The National Nanotechnology Policy Framework (2012-2021)

Executive Summary

In today's world, nanotechnology is regarded with great significance. Not only has it played a more pivotal role in business and industrial sectors, but it has also been one of the contributing factors to radical socio-economic change. It is a branch of technology with a variety of potential applications and further extension to new materials, products, equipment systems, and the latest inventions. Nanotechnology requires multidisciplinary research in which basic research plays an important role in gaining an understanding about how to develop more extensive and integrated technologies. Such development entails interdisciplinary collaboration among physicists, chemists, biologists; and electrical, computer, chemical, and materials engineers in order to start initiatives and lay the groundwork for other disciplines. Reliance is therefore placed on personnel competence, research support, integrated research system management, technology absorption and transfer, analysis and testing, physical infrastructure, intellectual property management, public awareness and understanding, safety management, ethical management, risk management, and linkages between the R&D sector and social and industrial sectors. Thailand's investment in nanotechnology may not have been substantial in the past; however, investment alone is not the most important condition of the equation. It is the sharp focus and innovative idea that are largely instrumental in the country's nanotechnology competitiveness and breakthrough.

According to the National Science Technology and Innovation Act 2008, the National Science Technology and Innovation Policy Office (STI) was assigned to propose the National Science Technology and Innovation Master Plan to the National Science Technology and Innovation Policy Committee (NSTIC) for consideration. STI and the National Nanotechnology Center (NANOTEC) have been collaborating to formulate the National Nanotechnology Policy Framework (2012-2021) to set guidelines and directions for Thailand's nanotechnology development over a period of 10 years. The formulating process of this Policy Framework was operated through the mechanism of the **National Nanotechnology Policy Framework** Steering **Committee (2012-2021)**, which is constituted of experts from all sectors to canvass the views and provide practical advice on defining goals, strategic intents, strategies, measures, and indicators that are in line with the Policy Framework.

On September 11, 2012, the cabinet approved the National Nanotechnology Policy Framework (2012-2021) and the Nanosafety and Ethics Strategic Plan (2012-2016). The Ministry of Science and Technology, and relevant agencies were afterwards entrusted with the implementation of the Policy Framework.

The National Nanotechnology Policy Framework (2012-2021)

The National Nanotechnology Policy Framework (2012-2021) was formulated in correspondence with needs, strengths, weaknesses, opportunities, potentiality, competency, challenges, and internal and external fundamental factors for the development of Thailand's nanotechnology. Constraints on how to optimize the limited resources in the long run were also taken into account. It has also taken relevant issues from the National Nanotechnology Strategic Plan 2007-2013, the National Science Technology and Innovation Policy and Plan 2012-2021, and the Eleventh National Economic and Social Development Plan (2012-2016) into consideration. However, due to the dynamism of nanotechnology, which has gone through a revolutionary change, it is essential to adjust the goals, strategic intents, strategies, measures, and key performance indicators that are suitable with the current situation and future trends of nanotechnology. To ensure effective implementation of the policy, the following visions and goals have been identified.

Vision

Nanotechnology strengthens economic competency, quality of life, society, and environment in a sustainable manner.

The National Nanotechnology Policy Framework (2012-2021) has targeted for three primary goals:

1. Improving agricultural technology and manufacturing industry that meet the demand of the market through nanotechnology.

2. Utilizing nanotechnology to develop materials, products, and equipments in order to enhance the quality of life, wellness, and environment.

3. Becoming ASEAN's leader in nanotechnology research and education.

Strategic Framework for Thailand's Nanotechnology Development

The National Nanotechnology Policy Framework (2012-2021) was designed to improve Thailand's nanotechnology competency, enhance economic growth, and improve existing industrial sectors as well as generate new ones. This Policy Framework is intended to improve the quality of life and society, as well as environmental consumption and conservation in a sustainable manner. Knowledge integration from various branches of technology is therefore indispensable to nanotechnology development and application that fill a need of stakeholders of all levels, from upstream to midstream and downstream sectors. These intentions give rise to the formulation of Thailand's nanotechnology strategic direction, which can be cascaded into four levels.

