news-public-document/ for public education.
- **Network Platform for Internet of Everything (NETPIE).** NETPIE is an IoT cloud-based platform-as-a-service that facilitates application developers and device manufacturers to interconnect IoT devices together. NETPIE offers connectivity, security, availability and scalability, thus freeing developers from system management. In 2019, the platform has serviced 29,888 users and was presented with an invention award from the National Research Council of Thailand (NRCT).

NSTDA Supercomputer Center (ThaiSC)

Based at Thailand Science Park, ThaiSC provides cutting-edge high-performance computing (HPC) resources to Thai research community on issues of national interest and S&T advancement with the focus on computational science, data analytics and artificial intelligence (AI). The center represents Thailand in the international supercomputing arena.

In 2019, with its current "TARA" HPC cluster system, the service statistics are as follows:

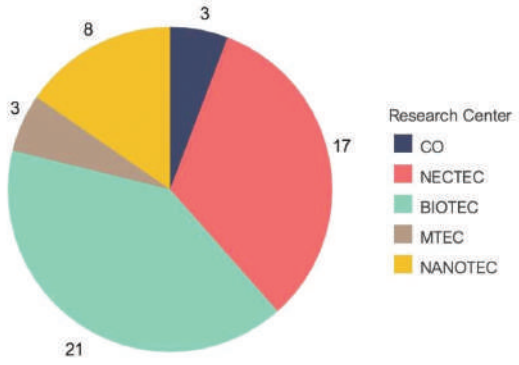
KPI	Target	Performance*
National computing platform	Service core-hours ≥ 10 millions	TARA 10.4 millions eScience 4.6 millions
	Resource utilization ≥ 70%	62.30%
	Active projects ≥ 30 projects	TARA 44 projects eScience 36 projects
	Big science/big project ≥ 2	2 projects (Biobank and TPMAP)
Customer service performance	Computing Service SLA ≥ 80%	99.30%
	Scale form user satisfactory survey ≥ 3.50 of 5	4.52

Note: * data as of 3 September 2019

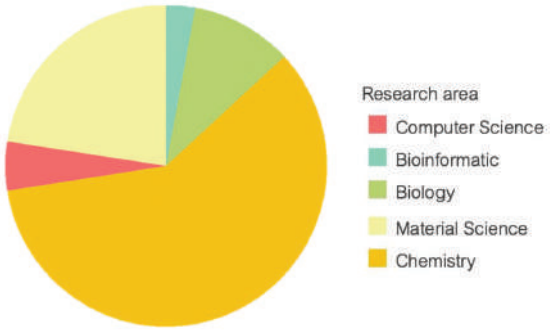
A number of knowledge sharing and training activities were organized to introduce infrastructure and services of ThaiSC to research community, and to exchange ideas and promote collaboration: NSTDA HPC School on 13 - 16 May 2019; a workshop with HPC experts from the University of Luxembourg on 30 July - 2 August 2019 and Info Session for TARA HPC: Full Launch on 13 and 20 September 2019.

TARA Usage Status

Computing served: 10.4 million core-hour
Active users: 44 Projects



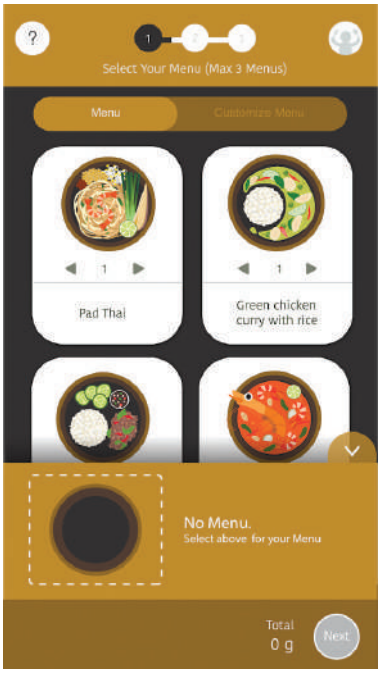
Number of projects by pillars

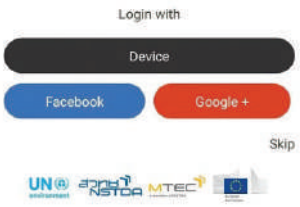


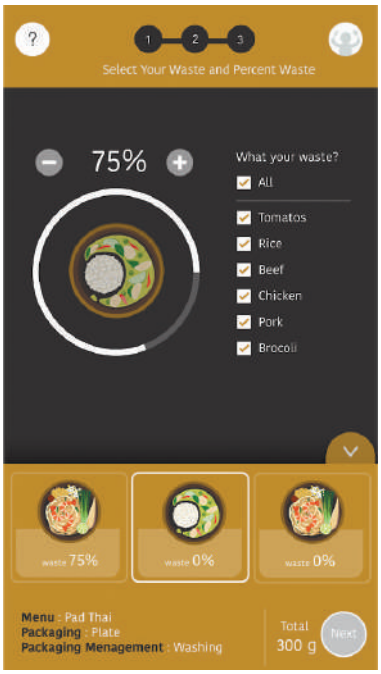
HPC resource consumption by research area

Technology and Informatics Institute for Sustainability (TIIS)

TIIS aims to be a national and regional leader in technology and informatics to support life cycle thinking (LCT). The institute develops data (products and services) as well as data management system and methodologies to support circular economy and sustainable growth, as well as enhance the nation's competitiveness. Moreover, TIIS provides technical services to raise awareness on sustainable development to the public and private sectors in collaboration with educational institutions.







In 2019, the following progress has been achieved:

- **Database and data management system for sustainability.** Improvement has been made on the database service efficiency and data quality to meet international standards so that users can have complete information over the suitable time period for each type of data.
- **Life Cycle Inventory (LCI) data and management systems.** The LCI database has been developed, maintained and improved both in quantity and quality aspects toward the international standards. Improvement has been made on the efficiency of LCI database service with accurate, reliable and current information.
- **Methodology and sustainability Indicator.** Methodology for calculating characterization factors (CF) concerning the impact assessment of occupational health and safety, as well as industrial sectors - such as food and beverage, chemical and petrochemical, and primary metal industries - has been improved to establish quality and indicators for sustainability assessment.
- **Knowledge dissemination.** The institute has engaged in commissioned research and collaborative research, as well as provided consultancy and training services to 4 organizations. Eco-efficiency assessment was performed for the Transport Company Limited, the Provincial Electricity Authority and the Industrial Estate Authority of Thailand, whereas LCA and carbon footprint assessment were made for Bangchak Corporation Public Company Limited. Guidelines for eco-efficiency assessment for state enterprises have also been developed.
- **Application and data integration.** Two mobile applications have been developed; LCA app and Lookie Waste app to promote the use of LCA concept and raise public awareness. The Lookie Waste enables users to monitor food waste and food packaging waste they have generated and assess the environmental impact of food and packaging waste from the life cycle concept. It aims to improve consumers' understanding of the impact of food waste and to change behavior for sustainable consumption. The information can be used to estimate total food waste for developing national policy on waste reduction. The research team plans to include the nutrition and health monitoring aspect to the application under the collaboration with the Department of Health.

National Quality Infrastructure (NQI)

National Quality Infrastructure serves as a central facility to provide services such as product design, testing, calibration, conformity assessment, inspection and certification to industry with an aim to increase competitiveness of Thai industry to meet international standards. NQI centers also focus on development of new analytical methodologies and provide analytical services as well as equipment services to support key industries to drive the new growth engine and create visibility of Thailand in the international community.

Electrical and Electronic Products Testing Center (PTEC)

PTEC provides professional testing, calibration, conformity assessment, inspection and certification of electrical and electronic products to be sold in Thailand, as well as imported and exported, using methods prescribed by international standards. The center also offers calibration service for measuring instruments used in electrical and electronic industry.

Performance in 2019 includes:

- **Battery and Electric Vehicle (EV) Testing.** PTEC worked with partner agencies on establishing standards for EV components such as EV electrical connectors and charging stations. The center operates an ISO/IEC 17025 accredited laboratory for testing battery cells and modules. PTEC, in collaboration with Mercedes-Benz Manufacturing (Thailand), became the first laboratory in Thailand and ASEAN to offer lithium-ion battery testing to support EV industry.
- **Aircraft Electronic Part Testing.** A testing laboratory for aircraft electronic parts was established for aircrafts used domestically. The laboratory supports RTCA DO-160, MIL-STD-704 and MIL-STD-461 standards.
- **Medical Device Testing.** PTEC worked with the Thai Industrial Standards Institute (TISI) and Thailand's Food and Drug Administration on developing industrial standards for medical devices, e.g. IEC 60601-2-X, and a capacity building program to educate SMEs on medical device standards such as IEC 60601 and ISO 13485.
- **Smart Electronic and Internet of Things (IoT) Testing.** In conjunction with the Office of The National Broadcasting and Telecommunications Commission and other agencies, PTEC established IoT standards such as ISO/IEC 14443, ISO/IEC 18092, ISO/IEC 15693, and ETSI EN 300. An IoT testing laboratory was established with the focus on connectivity testing of devices under various IoT protocols such as WiFi, Bluetooth, LTE, 5G and GSM-R.
- **Railway System Testing.** PTEC operates an ISO/IEC 17025 accredited electromagnetic compatibility (EMC) testing laboratory according to an EN 50121 standard. The center also offers testing of lighting equipment against the following standards: LM-79, LM-80, EN 61547, IEEE 1789 and IEC 62493. An MOU with the State Railway of Thailand has been reached to establish a laboratory for professional testing and inspection of railway parts and components to support projects such as the Thai-Chinese High-speed Rail and the High-speed Rail Linking Three Airports.

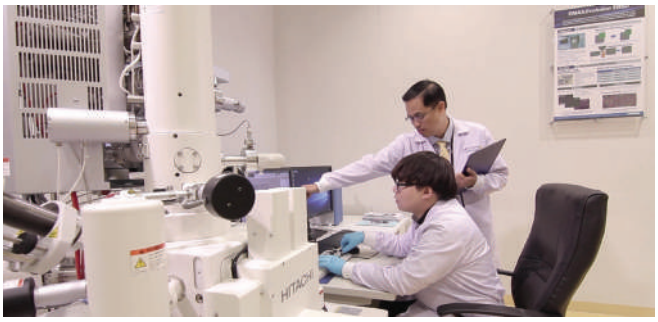
NSTDA Characterization and Testing Service Center (NCTC)

NCTC is an ISO/IEC 17025 accredited laboratory that offers a wide range of testing and analytical services covering a number of fields. It is a one-stop-service center equipped with state-of-the-art instruments and staffed with qualified technicians to provide exceptional services to its clients.