1. Defining the socio-economic development of the four target clusters: **1) Health and Medicine; 2) Agriculture and Food Sector; 3) Manufacturing Industry; 4) Energy and Environment.** Eight targeted industries have also been identified: **Food and Agriculture, Electronics, Automotive, Textile, Chemicals/Petrochemicals, Health and Medicine, SMEs/Community, and Energy and Environment.**

2. Defining seven flagship products which increase Thailand's potential for competition: **1) Nanosensors** manufactured from both bio and non-bio materials, e.g., gas detectors and monitors used in industrial, agricultural, and environmental fields; polymer electrolytes; medical diagnostic equipment. **2) Nanoelectronics,** e.g., organic nanoelectronics, solar cells, organic thin films, organic thin film photovoltaic materials. **3) Drug Delivery System,** e.g., drug delivery vehicle, targeted drug, herbal extracts in supplementary foods. **4) Nanocosmeceuticals,** e.g., extracts for cosmetics and skin care products. **5) Nanocatalysts and Nanofiltration Materials,** e.g., nano-zeolite catalysts, molecular filters, intrinsically conducting polymers. **6) Nano Coating Materials,** e.g., thermal insulation coating materials, surface coating materials, water-resistant and stain-repellent textile coatings. **7) Functional Nanostructure,** e.g., carbon nanotube reinforced composites.

3. Defining fundamental academic disciplines in nanotechnology and relating core technologies into three areas: **1) Nanomaterials, 2) Nanoelectronics**, and **3) Bionanotechnology.** Technology platform are specified into three areas: **1) Nano Coating Technology, 2) Nano Encapsulation**, and **3) Functional Nanostructure.**

4. Defining key strategic actions to improve the enabling factors at the fundamental level. These include: **1) Human Resource,** e.g. granting funds to the researchers and reforming the education system to promote vocational career paths. **2) Research and Development,** e.g. specifying nanotechnology research and development directions and technology platforms for the agricultural, industrial, and service sectors; encouraging collaborative research among government agencies, educational institutions, and private sectors to apply nanotechnology for commercialization. **3) Infrastructure Development,** e.g. promoting the national nanotechnology laboratory equipped with full capacities for research and analysis; supporting the Center of Excellence for nanotechnology; strengthening nanotechnology incubation units; investing in or licensing from overseas nanotechnology development companies; improving regulations, legal measures, and financial instruments to attract both domestic and foreign investments. **4) Management,** e.g. quality, standard, safety, and ethical system improvements for the quality of life and wellness; including nanotechnology in educational curricular to promote awareness. **5) Technology Transfer,** which results in knowledge dissemination and capability enhancements among the industrial sector and relevant agencies.

Strategic Intents, Strategies, and Measures

In order to achieve the three major goals, it is essential to drive the Policy Framework forward through the five strategic intents.

Strategic Intent 1: The Utilization of Nanotechnology to Improve Quality of Life, Health, Medicine, and Public Health

Nanotechnology research to improve quality of life, health, and medicine has recently advanced tremendously, especially in the field of nanomedicine, such as Nanosensors and Imaging, Targeted Drug Delivery and Controlled Release, and Regenerative Medicine.

The applications of nanotechnology to health-related issues for prevention, screening, detection, and treatments by using nanoparticles in molecular characterization to enhancing the quality of organ imaging, and performing sophisticated treatments and cell therapy.

Goals

1. Nanotechnology increases capabilities for the surveillance, control, prevention, and reduction of problematic diseases.
2. The public gains correct understanding about nanotechnology application in consumer products.
3. To develop a management system and guidelines for nanosafety and nanotechnology applications.

Strategy 1.1 **Support and promote nanotechnology R&D and its applications in improving the quality of life, health, and medicine**

Measure 1.1.1 Define nanotechnology R&D directions to improve the quality of life, health, and medicine.

Measure 1.1.2 Apply nanotechnology in diagnostic testing and in the prevention and treatment of diseases.