Imaging Mass Microscope

Texture Analyzer

X-ray Photoelectron Spectroscopy

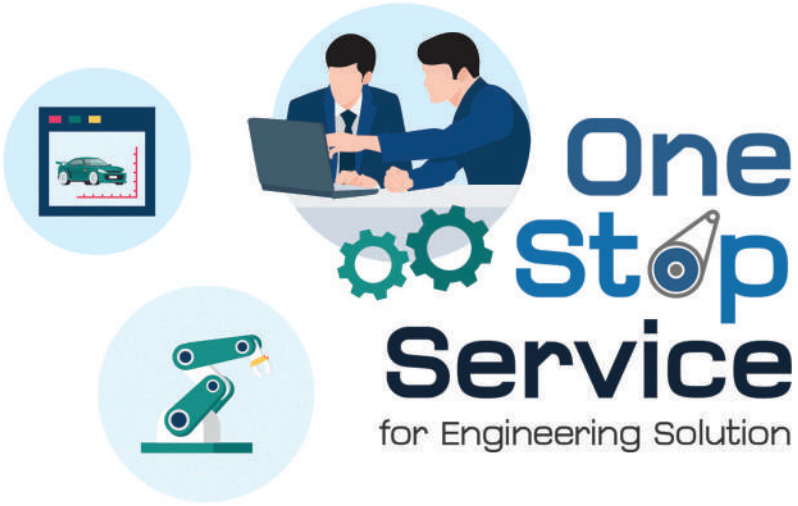


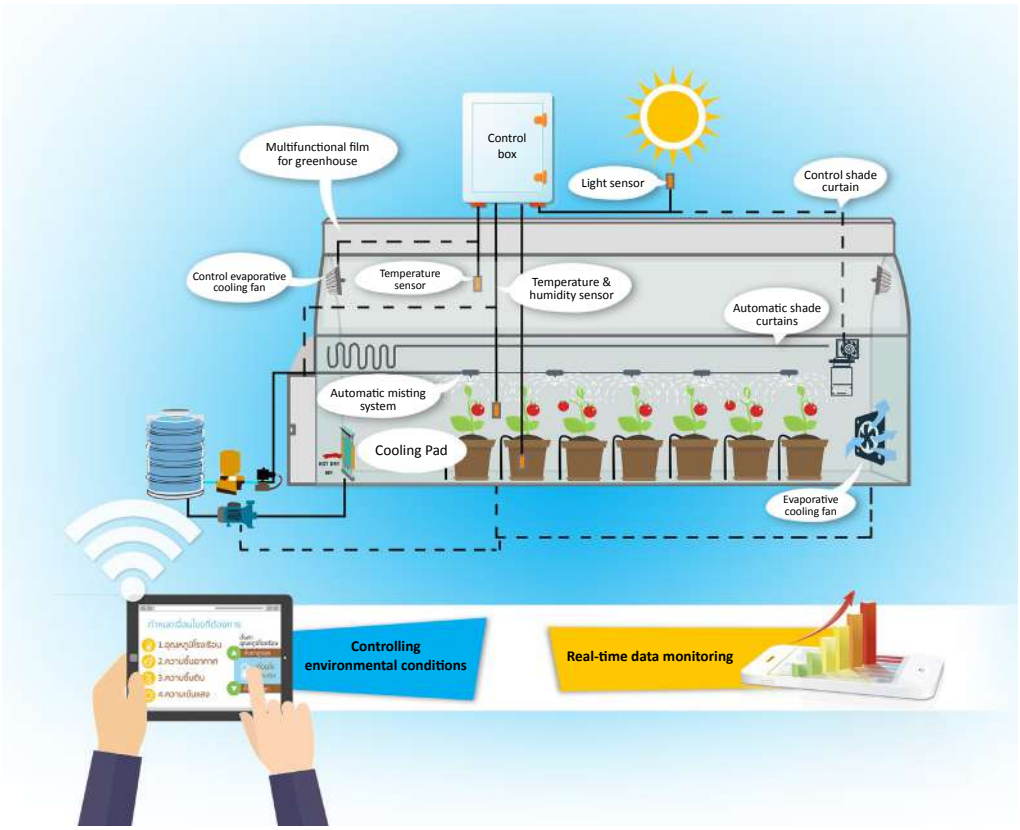
New services offered in 2019 include:

- **Molecular analysis with Imaging Mass Microscope (IMS).** IMS provides high-resolution morphological images and the distribution of the measured molecules, as well as their chemical analysis. This cutting-edge instrument offers high resolution and accurate images, with efficient data analysis for applications in industries such as food and pharmaceutical. Presently, NCTC is the only laboratory in ASEAN to offer services of this instrument.
- **Physical evaluation test with Texture Analyzer (EZ Test).** Texture Analyzer provides information on physical properties of an object under shear test, compression test, bending test, tensile test and resistance test. This test supports research projects and product quality improvement in a number of industries, including food, pharmaceutical, rubber and plastics.
- **Surface analysis with X-ray Photoelectron Spectroscopy (XPS).** XPS can identify the elements that exist on the surface of a material, as well as their properties. It is a highly sensitive surface analysis method that probes the top 3-10 nm of the surface. The analysis can be performed on various forms of material, including powder, solid, thin film and fiber. The information XPS provides has applications in a wide variety of industries, including electronic parts, ceramics, chemical, petroleum and petroleum-based polymer, metal and cement.
- **Thermogravimetric analysis with Thermogravimetric Analyzer (TGA).** TGA measures changes in mass or weight in response to increases in temperature or time. It also measures water content and amount of polymer additives (from plastic packaging) in products of various forms (powder, solid, thin film and essential oils).

Design & Engineering Consulting Service Center (DECC)

DECC provides consultancy services in problem analysis and solution development, prototype design, testing and simulation for a variety of industries.





In 2019, the center developed the prototypes to support research and industry as follows:

- **Smart Farming.** A prototype of smart greenhouse suitable for Thailand's conditions was developed. Six units were built at various sites; namely AGRITEC Station – a demonstration site at Thailand Science Park, Santisuk Organic Farm Community Enterprise in Nan province, Pong Raet Bio-Farming Center in Chanthaburi province, Jai Fa Farm in Lopburi province, King Mongkut's University of Technology Thonburi and All-Bio Company Limited.
- **Food Processing.** A prototype of semi-automatic grill machine was developed. The equipment was tested by food operators and met hygienic standards. Another project involved an improvement made on the exhaust system and the food cart design to enable a food cart business to be more eco-friendly.
- **Energy.** A prototype of smart meter was developed in collaboration with Nova Green Power System Company Limited. The smart meter employs internet of things (IoT) and artificial intelligence (AI) to enable energy efficiency. In addition, a prototype of battery management system for a power pack that can operate under a wide range of temperature was developed for the Provincial Electricity Authority to be used in remote areas where main electricity supply is not available.

Industrial Ceramic and Houseware Product Testing Center (CTEC)

CTEC is an ISO/IEC 17025 accredited testing laboratory providing integrated services in testing the quality, safety and performance of products such as tableware, ceramic tiles, sanitary ware and building materials against a wide range of national and international standards.

Examples of services performed in 2019 include:

- **Faucet and Shower Unit Testing.** CTEC was accredited by the Thai Industrial Standards Institute (TISI) to serve as a testing laboratory for faucets for sanitary wares and shower units for compliance with TIS 2066-2552 (2009) and TIS 2067-2552 (2009) standards for water-savings.
- **Food Contact Material Testing.** The testing is to ensure that products in contact with foods have the lowest quantities of metal release such as lead, cadmium, chromium, nickel, barium and other toxic metals in accordance with national and international standards and meet the requirements of imported countries. Over fifty additional tests such as water absorption, resistance to microwave usage, resistance to freezer to microwave usage, resistance to freezer to oven usage and dishwasher safe are also available.

RESEARCH, DEVELOPMENT AND INNOVATION MANAGEMENT

Research, Development and Innovation (RDI) Management supports and manages large-scale research projects, aiming to precisely address the national agenda. The main mission is to manage research projects, collaborative research projects with government agencies or the private sector, international cooperative research programs, research and innovation program for government demand and international research networks, as well as promote scientific quality and integrity to ensure that research conducted by NSTDA and its partners meets international quality standards with utmost professional, legal and ethical responsibilities.

Management of Research Collaboration with the Public and Private Sectors and International Partners

To strengthen the development of science, technology and innovation in partnership with local and international alliances, NSTDA carefully adopts the following steps to proceed the collaboration: examining the status of the subject, setting clear goal and research direction, coordinating the collaboration and working collaboratively to advance research results to real-world applications.

In 2019, NSTDA was in discussion to set up collaborative research with 8 potential public and private organizations and three initiatives were launched:

- **R&D Collaboration with the Metropolitan Waterworks Authority** to develop an automated system to detect and report on the presence of algae causing clogging and algal toxins in raw water sources.
- **R&D Collaboration with Electric Vehicles (Thailand) Public Company Limited** to modify existing diesel buses operated by the Bangkok Mass Transit Authority (BMTA) to electric buses.
- **R&D Collaboration with Sabai Motors (Thailand) Company Limited** to design and develop a high-performance electric motor and compare its performance with a modified electric motor in powering a used BMTA diesel bus.

RDI for Government Demand

To promote research, development and innovation in government agencies, NSTDA proposed "RDI for Government Demand" initiative. The initiative aims at encouraging all government bodies to engage and employ research and innovation in their roles and functions to serve the public by utilizing capability of Thai research institutes, universities and startups. The innovations resulting from this program can apply for listing on the Innovation List, enabling the products and services of such innovations to be eligible for government procurement program. RDI for Government Demand will drive innovation process by connecting demand and supply of technology and innovation, facilitate the development of applicable technology and innovation, support the transfer of technology to real-world applications, stimulate R&D investment and reduce importation of technology and innovation.

RDI for Government Demand was approved by the Cabinet on 8 January 2019 and published as Regulations of the Office of the Prime Minister in the Royal Gazette on 12 February 2019. NSTDA has been assigned to lead the implementation and set up a mechanism for the implementation. The following progress was made in 2019:

- Three Ministerial Notifications were issued: 1) definition and identification of other government organizations under the executive branch, 2) registration procedure for organizations eligible to carry out research and development, and 3) criteria and procedures for the appointment of project selection committee and project evaluation committee.
- An online system for the registration of organizations eligible to carry out research and development was established and an official website of RDI for Government Demand (https://www.nstda.or.th/gd/) was launched. 31 organizations have been registered on the system, and 67 government organizations have been informed of the program.
- Two projects were approved for the implementation, namely 1) Development of E-Referral Healthcare System commissioned by the National Health Security Office, and 2) Development of tuberculosis diagnosis commissioned by the Department of Disease Control.

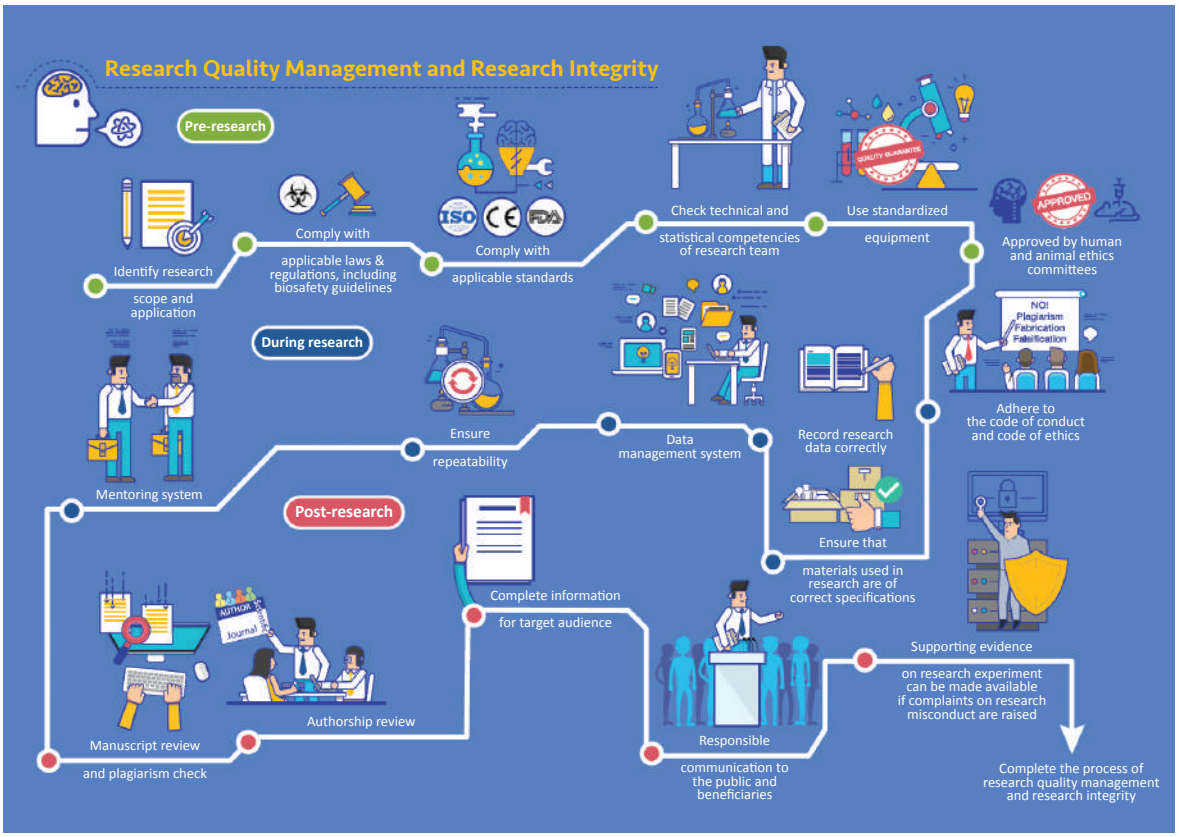
International Collaboration

NSTDA places significant importance on establishing linkages, alliances and collaborations with international bodies to create visibility and acceptance of Thai research and development on the world stage, to develop and share knowledge and manpower, and to facilitate technology transfer in order to prepare and build up long-term S&T capacity for Thailand. In 2019, collaborative research programs have been established with a number of countries and economies such as the United Kingdom, Germany, China, Japan, Taiwan, and ASEAN member countries, resulting in an outbound exchange of 68 research staff, an establishment of one joint laboratory and 23 MOUs and agreements. Examples are as follows:

- **Thailand-China Joint Laboratory on Microbial Biotechnology** is a collaborative lab among three major research institutes in Thailand and China, namely the Institute of Microbiology, Chinese Academy of Sciences (IMCAS), Thailand Institute of Scientific and Technological Research (TISTR) and BIOTEC- NSTDA. The joint laboratory aims to develop capacity in microbiology and microbial big data for microbial preservation and harnessing the power of microorganisms to underpin bio-based industry.
- **Research Collaboration on Cosmeceuticals** has been established with COSMAX, a South Korean cosmetics research and manufacturing company. The collaboration focuses on developing and utilizing nano-encapsulation technology to improve efficacy and create value addition to cosmeceutical products for global markets.
- **Collaborative Research Program on Food Safety, Biodiversity and Internet of Things (IoTs)** has been formed with The Scientific and Technological Research Council of Turkey (TÜBİTAK) to support research projects to be conducted jointly by Thai and Turkish scientists in the afore-mentioned areas.
- **Research Collaboration on Renewable Energy** was initiated with the ASEAN Center for Energy (ACE) to support research and community development in order to create a network of renewable energy and bioenergy research, as well as promote commercial use of bioenergy in the ASEAN region.

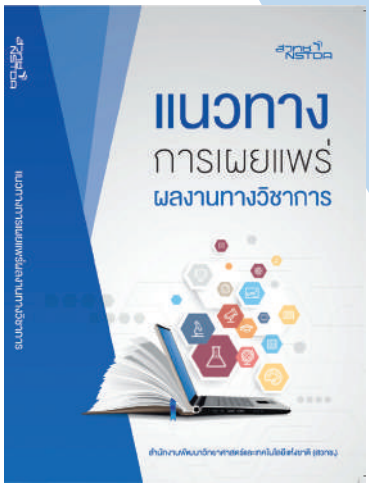
RDI Quality Management and Research Integrity

As a premiere research agency, NSTDA is committed to good research practices to ensure that research conducted by NSTDA and its partners meets international quality standards with utmost professional, legal and ethical responsibilities.



- **Research Quality Management.** NSTDA has developed and released a number of guidelines to facilitate quality assurance of research. Guidelines for data management help establish reliable and systematic research records and enable searchable database. Guidelines for research publications address the publication authorship according to individual contribution in the paper and help protect authors from potential allegations of research misconduct. Professional Authorship Center (PAC) was founded to assist researchers and scientific personnel to prepare the communications of technical information to international audiences, ranging from written scientific manuscripts for submission to international journals and project proposals for submission to international funding agencies, to oral presentations at international scientific conferences and interviews for international research grants.

- **Research Integrity.** NSTDA promotes research integrity through the following activities: 1) implementation of ethical principles in research by establishing a research ethics committee to review and investigate any suspected ethical misconduct in research and providing access to CopyCatch software for plagiarism detection; 2) implementation of ethical principles for the use of animals in scientific research by establishing a committee to supervise animal experimentation, setting up an office to provide advice on ethical issues in animal experiments and organizing seminars on this topic for researchers; 3) implementation of ethical principles in human research by establishing a committee to promote and support research involving human subjects and setting up an office to provide advice on ethical issues in human research; and 4) awareness creation by organizing seminars, workshops and trainings on topics such as the importance of ethics and how to avoid unintentional plagiarism.



COMPETITIVENESS ENHANCEMENT

NSTDA aims at enhancing the competitiveness of Thai businesses and industries through research and development program, upskilling program for industrial workforce, and knowledge and technology transfer program to supply innovative technologies and solutions to enterprises and industries. This goal is realized through a collaborative network formed with academia, government agencies and the private sector that enables NSTDA to provide integrated and one-stop services to its customers.

Platforms for Tech Companies

NSTDA encourages the development of technology and innovation businesses through the following mechanisms.

- **NSTDA Spinoff Mechanism** was launched in 2019 to promote research spinoffs. The mechanism supports NSTDA researchers to work with strategic partners from the private sector in creating new startups based on NSTDA research as well as an option of NSTDA joint investment to drive the businesses to success. Steps have been taken in preparing researchers as well as technologies and innovations to enter the spinoff process such as an implementation of Researcher Spinoff Acceleration Program designed for high potential researchers with matured technologies. The program provides researchers with knowledge on business planning, operational strategy as well as business pitching and presentation.
- **NSTDA Holding Company** was founded as a platform to promote and make investment or joint investment, directly or indirectly, in businesses commercializing knowledge, technology and innovation created by NSTDA, other government agencies, public and private universities or even overseas universities. It operates as a private company, enabling flexibility, agility and business-driven decision making. The company employs technology transfer and tech business investment as its main mechanisms to bring together all aspects of businesses including technology, trade and investment. At its initial stage, NSTDA Holding Company applies the following mechanisms to its operation: 1) investment in startups and spinoffs, 2) tech business incubation, 3) investment in private equity trust funds, 4) establishment of technical service companies, and 5) technology transfer and licensing.

Capacity Building of Tech Entrepreneurs

- **Innovation Driven Enterprise (IDE).** NSTDA strives to develop suitable mechanisms to transition startups and SMEs to IDEs. In 2019, three models were launched: 1) Food Innovation Model with participation of 53 enterprises, 2) Digitalization Model with participation of 19 enterprises, and 3) Internationalization Model with participation of 12 enterprises.
- **Thailand Technology Rating System (TTRS).** NSTDA initiated the development of TTRS which serves as a tool to evaluate a company in terms of technology, innovation and business prospect. The evaluation is performed by a team of experts with knowledge and experience in technology and innovation, finance, business and management. The rating results help the company to realize their strengths and weaknesses so that they can seek necessary support in business, technology and finance to make improvement and accelerate their journey to success. In 2019, TTRS was employed to analyze 42 enterprises and government agencies.
- **Career for the Future.** To prepare qualified workforce to meet the requirements of current and future industries, NSTDA designs and offers courses and programs for upskilling and reskilling manpower working in science and technology field. In 2019, new courses were offered to provide training for 26 professions such as automotive designer, smart system developer, agriculture system integrator and food product developer. A total of 225 training courses were offered and held 250 times with 6,542 participants in total.

Technology Development for Thai SMEs and Industries

Innovation Technology Assistance Program (ITAP) is a main mechanism to provide technological assistance to Thai SMEs by sending expert teams to work cooperatively with companies to conduct research and develop projects that will provide solutions to the problems faced by the companies. ITAP finances up to 50% of a project budget, at the maximum of 400,000 THB. In 2019, ITAP sponsored 1,791 new projects. ITAP projects generally involve working with a large pool of experts drawing from public and private domains, as well as domestic and international alliances. The work of ITAP has generated a 3.383 billion THB economic impact and attracted an additional R&D investment valued 948 million THB.

Upgrading Animal Farming Operation with Biogas System

From 2017-2019, ITAP provided experts to assist 40 animal farms to make the transition to sustainable agriculture. A number of solutions were designed and implemented, including a biogas production system suitable for small swine and poultry farms, a bio-scrubber system for removing hydrogen sulfide from raw biogas, and a biogas utilization system converting biogas to electricity. The project enables farmers to save 20,000 THB/month/farm on electricity cost on average. The biogas system also reduces environmental pollution caused by foul odor - if persists, will lead to the farm shutdown due to public complaints. This project generated a 1 million THB/farm investment on biogas system.

Improving Processing Efficiency of Rice Mills

Experts were dispatched by ITAP to make an improvement on rice milling process, which consisted of the following steps: removing dirt/gravel, dehusking, polishing, grading, drying, storing and transporting. The scope of work included making improvement on process and machinery, installing high performance machinery and training workers on operation and maintenance. A total of 219 rice mills participated in the project from 2011-2019. The project was successful in doubling the efficiency, from 60 tons/day to 120 tons/day, with a 10% increase of high-grade full grain rice. The improvement resulted in a 20% profit increase. From an economic impact study, 44 participating rice mills saw a combined profit increase of 1.135 billion THB based on this efficiency improvement.

Supporting Schemes to Create Innovation Ecosystem

- **Technology Financing Program** provides financial support in the form of low-interest loans to industrial operators who wish to employ research and development to develop new products, improve manufacturing processes, set up or make improvement on a laboratory, conduct reverse engineering and commercialize research breakthroughs. The loan can be up to 75% of total value of the project, at the maximum of 30 million THB for a duration of up to 7 years and up to 2-year grace period. Vet Products Research and Innovation Company Limited, a leading animal health company, received a loan for the purpose of setting up an analytical and product development laboratory. A pharmaceutical company Utopian Company Limited received a loan for establishing a testing lab and improving the production process of penicillin and cephalosporin to meet the requirements of Pharmaceutical Inspection Co-operation Scheme (PIC/S). Utopian currently employs an automated production system which helps reduce the production cost.

- **Innovation List** was initiated to drive innovation and promote local innovation-based businesses through government procurement. The list contains innovations (products and services) entitled to the fast-track treatment in the government procurement process. Thai companies are encouraged to register their innovative products and services resulting from research and development performed in Thailand. NSTDA has been tasked to assess the applications by evaluating the quality of those products and services; whereas the Budget Bureau checks on the pricing and officially publishes the innovations on the Innovation List. In 2019, 152 applications were received; 99 innovations passed NSTDA's evaluation and 103 new items were published on the Innovation List. Since the inception of the program, a total of 680 applications have been received with 368 innovations passing the evaluation and 329 items were published on the Innovation List. Procurements worth a total of 2.612 billion THB were made on items published on the Innovation List by government agencies between January 2016 - December 2018.

KEEEN OMR

KEEEN OMR is an example of innovation published on the Innovation List. KEEEN OMR is an onsite microbial reactor developed jointly by BIOTEC-NSTDA and KEEEN Limited for the production of microorganisms used in the wastewater treatment system. KEEEN OMR transforms a complicated microbial reactor operated by scientists in a laboratory into a smaller, automated machine controlled by microprocessor. KEEEN OMR has a production capacity of 1 billion cells/mL, delivering fresh microbes for effective degradation of organic matters.