Strategy 1.2 **Promote awareness and communication to develop an understanding of nanotechnology**

Measure 1.2.1 Establish communication and disseminate knowledge about nanotechnology to the public on a continuous basis through various channels at several levels.

Measure 1.2.2 Introduce topics and subject matter on nanotechnology starting in middle school curricula.

Measure 1.2.3 Build collaborative networks among the public sector, private sector, and people sectors in order to raise awareness. Apply, integrate and disseminate the knowledge acquired from nanotechnology development within the organization's strategies.

Strategy 1.3 Provide knowledge and mechanisms for nanotechnology in safety, monitoring, ethics, and standards

Measure 1.3.1 Provide efficient mechanisms for management and knowledge dissemination on safety and ethics in nanotechnology.

Measure 1.3.2 Support the roles of the national committee on nanotechnology safety and ethics.

Measure 1.3.3 Improve the quality control, standards, and safety of nanotechnology products.

Strategic Intent 2: Using Nanotechnology to Enhance the Agricultural Sector and Manufacturing Industry

Nanotechnology has been applied to enhance the competencies in the agricultural sector and manufacturing industry in several parts of the value chain; for example, in the development of controlled release fertilizers, plant nutrients and pesticides; using nanosensors for environmental monitoring on temperature, humidity, residue or toxins, heavy metals, and soil nutrients monitoring during the cultivation period. In addition, nanotechnology can be applied in food inspection; in the development of thin-film packaging that prevents water and air permeation; in the development of nanofibers used in the weaving process to enhance durability, stain prevention, and water resistance; and in the improvement of industrial materials to be stronger, more durable, and lighter.

Goals

1. Increasing investments in nanotechnology in the agricultural sector and manufacturing industry.
2. Increasing nanotechnology research works in the agricultural sector and manufacturing industry which can be applied in commercialization process.
3. Increasing employment rate in the field of nanotechnology in the agricultural sector and manufacturing industry.

Strategy 2.1 **Promote nanotechnology knowledge in manufacturing process and encourage value creation throughout the value chain**

Measure 2.1.1 Determine the directions of nanotechnology research and technology platform for the agricultural sector and manufacturing industry.

Measure 2.1.2 Support the development and extension of nanotechnology platform researches.

Measure 2.1.3 Provide access for information, including fundamental information, government's R&D information, and business information.

Strategy 2.2 **Promote R&D mechanisms and applications between R&D and business sectors**

Measure 2.2.1 Create R&D network on nanotechnology between R&D and business sectors at both national and international levels.

Measure 2.2.2 Provide support in initiating mechanisms or organizations that enable linkages between knowledge and collaboration between the public and private sectors.

Strategy 2.3 **Drive nanotechnology research towards applications and commercialization**

Measure 2.3.1 Create incentives to encourage business investments.

Measure 2.3.2 Encourage R&D collaborations between government agencies, educational institutions, and private sectors. Drive nanotechnology research findings towards applications and commercialization.

Strategic Intent 3: Nanotechnology for Energy Security and Environmental Conservation

The trends of energy needs and global energy security are becoming crucial problems. Industrial development increases consumption of natural resource and create environmental impact. Nanotechnology in the areas of energy and environment therefore plays a very important part in strengthening security and reduction of environmental impact. Examples of such nanotechnology include insulation made from nanomaterials, nanotechnology for fuel cell production, the application of nanotechnology in water toxicity detectors, and nanotechnology that helps reduce greenhouse gas emissions.

Goals

1. Research findings can be applied in energy security enhancement.

2. Thailand becomes a leader in nanotechnology applications in developing and producing both energy and alternative energy in ASEAN.
3. Nanotechnology plays a role in supporting and improving green manufacturing with 0.5% reduction in waste and pollution and reduction in greenhouse gas emission.

Strategy 3.1 Promote R&D activities in nanotechnology to increase the efficiency of energy and alternative energy production

Measure 3.1.1 Support R&D on nanotechnology platforms for applications in the enhancement of energy and alternative energy productivity.

Measure 3.1.2 Apply nanotechnology to reduce greenhouse gas emission and environmental impact.

Strategy 3.2 Develop nanotechnology to mitigate impacts on the environment and to efficiently use natural resources

Measure 3.2.1 Develop nanotechnology for clean manufacturing system and encourage more utilization in the industrial sector.

Measure 3.2.2 Promote technology transfer for practical applications of waste treatment and reduction for industrial sector.

Measure 3.2.3 Develop equipment to efficiently monitor pollution in the environment.

Strategic Intent 4: Human Resource Development (HRD) for Nanotechnology

To strengthen Thailand's development, it is necessary to build and prepare nanotechnology manpower at a critical mass level to serve for today and future demand. There must be an adequate number of researchers in order to engage R&D activities towards efficient applications of the existing technologies, and to be able to continuously generate innovations at a competitive pace and beyond. There is a necessity, then, for a steady movement of HRD in nanotechnology and a well-defined career path for nanotechnology personnel at the operational level.

Goals

1. The number of nanotechnology R&D personnel to population is 2.5:10,000.
2. Fifty percent of nanotechnology operational workforce is in the business sector.

Strategy 4.1 Increase the number of nanotechnologist exponentially

Measure 4.1.1 Offer educational grants to improve the competencies of Thailand's researchers and instructors.

Measure 4.1.2 Promote the exchange of researchers among organizations both at national and international levels.

Measure 4.1.3 Provide support to researchers to present their work in international nanotechnology research conferences.

Strategy 4.2 Promote nanotechnology manpower jointly built by industries, educational institutions, and government agencies

Measure 4.2.1 Provide support to higher education in designing academic curricula that accommodate academia and industry.

Measure 4.2.2 Provide grants for nanotechnology research and study.

Measure 4.2.3 Encourage appropriate incentives to attract foreign researchers or experts.

Strategy 4.3 Strengthen knowledge and practical skills of manpower for public and industry

Measure 4.3.1 Promote collaborations among educational, research institutions and industrial sector in shaping qualified nanotechnology manpower.

Measure 4.3.2 Provide training courses to relevant personnel on nanotechnology in practice and tool maintenance.

Measure 4.3.3 Promote research findings through public dissemination.

Strategic Intent 5: Development of Infrastructure and Enabling Factors

Nanotechnology infrastructure is regarded as the most important enabling factor to enhance STI competencies. It helps ensure that Thailand can be competitive in the long run by focusing on making connections and collaborations in forms of research networks among educational institutions, research

institutions, the manufacturing sector, and related organizations in Thailand and overseas. Examples of infrastructure include the Nanotechnology Center of Excellence, expertise networks, laboratories in the national center and regional networks, and a database system. These facilities are enabling instruments to R&D as well as for the manufacturing and service sectors to improve their product quality to meet the standards. Not only does the development of infrastructure and enabling factors help reduce the production cost, but having a central database system also leads to worthwhile non-repetitive and directional resource management.

Goals

1. Thailand's nanotechnology competency is in the lead among ASEAN nations, with national nanotechnology R&D spending totaling to 0.2% of GDP.
2. Creation of bridging mechanisms that link between the public, education, and business sectors, with national nanotechnology R&D spending from the government and business at 50% each.
3. Creation of incentives that attract business investment from within Thailand and overseas and promotion of technology transfer.

Strategy 5.1 Declare the policy and investment allotment on nanotechnology R&D

Measure 5.1.1 Government agencies, research units, and business sectors collaborate in R&D by using government budget, monetary funds, loans, and business investments. Redundancy in operation and budget utilization is therefore reduced, resulting in efficient use of the budget.

Measure 5.1.2 Develop a database system on national nanotechnology infrastructure.

Measure 5.1.3 Encourage nanotechnology R&D activities and mega research projects by using large-scale flagship projects as groundwork.

Strategy 5.2 Build confidence and provide support for investment attraction

Measure 5.2.1 Improve regulations, legal measures, and standards to increase confidence in tools/products.

Measure 5.2.2 Improve regulations, legal measures, and financial instruments to create incentives and attract business investment from both Thailand and overseas; and promote technology transfer.

Measure 5.2.3 Use the government market to stimulate mass production from R&D works.