Photo credit: https://keeen.co.th/

- **Certification of R&D Projects for 300% Tax Exemption.** Since 2002, NSTDA has served as a certifying body for research, development and innovation projects submitted for tax privileges by companies. In 2019, 456 projects, with a combined value of 2.011 billion THB, were submitted for certification by 91 companies, 23 of which were first timers. 383 projects, with a total value of 1.855 billion THB, were certified. Additionally, training courses were regularly organized to educate enterprises of this tax incentive.
- **Thailand Tech Show 2019.** NSTDA continued to implement "Thailand Tech Show" into the fifth year. Thailand Tech Show provides investors, business operators and SMEs with easy access to intellectual properties owned by public research and academic institutes by offering a license to an IP to interested SMEs at a flat-rate fee of 30,000 THB per IP and a royalty payment of 2% of net sales. Thailand Tech Show now contains technologies and innovations from over 40 academic and research institutes in Thailand. Thailand Tech Show 2019 was held on 5-6 September 2019 at Centara Grand & Bangkok Convention Centre at CentralWorld, showcasing 230 inventions to prospective entrepreneurs with engaging activities such as business pitching, seminar and consultation services. The event attracted over 2,000 participants. 224 licensing applications were received, and 59 licensing agreements were executed in 2019.
- **Startup Voucher** is a scheme designed to assist startups to build capacity in business operation, grow their business and expand their markets locally and internationally. This is achieved through the development of e-learning courses, the organization of national events and supporting the participation of Thai startups in international events in order to create visibility in international markets and initiate technological and business collaboration with international partners. The scheme provides a voucher of 800,000 THB per project. In 2019, 62 projects were funded, and participating startups earned a combined revenue of 100 million THB. These grant recipients have credited the scheme for enabling them to develop products and expand their domestic and international markets.

CAPACITY DEVELOPMENT FOR FARMERS AND COMMUNITIES

NSTDA aims to strengthen communities and farming sector through the transfer of knowledge and technologies and capacity building. To achieve this goal, the agency works collaboratively with networks of academia, government agencies, local authorities, enterprises, industries and communities.

Available Technologies

Production Technology
(crop varieties / seed production / farm management)

- Rice / cassava / rubber tree / mungbean / chili / tomato / mushroom / strawberry / coffee

Eco-friendly Technology for the Production of Natural Rubber

- Ultra-low ammonia concentrated natural rubber latex (BeTHEPs)

Biocontrol

- *Beauveria bassiana* for controlling aphids
- NPV for controlling armyworm
- *Streptomyces* for controlling fungi and bacteria infecting cucurbits

Animal and Aquaculture Production Technology
(rearing / feed)

- Fairy shrimp / Siamese plankton as aquaculture feed
- Closed-system shrimp cultivation
- Production of stingless bee queens / Quality improvement of honey
- Forage cane
- Silage
- Diagnostic kits for animal diseases
- Microorganisms for controlling foul odor in animal farms

Technology for Soil and Water

- Compost from agricultural wastes
- No-turn composting
- Vermicomposting
- Irrigation systems

Processing Technology

- Processing of agricultural produce
- Good Hygiene Practice (GHP) for food processing

Equipment and Machinery

- Rice milling machine for community usage
- Photoselective plastic film greenhouse

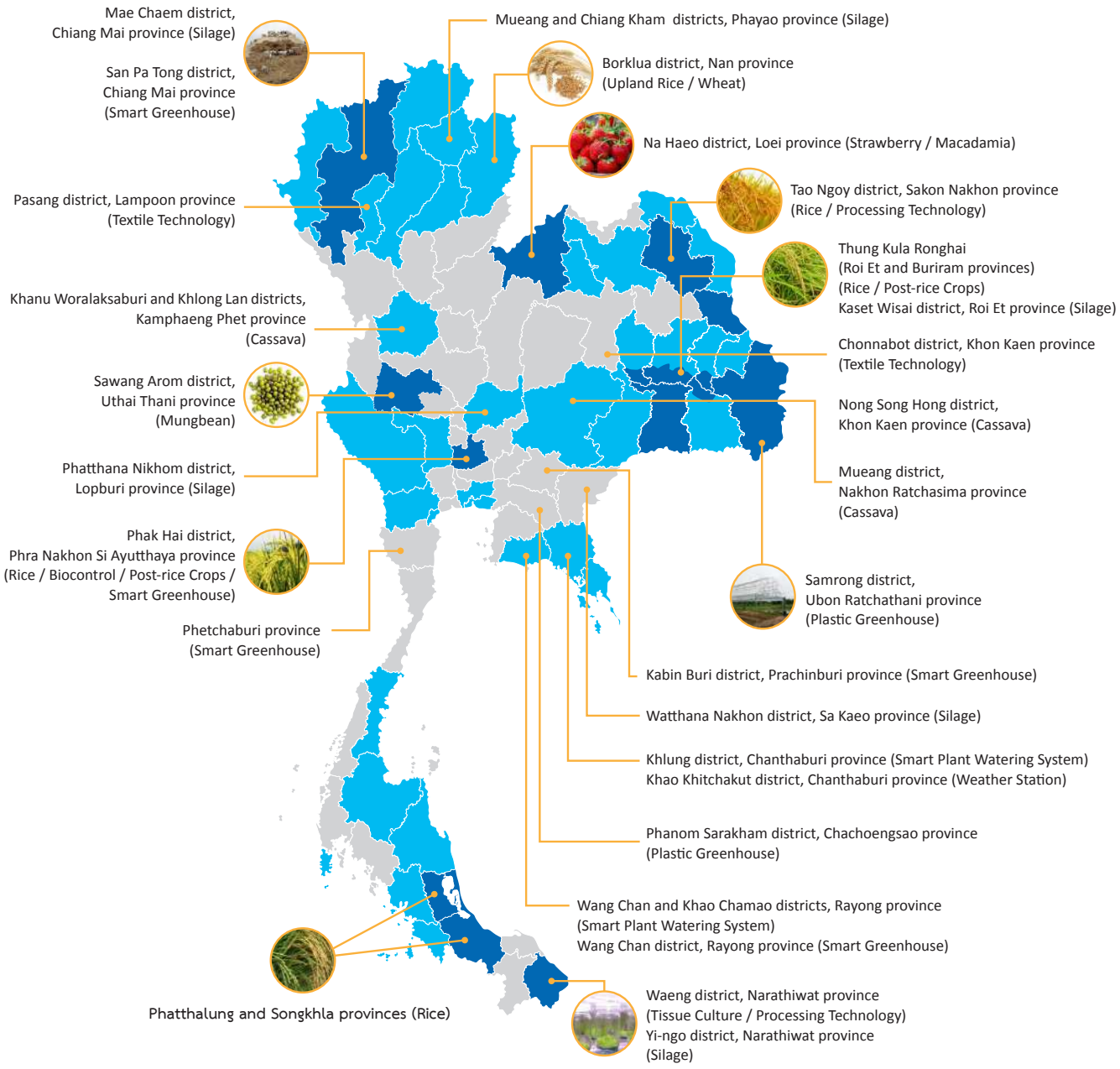
Smart Farming Technology

- Smart greenhouse
- Weather station
- Smart plant watering system
- TPMAP: Thai People Map and Analytics Platform
- Agri Map: Online Tool for Agricultural Management

Textile Technology

- ENZease, smart enzyme for desizing and scouring of cotton fabric
- Preparation of natural dyes from local materials
- Nanotechnology to impart special properties to the fabric

Examples of Technology Transfer in 2019



500 communities in 53 provinces (as of September 2019)

Kanchanaburi, Kalasin, Khon Kaen, Chanthaburi, Chachoengsao, Chonburi, Chai Nat, Chumphon, Chiang Rai, Chiang Mai, Trat, Tak, Nakhon Phanom, Nakhon Ratchasima, Nakhon Si Thammarat, Nakhon Sawan, Narathiwat, Nan, Buriram, Pathum Thani, Prachinburi, Pattani, Phra Nakhon Si Ayutthaya, Phayao, Phatthalung, Phetchaburi, Phetchabun, Phrae, Phuket, Maha Sarakham, Mukdahan, Mae Hong Son, Yasothon, Roi Et, Rayong, Lopburi, Lampang, Lamphun, Loei, Sisaket, Songkhla, Satun, Sa Kaeo, Saraburi, Sing Buri, Sukhothai, Suphan Buri, Surin, Nong Khai, Nong Bua Lam Phu, Udon Thani, Uthai Thani, Ubon Ratchathani

Promotion of Smart Farming

A number of technologies have been transferred to support the transition to smart farm communities:

- **Photoselective plastic film greenhouse.** The technology was introduced to a fruit and vegetable community enterprise in Phanom Sarakham district, Chachoengsao province. The greenhouse shortens the growing cycle and gives healthier crops. Multiplier onion takes 28-30 days, instead of 38-40 days, whereas Tokyo Bekana cabbage matures in 25 days, instead of 30 days, weighing around 250-300 grams/head. After the installation of plastic film greenhouses, the enterprise earns 12,000 – 16,000 THB income/production cycle/greenhouse on average.
- **Weather Station.** The technology was introduced to mangosteen growers in Khao Khitchakut district, Chanthaburi province. A weather station provides information on wind speed, soil moisture and light intensity, enabling growers to make decision on irrigation schedule to regulate flowering. The technology has resulted in a production increase from 25 tons/year to 30 tons/year, corresponding to a 200,000 THB income increase for a 30 rai (4.8 ha) orchard.
- **Smart Plant Watering Control and Weather Monitoring System.** Smart Plant Watering Control and Weather Monitoring System enables the owner of Bua Kaew Durian Orchard in Wang Chan district, Rayong province to provide water input to meet the requirement of each growth stage. Environmental information provided by the system also facilitates the management of fertilizer inputs. With this technology, the earning increases by 156,000 THB/rai (975,000 THB/ha) due to better quality fruits, higher productivity and less production loss caused by fallen fruits.

Training of Smart Farmers

To create adoption of smart farming technologies among farmers and growers, NSTDA strategically engages young farmers and community leaders in a capacity building program in which they are provided with knowledge and demonstration of useful technologies and subsequently help raise awareness of smart farming technologies in their communities. In 2019, the program has trained 130 new smart farmers.

> **Working with NSTDA has led us to new opportunities beyond cultivating strawberries. We would like to be a leader of modern solutions and demonstrate them to other growers so that they can employ technologies to reduce production costs.**

Phu Bhum | **Khao Kho district, Phetchabun province**

Smart greenhouse for the production of temperate climate crops

"In the old days, we used common sense and experience in applying water and fertilizer. We never took measurements of water input nor observed whether the water input met the crops' demand. After sensors were installed, we took the readings and matched the measurements to our experience to establish guidelines for farm management. Now, we hardly experience production losses and the fruits grown in the greenhouse taste better than those grown outside under uncontrolled conditions."

"Raipueankun" by Mr. Surathep Surasajja
Prakhon Chai district, Buriram province

WiMaRC: Wireless sensor network for Management and Remote Control

This young smart farmer in Buriram province uses WiMaRC in his greenhouse for the production of melon, pumpkin, watermelon, Chinese kale, bok choy, yardlong bean and cucumber. Measurements of soil moisture, humidity, temperature and light intensity provided by sensors help the grower to effectively manage his farm activities such as water input, resulting in production cost saving and increased productivity. Proportion of Grade AA products has increased from 40-50% to 70%.

Development of Agriculture System Integrators (ASI)

As a way to promote smart farming businesses and create suppliers to fulfil the market, NSTDA designed a training course to equip entrepreneurs and business operators with necessary skills and knowledge to successfully run a business providing smart farm solutions. Agriculture System Integrator (ASI) Training Course covers information and hands-on practice on smart farming technologies, marketing strategy, business planning and applicable laws and regulations. In 2019, a total of 48 people attended this training course.

Seed Production Technology for Preservation and Utilization

NSTDA, in collaboration with the Department of Agriculture Extension, the Cooperative Promotion Department and Kasetsart University, implemented a project to transfer seed production technology of new mungbean cultivars to seed farmer groups – accounting for 1,800 rai (288 ha.) of land in total - in Uthai Thani, Suphan Buri and Sisaket provinces. These farmers earn an extra income of 2,500 THB/rai (15,625 THB/ha.) from selling high quality mungbean seeds.