Strategy 5.3 Support the infrastructure for analysis and testing

Measure 5.3.1 Support the Center of Excellence and expertise networks in key areas of nanotechnology.

Measure 5.3.2 Enhance the competencies of the agencies involved in testing and issuing nanotechnology standards.

Measure 5.3.3 Support the establishment of nanotechnology national laboratory that has capabilities to accommodate research, diagnosis and testing, and provide services that meet international standards.

Policy Management Mechanism Towards Implementation and Evaluation

For the National Nanotechnology Policy Framework (2012-2021), three levels of operational structure are defined—policy level, action plan enforcement level, and implementation level—in order to ensure inclusive management from policy to implementation. At the policy level, management and control of related government agencies and private firms are directly responsible for NSTIC. The National Science Technology and Innovation Policy Office (STI) takes charge in policy research and acts as an agency that monitors the world's nanotechnology trends, and then proposes the policy to NSTIC. In cooperation with the **National Nanotechnology Center**, the two agencies work as a secretariat of NSTIC, which may appropriately form sub-committees to implement the following key activities: **1) Sub-committee for driving nanotechnology policy:** responsible for enforcing the implementation according to the Policy Framework, coordinating with other agencies to follow the Policy Framework, and considering proposals or measures regarding high-impact nanotechnology and proposing them to NSTIC. **2) Sub-committee for monitoring and assessment of the National STI Policy and Plan:** responsible for reporting the implementation results; monitoring and evaluating the nanotechnology policy and plan; monitoring key activities in nanotechnology; and raising opinions to NSTIC by pushing forward through the government agencies or private firms, or through expert or working teams which can be further formed in each sub-committee as appropriate to help carry the plan towards implementation.

The evaluation is performed by the well-recognized and qualified agency that has an expertise in nanotechnology. Responsible for monitoring the progress and achievement of projects or key activities, the agency reports the results of evaluation to NSTIC for acknowledgement and recommendations on the policy framework, goals, strategic intents, strategies, measures, and action plans, all of which have to be compatible with the changing situations. The Secretariat of Nanotechnology Policy Framework acts as a coordinator

among relevant agencies at all three levels—policy, plan enforcement, and implementation—in revising the Nanotechnology Policy Framework and taking action according to the recommendations of NSTIC.

Key Success Factors for Enforcement Policy Framework towards Implementation

Nanotechnology is regarded as a key success factor for the development of several technologies. To implement the established goals of the Policy Framework, the fundamental success factors of commitment, focused planning, evaluation, and strategic alignment are required. In addition, at least three key success factors (KSF) have to be taken into consideration: **1) Budget:** With appropriate amount and continuity, the budget will enable knowledge development and extension for the benefits of short-term applications and long-term development of the infrastructure. This requires proper resource management and the ability to assess efficiency and effectiveness in order to meet the demands of the people. **2) Incentives:** There need to be measures to reinforce strengths and minimize weaknesses by focusing on the development and application of nanotechnology; and by offering attractive incentives for R&D activities and R&D investments both at domestic and international levels including grants, tax measures, and enabling measures to attract talent mobility in nanotechnology. **3) Government market:** This includes supporting government procurement, encouraging market expansion, enhancing infrastructure capabilities, and enabling flexibility in certain industries. Some examples of supporting the government market are through flagship projects that provide active support to the public and private sectors; by increasing strengths; by enabling the development of innovative products by starting from using domestic raw materials and reducing imports; by promoting targeted industries with domestic market; by creating jobs and occupations; by winning acceptance and confidence in standard quality; by enhancing competencies of Thailand's nanotechnology development to a certain degree that enables the country to stand robust in global competition; and, finally, by being able to remain internationally competitive in the circumstances where a large amount of budget is injected and spent on R&D activities at a fast pace.