Establishment of Training and Learning Stations

NSTDA established 28 training and learning stations to demonstrate agricultural technologies to promote technology adoption. AGRITEC Station was set up at Thailand Science Park, showcasing technologies and solutions such as sensor systems, smart plant watering system, weather station and biocontrol agents. Wang Chan Learning Station was established in Wang Chan district, Rayong province, in collaboration with PTT Public Company Limited and Chitralada Technology Institute. 23 learning stations were founded in several provinces, such as Phetchabun and Buriram, to promote technologies at the community level.

AGRITEC Station

- Sensors
- Smart Plant Watering Control and Weather Monitoring System
- Farm WiMaRC (Wireless sensor network for Management and Remote Control)
- WATER FiT: Smart Plant Watering Control System
- Weather Station
- Biocontrol
- Biological Control of Weeds

Wang Chan Learning Station

Community Learning Station

Phetchabun Province

Buriram Province

Ayutthaya Province

DEVELOPMENT AND MANAGEMENT OF INNOVATION HUBS

Innovation hub is an essential infrastructure with supporting mechanisms to promote innovation in the private sector. Innovation hubs under NSTDA's management include Thailand Science Park, Software Park Thailand, the Eastern Economic Corridor of Innovation (EECi) and Food Innopolis. Each hub serves as a conduit connecting academic and research institutes to entrepreneurs and industry in order to expedite the innovation process and attract local and international investment.

NSTDA develops S&T infrastructure and provides rental space for private companies interested in conducting research and development, leading to the creation of novel technologies and innovations for societal and industrial applications, as well as the commercialization of technologies. Currently, rental space is available at Thailand Science Park and Software Park Thailand. Thailand Science Park is the first park dedicated to science and technology in Thailand. Apart from being a base for national research centers, it provides lab and office spaces for lease with fully-integrated services to support technology businesses and companies looking to expand their R&D activities.

In 2019, Thailand Science Park was home to 96 leading local and multi-national companies, occupying 78% of its total rental space. Software Park Thailand hosted 53 companies, taking up 93% of its total rental space. Various types of lease space are available to meet client needs, ranging from office space to laboratories and pilot plant facilities. Some examples of successful tenants are illustrated in this report.

Smart Tec Center Company Limited. Smart Tec Center is an R&D company of Smart Vet Group, specializing in products - e.g. feed, feed supplements and pharmaceutical supplies - for livestock, pets, and aquatic animals. Smart Vet became the tenant of Thailand Science Park in September 2014, aiming to link with NSTDA's research centers and universities to develop innovations in the areas of food, agriculture and livestock, as well as establish a laboratory providing chemical and pathogen testing services to livestock, agriculture and environmental sectors. Smart Tec Center Company Limited was subsequently established functioning as an R&D and testing center in May 2017.

Smart Tec Center is located in Innovation Cluster 2 building (INC2). As a tenant of Thailand Science Park, the company received ample opportunities to connect with NSTDA's units and enjoyed the supporting mechanisms offered by the park. With NSTDA's support, Smart Tec Center participated in several invention events such as the International Trade Fair 'Ideas, Inventions and New Products' (iENA 2018) in Nuremberg, Germany where it won two bronze awards for TECKit CDV – a sensitive antigen rapid test for canine distemper virus detection and TECKit CPV/CCV – a rapid test for the simultaneous detection of canine parvovirus and canine coronavirus for diagnosis of canine viral enteritis. The company was also awarded a silver medal for GlyiTEC – a preparation process of copper zinc iron and manganese amino acid chelates – at the Seoul International Invention Fair 2018 (SIIF 2018) in Korea.

Lion Corporation (Thailand) Limited. Lion Corporation (Thailand) is a joint venture between Sahapattanapiboon Company Limited and The Lion Fat and Oil Company Limited of Japan. The company manufactures consumer products with five major product lines, including powder detergent, fabric care, home care, beauty care, oral care and baby care. Lion (Thailand) established an R&D center at Thailand Science Park in 2016. Currently located in Innovation Cluster 2 building (INC2), the company has developed a number of products in collaboration with NANOTEC-NSTDA and the Herb and Thai Traditional Medicine Division. Lion (Thailand) participated in the Seoul International Invention Fair 2018 (SIIF 2018) with the support of NSTDA and won two awards – a gold medal for "Development of high concentrated active agent from Triphala with green extraction process for oral care products" and a silver medal for "Nano-encapsulation agent without volatile organic compounds by eco-friendly process for application in cosmetic products".

In addition to rental space and supporting mechanisms, NSTDA focuses on developing linkages and networks with other science parks located in Thailand and overseas. The agency hosted ASEAN Science Park Management Conference 2019 during 29-30 August 2019 at Thailand Science Park Convention Center. The conference served as a learning and networking platform for managers of science parks and innovation hubs in Thailand and ASEAN and strengthen collaboration among ASEAN member countries. The conference attracted over 100 participants, including executives and representatives of science and technology parks in all ten ASEAN member countries and CEOs of public and private organizations. At the conference, an agreement between NSTDA and the World Business Angels Investment Forum (WBAF) was signed to develop and strengthen financial instruments to help advance research to commercialization. A WBAF Thailand Country Office was launched, marking the first WBAF country office in ASEAN region. This office will serve as a critical financial mechanism to accelerate research and innovations in ASEAN to reach local and international markets.

Eastern Economic Corridor of Innovation (EECi)

NSTDA was designated to spearhead the establishment of Eastern Economic Corridor of Innovation (EECi) in collaboration with domestic and international partners. EECi will serve as a key infrastructure to drive research, development and innovation to support new growth engines according to Thailand 4.0 initiative. It aims to underpin sustainable bioeconomy with the focus on 6 major industries, namely 1) modern agriculture and biotechnology, 2) biofuels & biochemicals, 3) high performance battery and modern transports, 4) automation, robotics and smart electronics, 5) aviation and aerospace, and 6) medical devices.

EECi is located in a vast 3,455 rai (approximately 550 hectares) area in Wangchan Valley, Rayong province. Within the next 3-5 years, this space will be developed into an innovation hub complete with an innovation ecosystem, comprising universities, research centers, pilot plants, demonstration plants and testing labs, along with supporting mechanisms to foster enterprises. Residential area in EECi will be completed with hospital, hotel and community market. Testbed and innovation sandbox will also be established for testing new technologies. Progress made in 2019 includes:

1. **Construction.** A groundbreaking ceremony presided over by Prime Minister General Prayut Chan-O-Cha was held on 27 February 2019 to kick off the construction of EECi Phase 1A. As of 30 September 2019, the construction is 13.53% complete. The progress is slightly below the milestone of 15% due to construction suspensions caused by some heavy rains.

2. **BIOPOLIS – Innovation Platform for Bioindustry.** A blueprint of greenhouse has been developed and a project to test and demonstrate the plant phenomics system has been launched. The plant phenomics facility will be ready for operation in 2020.
3. **ARIPOLIS - Innovation Platform for Automation, Robotics, and Smart Electronics Industry.** A platform to link environmental data to greenhouse control system has been constructed to showcase a smart agriculture concept. A pilot project employing artificial intelligence (AI) to manage a large-scale sugarcane plantation has been launched in collaboration with Mitr Phol Sugar Corporation. Physical Analytics Integrated Data Repository and Services (PAIRS) platform is used in this project. Data collected from this pilot project will be useful when the project is expanded to the farming areas in and around EEC and EECi zones, covering Chonburi, Rayong and Chachoengsao provinces.
4. **Science, Technology and Innovation for Community Development.** Agri-related technologies were introduced to 57 communities in 6 provinces –Rayong, Chanthaburi, Sa Kaeo, Prachinburi, Trat and Chachoengsao. A total of 18 technologies were transferred to the communities, including crop production and farming, food processing, sensors and electronics, rubber post-harvest and processing, and textile-related technology. Training of community leaders and young smart farmers was also provided to 82 participants.
5. **Science, Technology and Innovation for Enterprise Development.** NSTDA assisted 119 SMEs and startups in EEC area on the technology development and capacity building through activities such as consultancy services, training workshops and seminars. In addition, NSTDA in collaboration with the Federation of Thai Industries has conducted a survey to understand demands of the private sector in the EEC.

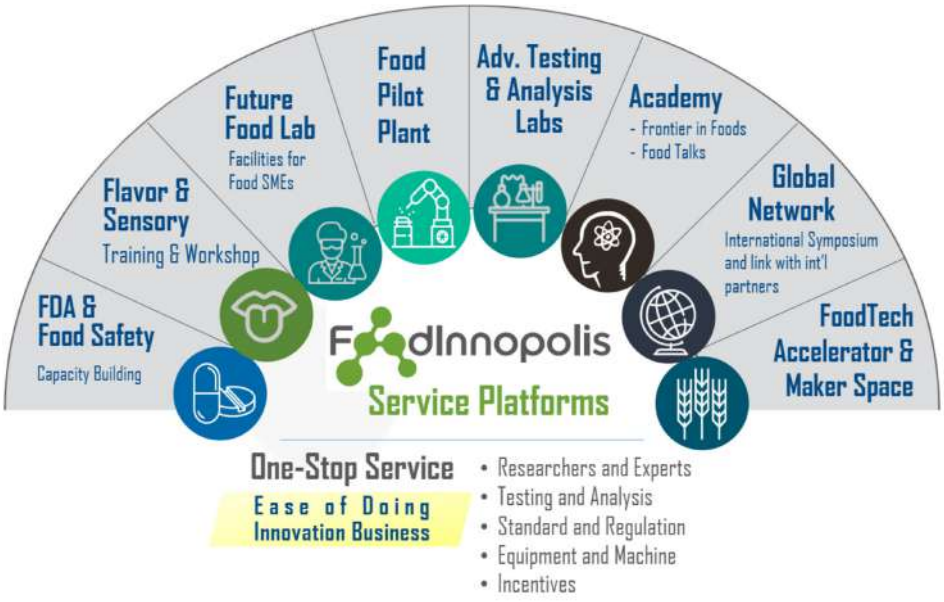
A number of enterprises from various sectors have expressed strong interest to move into EECi. They represent a wide range of industries, ranging from bio-based, to modern agriculture, robotics, energy storage and UAV manufacturing. Attractive privileges provided to industry include long-term land lease to establish research centers, rental lab space in the public research facilities, access to premium infrastructures such as scientific equipment, testing facilities, pilot plants, co-working space, experimental area & testbed, 13-year exemption of corporate income tax, a 17% flat-rate personal income tax for high-level experts, work permit for foreign experts, access to regulatory sandbox and access to scientists and experts in public research organizations.

Food Innopolis

In 2019, NSTDA was assigned to manage and implement Food Innopolis, a research, development and innovation hub for food industry. Food Innopolis was initiated in order to upgrade Thailand's food and food-related industries to a world-class level by offering fully-integrated services in research, development and innovation. It is committed to create an innovation ecosystem with comprehensive food innovation platform to strengthen business and also innovate food industry. Examples of its key achievements include:

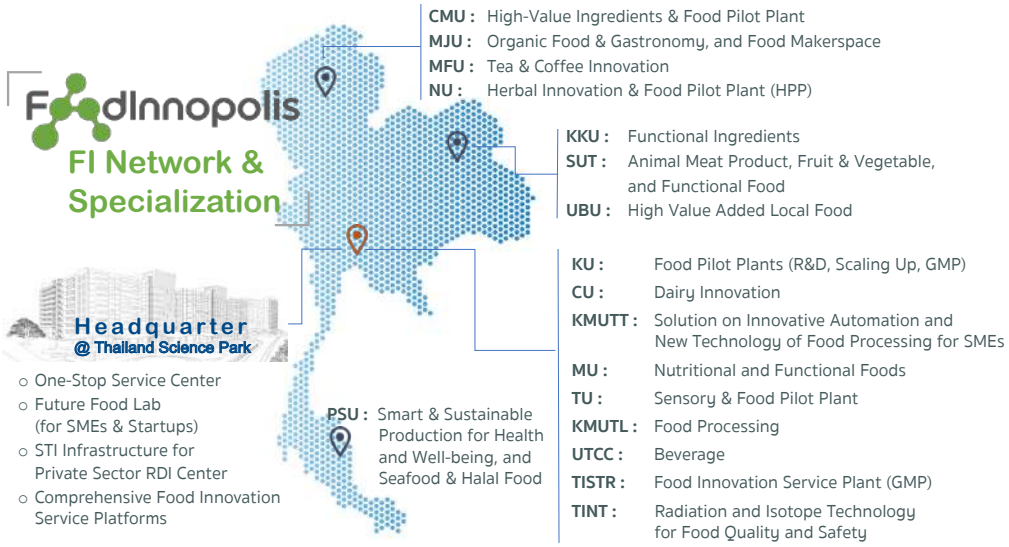
FoodInnopolis
Thailand Most Influential
Food Innovation Platform

1. **One-stop Service.** Food Innopolis established a one-stop service program to facilitate research, development and innovation in the food industry by linking enterprises to research and academic institutes. Presently, the services are offered under 8 service platforms as illustrated below. In 2019, this mechanism has served 120 clients.
2. **Service Platform.** Varieties of activities were organized to support capacity building of industry. For instance, PADTHAI, Program to Accelerate and Develop Thai Food SMEs, is a comprehensive 5-day acceleration program designed to support the growth and development of SMEs and entrepreneurs in food industry and provide access to strategic partners to advance their businesses.



3. **Tenants.** Currently, there are 31 companies located in Food Innopolis which is situated on the campus of Thailand Science Park and 14 companies in FI Network. 17 new SMEs utilized the service of Future Food Lab at Thailand Science Park.

4. **FI Network.** To reach out to industry located across the country, Food Innopolis cultivates collaborative relationships with central and local universities and government agencies to form FI Network to help food industry address the challenges and reach its full potential. Presently, FI Network comprises 17 nodes. In 2019, each node has developed a strategic roadmap. A list of pilot-scale food processing plants and food testing labs has been compiled. A one-stop service center has been established and a renovation of pilot plant and food innovation center has been completed at Kasetsart University.



FI Network

STI HUMAN RESOURCE DEVELOPMENT

Recognizing the importance of competent and skilled manpower in driving forward science and technology in Thailand, NSTDA implements a range of human resource development programs to serve various purposes, ranging from inspiring young children to pursue S&T education, to developing S&T workforce for new industry and upgrading skills of S&T workforce. Several strategies and mechanisms are devised to effectively carry out this mission such as providing scholarships and fellowships in the target industry, building partnership with academic institutes to develop new graduate programs in response to industry's need, employing new technologies to encourage creativity and learning ability, as well as using Sirindhorn Science Home as the learning center for developing human resources in science and creating science awareness.

STI Manpower Development

Building critical mass of S&T students and professionals. NSTDA provided a total of 521 scholarships to high-school, undergraduate and graduate students, through various programs namely, Junior Science Talent Project (JSTP), Young Scientist and Technologist Program (YSTP), Thailand Graduate Institute of Science and Technology (TGIST), TAIST-Tokyo Tech and Food Engineering Practice School (FEPs).

Since the inception, these scholarship programs have resulted in a total of 2,108 graduates. Of this number, 1,058 graduates (50%) have been working in science and technology fields and 734 graduates (35%) have pursued further studies.

In addition, laboratories of NSTDA research centers also welcome university students and research staff from domestic and overseas collaborators to work on NSTDA active research projects. In the past year, 437 students/research staff have joined NSTDA workforce in various capacities, namely 36 collaborative research students, 56 co-investigators and 345 research assistants.

Inspiring children to pursue S&T education. NSTDA promotes science learning and stimulates interest in science and technology among young minds through events and science camps. In 2019, 68 events and science camps were organized with participation of 5,800 children. NSTDA enrichment program offers students from high school level upward opportunities to work with NSTDA scientists on current research projects or participate in other international S&T talent development programs.

Inspiring Children to Pursue S&T Career Path

An activity under Thailand Children's University Project was organized for students to learn about agricultural innovation with the support of "Chevron Enjoy Science" project. A total of 120 high school students participated in the activity which was held on 15 August 2019 at Sirindhorn Science Home located at Thailand Science Park. The activity introduced students to science behind plant factory, a new research facility at NSTDA. Students learned about light, the effect of light spectrum on plant growth and how to conduct scientific experiment on plant growth from researchers and participated in fun activities such as building a plant factory, making a simple LED circuit for plant factory and growing microgreen.

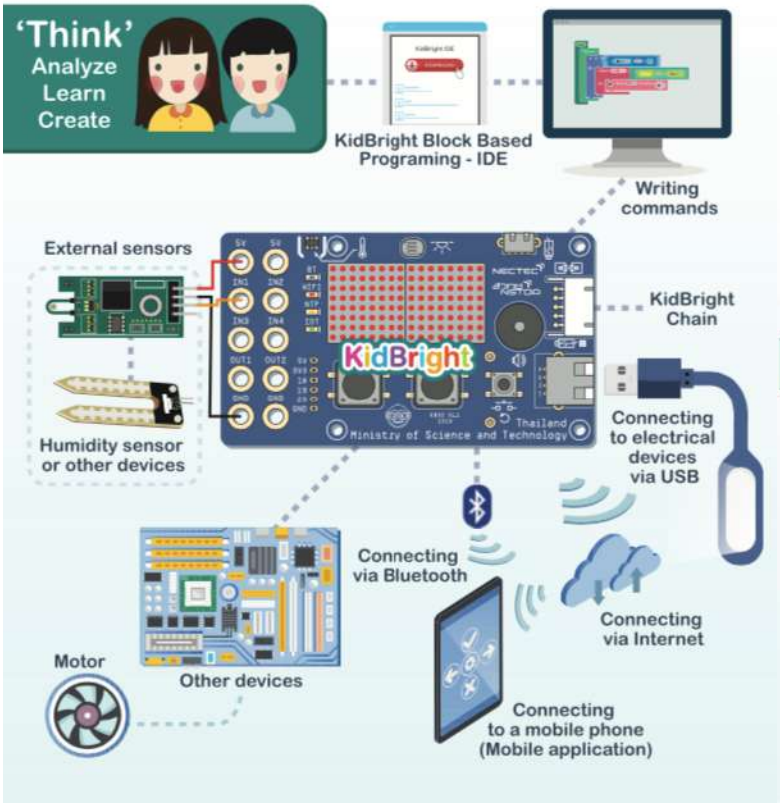
Under NSTDA enrichment program, 87 high school students were invited to work with NSTDA research teams at laboratories in Thailand Science Park from March to May 2019. The program helps students to develop laboratory research skills, introduces students to careers in research and fosters gifted learners.

Coding at School with KidBright

Coding at School is a project designed for Thai children to learn about computer programming. Under this project, KidBright, an embedded board, was developed as a tool for kids to easily learn about coding. With KidBright, children can develop logical thinking process and creativity, thus supporting the growth of the maker culture in Thailand. The project also helps improve STEM education teaching and communication skills among educators and teachers.

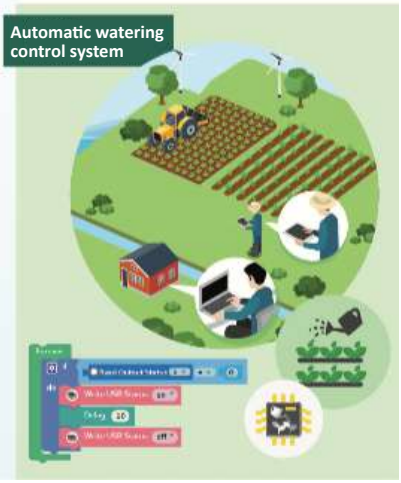
Developed by NECTEC-NSTDA, KidBright consists of two parts: the embedded board and the coding commands in the KidBright Integrated Development Environment program, or KidBright IDE. It is easy to use by dragging and dropping command blocks. The command is then sent to the embedded board to work as it is programmed such as watering plants according to specified humidity level or switching the light on or off at specified time.

A total of 200,000 boards were manufactured and distributed to approximately 2,000 schools nationwide, and over 4,000 teachers and educators participated in “train-the-trainer” sessions. KidBright contest was held with participation of over 3,000 students responsible for more than 1,000 submissions. A website, www.kid-bright.org, was created to offer teachers and students access to tools and tips to learn and enjoy coding with KidBright. This innovation has enabled children to improve their coding skill and apply coding to real-life application. It helps transform Thailand into a Makers Nation, a driver of Thailand 4.0 policy. Economic impact of this project was estimated to be 1 billion THB.



KidBright is an embedded board or a tiny computer that has a LED display and sensors. It is able to connect to other devices via WiFi, or Bluetooth. It can work with offline and online modes, i.e., Internet of Things (IoTs).

You can create a watering machine, an automatic lamp, a waste segregation machine, a thief detector at home and even more novel schematics. The possibilities are endless.



Creating Future Innovators with Fabrication Lab

Fabrication Lab (FabLab) is a project to set up laboratories, fully equipped with engineering and measuring tools and instruments, in schools and learning centers nationwide, and develop activities for students and teachers to acquire creativity and skills in design, research and engineering through the creation of innovations in these labs. The project aims to inspire students to become engineers and innovators – essential professions for an innovation-driven economy. A total of 150 schools in 67 provinces were selected to take part in this project.

The tasks of lab setup, equipment procurement and hiring qualified engineers for 150 fabrication laboratories have been completed. Over 50 training workshops and activities were organized with participation of 21,394 students and 2,319 teachers/educators. FabLab Thailand Student Design and Engineering Project Competition garnered plenty of attention and received over 240 submissions from students. With FabLab, students are able to unleash their creativity to build innovations, as well as gain knowledge and feel empowered through the process.

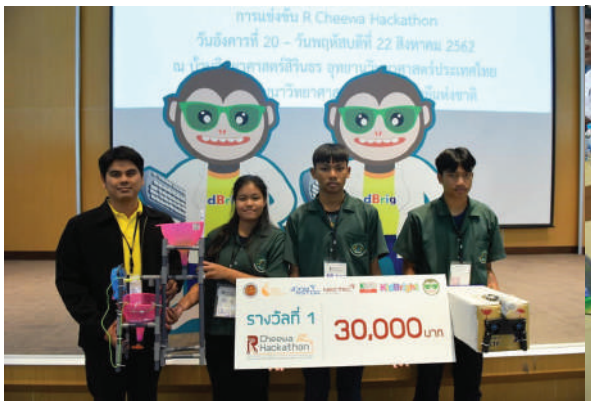
Supporting Young Talents to Enter IDC RoBoCon 2019

MTEC-NSTDA, in collaboration with the Faculty of Engineering, Chulalongkorn University, led winners of RDC2019, the national robot design contest, to compete in an international design contest, IDC RoBoCon 2019, hosted by Massachusetts Institute of Technology (MIT) in the United States on 29 July – 9 August 2019. Held under the theme "Moonshot – We choose to go to the Moon", the IDC RoBoCon 2019 attracted participation of 60 students from 10 countries, including the US, Brazil, Japan, China, Korea, Singapore, India, Egypt, Mexico, and Thailand. Twelve teams, each consisting of 5 members from different countries, were formed on site. Teams were asked to design and build robots over a two-week period. Two Thai students were part of the winning teams. Mr. Huthaned Virulsri from King Mongkut's University of Technology North Bangkok was a member of the first-place winning team. Mr. Damronglit Thaeptham from Udon Thani Rajabhat University was in the second-place winning team.