Key Success Indicators

Examples of key success indicators for the Policy Framework can be categorized as follows:

1. Indicators on social development, quality of life, health, medicine and public health, and nanotechnology awareness

- Number of health and medical products with components from nanotechnology application or that apply nanotechnology in the manufacturing process

- Public awareness regarding the importance and ethics of nanotechnology applications
- Number of books, textbooks, publications, or testing and demonstration equipment that provide nanotechnology knowledge to the public
- Number of websites that provide knowledge and public information on nanotechnology

2. Indicators on capacity building of the agricultural sector and manufacturing industry

- Number of products with components from nanotechnology application or that apply nanotechnology in the manufacturing process
- Value of products and services that apply nanotechnology knowledge to GDP
- Number of enterprise networks in core industries with nanotechnology applications
- Nanotechnology-related employment rate

3. Indicators on adaptation to climate change, energy, and environmental security

- Number of products relating to adapting to climate, energy, and environmental change with components from nanotechnology or that apply nanotechnology in the manufacturing process
- Number of projects that apply nanotechnology knowledge in adapting to climate change
- Reduction in greenhouse gas emissions in the fields of energy, transportation, manufacturing industry, construction, and agriculture
- More efficient use of energy
- Increase in renewable and alternative energy consumption
- Number of projects with efficient management and nanotechnology application to reduce waste that has an impact on the ecosystem

4. Indicators on human resource development in nanotechnology

- Number of researchers, research assistants, and personnel equipped with knowledge in nanotechnology
- Number of technicians with knowledge and skills for maintenance of equipment and tools used in nanotechnology R&D activities
- Number of educational institutions that offer curricula and degrees in nanotechnology

- Number of nanotechnology-related publications in academic journals that are internationally accredited
- Employment rate of graduates in the nanotechnology field

5. Indicators on the development of infrastructures and enabling factors in nanotechnology development

- R&D expenditure to value creation of the industries that use nanotechnology
- Percentage of government R&D expenditure to business R&D expenditure in nanotechnology
- Number of nanotechnology laboratories
- Number and type of equipment and tools that facilitate R&D in nanotechnology
- Number of R&D projects and investment value from companies that received financial and technical support from government agencies
- Number of companies that own innovations derived from nanotechnology R&D activities
- Number of registered patents and number of nanotechnology inventions

Expected Outcomes for Thailand

The National Nanotechnology Policy Framework (2012-2021) clearly defines goals, strategies, measures, and directions for the country, with expectations on building Thailand's capabilities to pursue advancements in technology and to cope with changes that may occur in the future. From the development of this Policy Framework, the following outcomes are expected to benefit the country.

Expected outcomes on the economic sector

- Thailand becomes a top-three food and agriculture exporter in the world by increasing resource management efficiency in production process and by reducing production costs
- Value creation in the fashion and textile industries as well as other innovative fashion products such as leather, gemstone, and jewelry accessories
- Creation of new entrepreneurs or development of nanotechnology businesses among no fewer than 500 companies, leading to investment, productivity, employment, and market creation

including clean and more highly efficient energy material technology, development of ready-to-use medical diagnostic kit, medicine, and medical equipment

Expected outcomes on people and society

- Acquisition of new patterns of learning development and social education
- Value creation of local products
- Increase in abilities to control, prevent, and reduce the rate of problematic diseases
- Correct knowledge and understanding about the application of nanotechnology in consumer goods
- Awareness of the negative and ethical impacts resulting from the application of nanotechnology

Expected outcomes on the environment

- Application of nanotechnology to develop and produce renewable energy
- Reduction of pollution from fossil fuel usage and greenhouse gas emissions
- Environmental conservation and reduction of environmental impact resulting from industrial development

Expected outcomes on Thailand's science and technology capabilities

- R&D expenditure on nanotechnology reaches 0.2% of GDP
- Percentage of research works conducted by government to business is 50:50
- Number of nanotechnology R&D personnel to population is 2.5 to 10,000
- Percentage of R&D personnel in business sector is 50%
- Ability to register no fewer than 500 patents and have no fewer than 2,000 publications in international academic journals
- Mechanisms to create the ability for technology absorption and technology transfer from Thailand and overseas; possession of legal-enabling factors; adoption of incentive creation measures to attract investment; and improvement of financial regulations
- A higher position in IMD's World Competitiveness Rankings by becoming one among the first 15 of the rankings