MTEC-NSTDA and partners have been organizing the national robot design contest and supporting winners to compete in the design contests at the regional and international levels, as part of its commitment to build a deep pool of workforce in automation and robotics to underpin the transition to Thailand 4.0.

Developing Programming and IoT Skills through R Cheewa Hackathon 2019

R Cheewa Hackathon 2019 is a contest designed to build capability and skills of technical-college students in science, technology, engineering and math (STEM). The competition was opened to technical-college students studying in the Eastern Economic Corridor (EEC) area to design an automated system with their coding and IoT skills as well as a KidBright embedded board. Held under the theme “Smart Farm, Smart Home, Smart Factory”, the competition took place from 20-22 August 2019 at Sirindhron Science Home located in Thailand Science Park. Twenty teams - made up of 80 students and advisors from 16 technical colleges situated in four provinces in eastern Thailand, including Chachoengsao, Chonburi, Rayong and Lopburi - entered the 38-hr-long intense competition. LBCAT KidBright Team from Lopburi College of Agriculture and Technology was crowned the winner with their “smart swine farm” innovation. Organized by NSTDA in collaboration with the Office of Vocational Education Commission and other partners, R Cheewa Hackathon aims at developing future makers and innovators that will help develop innovative solutions to enhance the competitiveness of Thailand’s manufacturing and service industry.



Promoting Technology Utilization in Southern Thailand

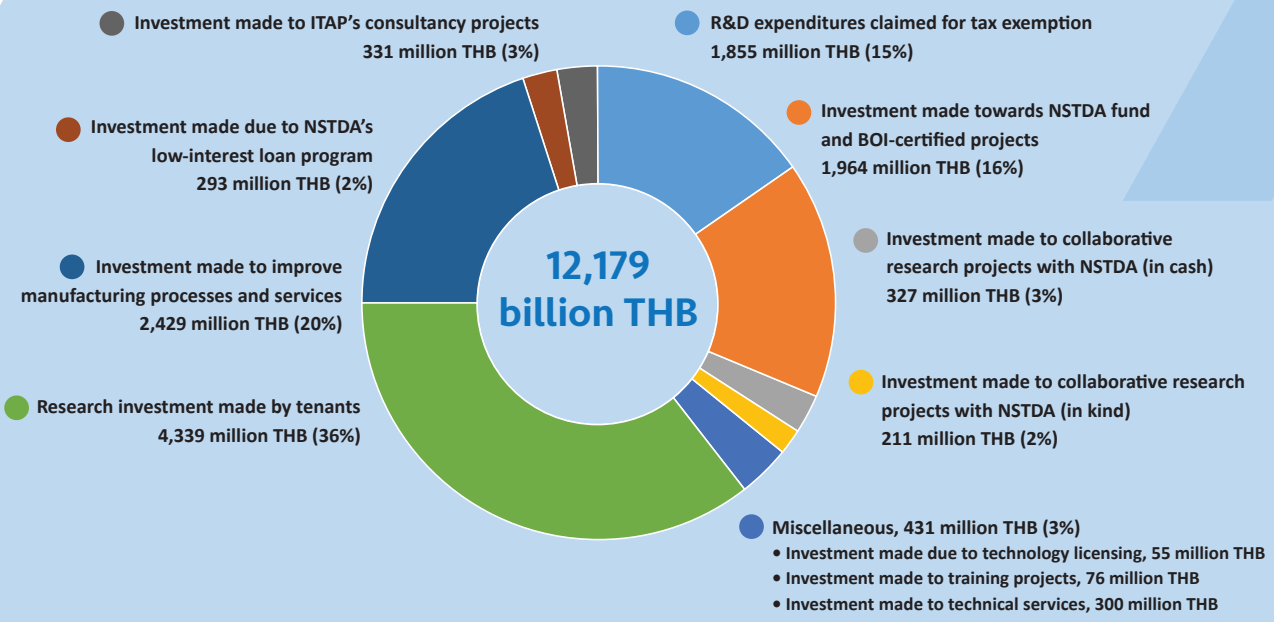
To promote the exploitation of research and innovation to improve competitiveness of farming sector, businesses, industries and communities located in southern Thailand, NSTDA organized a conference and exhibition on 21 February 2019 in Hat Yai district, Songkhla province. The event was attended by 500 participants from all sectors involving in the innovation process, including academia (faculty members, researchers and students), SMEs, local government agencies, farming sector (growers and business operators), local chamber of commerce and local office of the Federation of Thai Industries. The exhibition showcased technologies and innovations that can be applied to businesses and community development, as well as projects that NSTDA can partner with academic institutes in the south to facilitate manpower development and provide scientific and technical assistance to enterprises and industries in this region.

NSTDA Annual Conference 2019 (NAC2019)

NSTDA Annual Conference 2019 (NAC2019) was organized from 25-28 March 2019 at Thailand Science Park, Pathumthani, under the theme "Moving Towards Thailand's Future Economy with Science, Technology and Innovation". The opening ceremony which took place on 25 March was presided over by HRH Princess Maha Chakri Sirindhorn. NAC2019 showcased achievements of basic and applied research performed by NSTDA and partner organizations. The program consisted of 49 tracks of scientific conferences, seminars and workshops. On display in the exhibition zone were over 100 inventions developed by NSTDA and its alliances from public, private and academic domains, as well as by tenants of Thailand Science Park. An open house activity introduced visitors from the private sector to laboratories of NSTDA and tenants of Thailand Science Park that offer research and testing services. NAC2019 attracted a good number of visitors — 5,020 participants to the scientific seminars/ workshops, 4,065 visitors to the exhibition and 367 attendees to the open house activity - an increase from the previous year.

SOCIO-ECONOMIC IMPACT

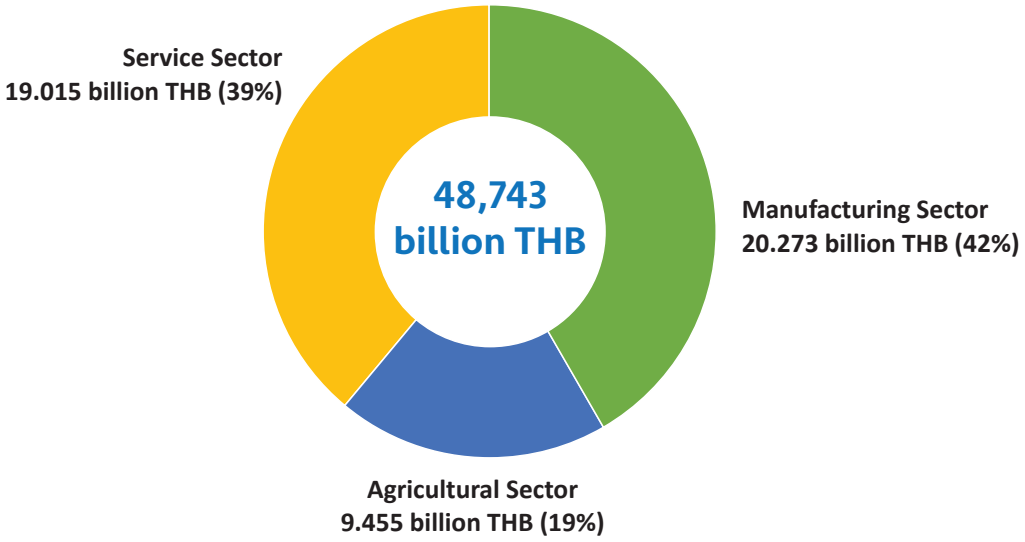
NSTDA strives to enhance the nation's competitiveness on the global scale based on strength in science and technology with intensive research and development. This is reflected in its vision that positions the agency to be a key partner supporting every sector — manufacturing, service and agriculture — in applying science and technology to improve efficiency. In doing so, S&T investments are made by involving parties in manufacturing, service and agricultural sectors. NSTDA's performance is therefore measured in the form of S&T investment made by its partner organizations. In 2019, this S&T investment totaled 12.179 billion THB with details as follows:



S&T Investment by Category in FY 2019

1. After acquiring technologies from NSTDA, partner organizations made an investment to improve or expand their manufacturing processes and services, procure machineries and equipment, and increase their employment, totaling 2,428 million THB.
2. R&D investment made by the private sector through participation in NSTDA schemes designed to stimulate R&D in enterprises, e.g. donations to NSTDA fund, R&D investment made by tenants in Thailand Science Park and Software Park Thailand, R&D expenditure claimed for 300% tax exemption, investment made to ITAP's consultancy projects and investment made on projects seeking low-interest loan, totaling 8,782 million THB
3. Investment made to collaborative research projects with NSTDA by both public and private sectors was 538 million baht, comprising 327-million-THB in-cash investment and 211-million-THB in-kind investment (facilities, equipment and R&D personnel).
4. Investment made to other S&T services offered by NSTDA including analytical /technical services, training and technology licensing, totaling 431 million THB.

NSTDA is committed to conduct research and development to create S&T innovations to benefit the nation. In 2019, data collected from beneficiaries of NSTDA's projects/programs showed an economic impact of 48.743 billion THB. Beneficiaries of NSTDA's innovations are categorized into the manufacturing sector, service sector and agricultural sector.



Economic Impact Categorized by Beneficiary in FY 2019

Economic benefit to the manufacturing sector was 20.273 billion THB. This number was mainly contributed to by the research and development projects resulting in new products or solutions to improve product quality fulfilling consumers' requirements and meeting industry standards. An outstanding example is a ULA (ultra-low ammonia) latex for mixing with asphalt cement. ULA latex is a new type of concentrated natural rubber latex developed to be free of toxic chemicals and allergens. It is designed for mixing with asphalt cement for road construction. In 2019, the material was used to build 1,200 km. of road. In addition, the technology was employed to develop concentrated latex suitable for the production of latex foam pillows and mattresses. This technology has generated an economic impact of 742 million THB in 2019.

NSTDA's R&D projects/programs have benefited the service sector — public and independent organizations, public health service, academic institutes and mass communication services — at the value of 19.015 billion THB. A highlight of innovation in this category is Thai School Lunch. Developed by NECTEC-NSTDA, Institute of Nutrition of Mahidol University and the School Lunch Project Fund, Thai School Lunch is an automated system employing artificial intelligence to provide recommended school lunch menus. The system is a useful tool to help schools self-plan nutritious school lunch menus at an optimal budget. With proper planning, school lunch budget can be managed more effectively, and cost can be saved. With the collaboration of the Office of the Basic Education Commission (OBEC), Thai School Lunch has been implemented in all OBEC's primary schools throughout the country, as well as a number of schools under the Office of the Private Education Commission, the Local Administrative Organizations and the Border Patrol Police. In 2019, a total of 57,818 schools employed Thai School Lunch system and an economic impact was estimated to be 5.147 billion THB.

Some of NSTDA's projects have resulted in a productivity improvement in the agricultural sector and the economic impact of these projects was approximated to be 9.455 billion THB. One notable example is a project to investigate a causative pathogen and symptoms of shrimp early mortality syndrome (EMS). The project was conducted by BIOTEC-NSTDA is collaboration with Mahidol University with an aim to control the disease by developing diagnostic tools. Results of the study enabled the mitigation of the shrimp production loss and led to the formation of Shrimp Health Research Network with participation of industry and government agencies. Economic impact of this project was estimated to be 330 million THB in 2019.

SAFETY AND ENVIRONMENT MANAGEMENT

Safety Management System

NSTDA places great emphasis on creating a safe workplace for its employees, customers and all stakeholders, ensuring sustainable consumption, as well as caring for the environment. All of its activities are implemented with measures to provide safety and minimize pollution, with continuous improvement on safety management. The agency is certified according to the occupational health and safety management system ISO 45001:2018.

NSTDA safety management is led by a NSTDA senior executive and implemented by the Safety and Environment Working Group and the Safety, Health and Environment Division. Hazard identification and risk assessment are routinely performed at the start of fiscal year and the results are used to define control measures and set an annual work plan, an operational control plan for safety, as well as monitoring and evaluation. For emergency situations, NSTDA has an emergency response plan and procures proper equipment for handling situations such as fire, chemical spills and gas leaks. A total of 30 drills were conducted throughout the year. Training courses are organized for safety officers in supervisory, management and safety committee levels. Fire safety and first aid training is provided to ensure that NSTDA staff are properly equipped with understanding and skills to promote safe and healthy workplace.

In 2019, NSTDA Risk Management in four areas, namely strategy, operation, finance and compliance, as well as a PESTEL analysis – investigating Political, Economic, Social, Technological, Environmental and Legal factors that have an impact on an organization's performance – were used to assess risks and

opportunities in heath and safety. Performance of 2018 safety and environment implementation was reviewed and NSTDA safety and environment implementation plan for 2019-2021 has been designed taking into account NSTDA's Strategic Plan. NSTDA safety and environment implementation plan for 2019-2021 sets a clear objective and contains some new initiatives that will support NSTDA's operation to fulfill its mission. Essential deliverables of this plan include retaining ISO 45001 certification, establishing a central safety and environment database system that can be accessed by all NSTDA staff, and employing biosafety practices and Thailand Industrial Standards on nanotechnology (TIS 2691) in the operation of BIOTEC and NANOTEC, respectively. For long-term occupational health and safety management, NSTDA continues to create and maintain the culture of safety by engaging its employees. Employees are encouraged to monitor and report on unsafe actions taking place.

Environment Management System

Potential impact to the environment caused by NSTDA's operation is of paramount concern. Environmental quality is constantly monitored, including quality of discharged wastewater, levels of heavy metals in treated wastewater, quality of wastewater from individual buildings, air quality in Thailand Science Park, quality of emissions from an incineration plant, quality of groundwater in Thailand Science Park, quality of water in the reservoirs in the vicinity of Thailand Science Park and levels of heavy metals in soil.

NSTDA wastewater treatment system can accommodate various types of wastewater, different organic loads and wastewater quantity. The system is able to achieve the discharge quality meeting the regulatory standard. A centralized system is established for hazardous waste management for cost effectiveness. Hazardous wastes from various units are segregated and sent to a hazardous waste management facility.

In FY 2019, 127,221 cubic meters of wastewater were produced in Thailand Science Park. NSTDA ensures that wastewater in Thailand Science Park — whether from office, laboratories or tenants — is effectively treated, and the discharge quality meets the regulatory standard. Treated wastewater is reused for cleaning and watering plants in Thailand Science Park. The goal is to become a zero-discharge facility. Sewage sludge is used as a soil amendment in Thailand Science Park and also distributed to employees.

A total of 72.30 metric tones of hazardous wastes were generated from NSTDA laboratories and tenants, a 15.81% increase from the previous year. Hazardous wastes are segregated into incinerable hazardous waste and non-incinerable hazardous waste. Portion of incinerable hazardous waste is handled by NSTDA's incineration plant; the rest is sent to incinerators operating outside the premises in order to

minimize the risk of NSTDA employees. NSTDA hazardous waste management complies with ISO 9001 standard, ensuring proper incineration and proper treatment of flue gas so as not to impact air quality. There is a unit within NSTDA assigned to manage non-incinerable hazardous waste by contracting an external treatment facility to remove and treat this type of waste.

Carbon Footprint for Organization (CFO)

In FY 2019, NSTDA was awarded a certificate verifying that its quantity of greenhouse gas in FY 2018 (1 October 2017 - 30 September 2018) met the requirements of TGO Guidance of the Carbon Footprint for Organizations (CFO) for the fourth consecutive year. This certificate covers NSTDA facilities located in and outside Thailand Science Park. The total greenhouse gas emission in FY 2018 was 22,156.24 tons of CO_2e. In FY 2019 (1 October 2018 - 30 September 2019), the total greenhouse gas emission was measured at 23,090.48 tons of CO_2e, a 4.22% increase from the previous year.

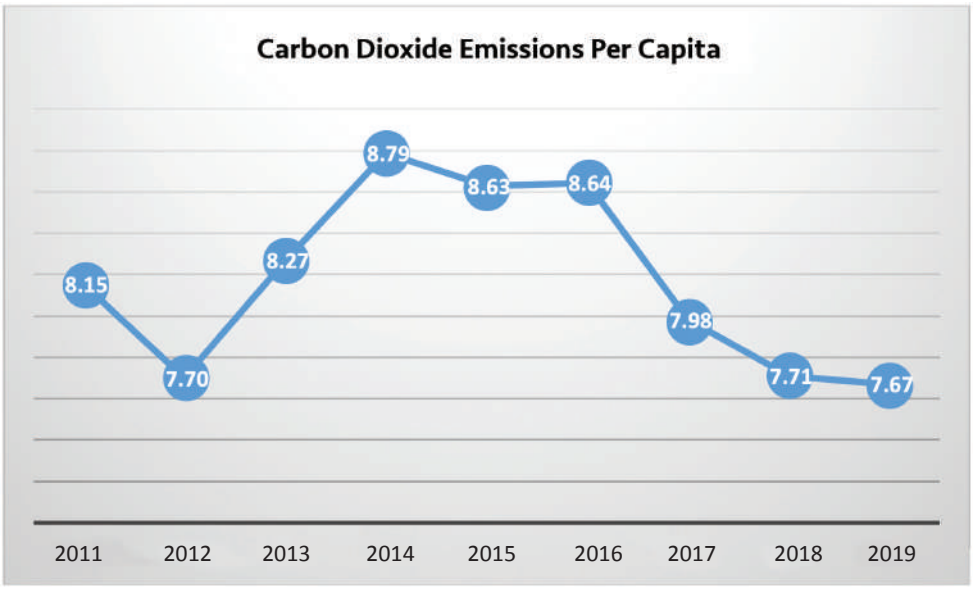
Scope*	FY 2018		FY 2019		Remark
	Greenhouse gas emissions	Percentage	Greenhouse gas emissions	Percentage	
Scope 1	2,800.08	12.64	2,776.08	12.02	A decrease in greenhouse gas emissions in FY 2019 is attributed to the reduction in fuel consumption used by vehicles and lawn mowers.
Scope 2	18,419.51	83.14	19,364.67	83.86	An increase in greenhouse gas emissions in FY 2019 is due to an increase in electricity consumption caused by an opening of more working space in the Innovation Cluster 2 Building, and more events/activities held at Sirindhorn Science Home and TSP Convention Center.
Scope 3	936.65	4.22	949.73	4.11	An increase in greenhouse gas emissions in FY 2019 is caused by an increase in paper usage, water consumption, and the amount of hazardous waste treated by external incineration facilities.
Total	**22,156.24**	**100**	**23,090.48**	**100**	

Note: * Three scopes are:

Scope 1: Greenhouse gas emissions from the consumption of fuel in general activities such as LPG consumption in laboratories and by electricity generators; diesel consumption by electricity generators, fire-fighting pumps and incinerators; gasoline consumption by electricity generators, floor grinders, water pumps and lawn mowers; fuel consumption in transportation such as NSTDA's vehicles (gasohol and diesel), vehicles operated by sub contractors used in NSTDA's activities (diesel and NGV) and NSTDA executives' cars (gasohol); carbon dioxide generated from fuel combustion in laboratories; SF6 consumption in switchgear and substations; consumption of chemicals such as R134 and R410A refrigerants, lab chemicals (carbon dioxide and nitrous oxide) and fire suppression agents (CO_2, HFC-227ea); N_2O from urea fertilizers and toilet usage; and greenhouse gas (methanol) generated by NSTDA's incineration plant.

Scope 2: Greenhouse gas emissions from the consumption of electricity.

Scope 3: Greenhouse gas emissions from vehicular transportation such as office shuttle buses (diesel and NGV); the usage of consumables such as office papers and toilet papers; the consumption of resources such as water and drinking water; and hazardous waste treatment such as the consumption of fuel by external incineration facilities.



(unit: tons of CO2 eq)

With the number of 3,009 employees in FY 2019, the greenhouse gas emission was 7.67 tons of CO_2 eq/person, a decrease by 0.04 tons of CO_2 eq/person from the previous year.

RISK MANAGEMENT

NSTDA sets its risk management system and framework in accordance with the ISO 31000:2009 risk management standard. Effective since FY 2012, NSTDA risk management consists of three levels: Enterprise Risk Management (ERM), Strategic Business Unit (SBU) Risk Management and Major Program and Project (MPP) Risk Management. The goal is to seamlessly incorporate risk management into all work processes so that it eventually becomes part of the organization's culture.

A Sub-committee on NSTDA Risk Management has been established by the NSTDA Governing Board with the role to give advice on appropriate policy and actions on the risk management as well as to regularly provide an update and a performance report on risk management to the NSTDA Governing Board. NSTDA Risk Management Working Group was set up to develop policy, work plan and system for risk management. NSTDA Risk Management Committee, chaired by the NSTDA President, was established with the responsibility of risk management, including taking actions to prevent and mitigate potential impacts of risk factors, reviewing and revising risk management process at an appropriate frequency, and communicating and raising awareness of risk management among employees at all levels.

NSTDA risk management methodology follows the ISO 31000:2009 risk management standard which consists of cause analysis, impact assessment, identification of actions to take and weaknesses to overcome, and subsequently assessment on the occurrence likelihood and impacts before and after the action of risk management. Bow Tie Diagram is used as a tool for analyzing causes, impacts and measures to control/mitigate risks which lead to evaluating options and identifying risk response. The diagram is used for meetings, reports, consultations and communication with NSTDA Risk Management Committee and stakeholders.

In FY 2019, eight risks were identified, covering four areas: Strategy (S), Operation (O), Finance (F) and Compliance (C). Out of eight risks identified, four were scored very high and four were high. Risk control plans were developed for all eight risks. The plan was executed and as a result, the scores of three risks were reduced and met the targets, whereas the scores of five risks were reduced and exceeded the targets. The risks meeting the targets were (1) REO-6 Inability to create new financing mechanisms to encourage technology utilization, (2) RES-6 Inability to adapt to change, and (3) RES-7 Inability to meet the target on the preparation of manpower to drive Thailand 4.0 agenda. Five risks that the reduction exceeding the targets were (1) RES-5 Inability to achieve the goal of EECi (Eastern Economic Corridor of Innovation) development, (2) REF-1 Inadequate income to execute activities under the set mission, (3) REC-1 Damaged reputation caused by mis-management or mis-representation in the public media, (4) RES-1 Impact generated by R&D outputs not meeting the target, and (5) RES-4 Collaboration with key strategic partners not achieving the goal of NSTDA mission.

After reviewing the risk management performance and examining the internal and external factors, NSTDA Risk Management Committee decided on risk management plan for FY 2020 by continuing to work on six risks, keeping two risks, RES-6 and REC-1, under monitoring, and adding two new risks. FY 2020 risk management plan covers the following ten items:

Strategic Risk

1. RES-1 Impact and investment generated by R&D outputs not meeting the target
2. RES-4 Lack of cohesiveness in establishing collaborations with key strategic partners
3. RES-5 Inability to achieve the goal of EECi (Eastern Economic Corridor of Innovation) development
4. RES-7 Inability to meet the target on the preparation of manpower to drive Thailand 4.0 agenda
5. RES-8 Internal mechanisms unable to support strategic plan implementation

Operational Risk

6. REO-6 Ineffective financing mechanisms to encourage technology utilization
7. REO-7 Weak coordination between an innovation hub team and other teams
8. REO-8 Ineffective communications

Financial Risk

9. REF-1 Inability to meet the target revenue

Compliance Risk

10. REC-1 Damaged reputation caused by R&D outputs

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