KEMENTERIAN SAINS, TEKNOLOGI DAN INOVASI
MINISTRY OF SCIENCE, TECHNOLOGY AND INNOVATION

NATIONAL NANOTECHNOLOGY POLICY & STRATEGY 2021-2030

Enabling STI Advancement for a Progressive and Prosperous Nation

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Chapter 1: Aspiration for Nanotechnology in Malaysia

STI Advancement for a Better Tomorrow

Our world is seen by many in the throes of a major transformation brought on by the challenges of the 21st century, namely, globalisation, digitalisation, a looming global economic crisis, and a host of disruptive technologies. With the arrival of the Fourth Industrial Revolution, a range of new technologies that are fusing the physical, digital, and biological worlds, is now impacting all disciplines, economies and industries, and even challenging ideas about what it means to be human. The unprecedented changes that we are witnessing in the way people live, work, and relate to one another, are unlike anything humankind has ever before experienced in terms of scale, scope, and complexity.

Innovation-led and knowledge-intensive economy is redefining the global socio-economic landscape. In this new economy, disruptive technologies, such as big data and Internet of Things (IoT), have been identified as the principal drivers of change. However, the influence of other impacts, such as rapid urbanisation and technological breakthroughs, cannot be discounted across the spectrum of businesses, industries, and society. Perhaps there may be other influences as well to contend with.

From a futurist's viewpoint, the world in going forward needs to straddle equitably between four major convergences - humans and machines, software and biology, the physical and virtual worlds, artificial intelligence, and human intelligence. Indeed, several recent published studies have already alluded to the emergence of a NBIC revolution, that is, a convergence of Nanotechnology, Biotechnology, Information Technology and Cognitive Science. This signals an era not only of extraordinary technological breakthroughs, but also of technological convergence. Many emerging technologies are already demonstrating this trend.

In the light of the foregoing, many countries have committed to investing their resources into building and advancing their Science, Technology, and Innovation (STI) capacity and capabilities, as well as in harnessing STI through the emerging and disruptive technologies for their socio-economic transformation and competitiveness. In this endeavour, nanoscience and nanotechnology hold the keys for rapid and important advancements in many frontier areas of STI, which explains their prestigious hold on research undertaken both in academia and industry across the globe.

Nanotechnology: Revolutionising the Future and Enabler of STI Advancement

Nanotechnology is no longer peculiar in today's technology development. It is vitally positioned as an emerging technology that has and will contribute significantly to the economic growth and job creation in the coming decades as well as in bringing a profound revolution to the future. Nanotechnology comprises of a disparate array of unrelated technologies that cut across many traditional scientific disciplines which includes the utilisation of nanoscale materials or nanomaterials with unique properties (electromagnetic, magnetic, thermal, and optical) that cannot be harnessed from their bulk counterparts. This novelty in properties has since improved and revolutionised many technological and industrial sectors including but not limited to medicine, food and water security, information technology, communication, transportation as well as environmental degradation mitigation.

In fact, the importance of nanotechnology has been recognised since the late 1990s to early 2000s where nanoscience has since then referred as "horizontal", "key" and "enabler" due to its pervasiveness in virtually all technological sectors. In the last two decades, the global approach to nanotechnology governance has evolved considerably starting with the confirmation on the viability and societal importance of nanotechnology applications, to economic and societal outcomes of nanotechnology products especially in environmental, health and safety aspects as well as its ethical, legal, and social implications of nanotechnology.

Envisioned to reach mass applications in products and processes, nanotechnology nowadays has shifted towards more complex generation of nanotechnology products and processes, and the need to responsibly address broad societal challenges such as sustainability and health. This migration in scientific capability to complex nano-systems and molecular bottom-up nanotechnology-based components is projected to multiply the potential for societal benefits and STI advancement.

As a cost-effective enabling platform with mammoth potentials, new materials, products, applications, and processes can be created through nanoscale manipulation, leading to entirely new industrial and socio-economic paradigms. It enables systems that are smaller, lighter, less expensive and more power efficient.

Convergence of knowledge and technology at the nanoscale is leading the world to many exciting growth opportunities (Figure 1a). This concept of nano-convergence is expected to meet almost every industrial, product and consumer needs of the future. It will also dovetail perfectly with the evolving Green Economy as nanotechnology provides a host of products and applications for a clean, sustainable, and waste-free green technology. It will solve pressing energy and environmental needs simultaneously.

Convergence of nanotechnology with other key technologies then lead to divergence into emerging and integrated technology platforms (Figure 1b). Integration of foundational and general technologies will then branch out to new fields of research and production. This feeds into a convergence–divergence process for Science and Technology (S&T) megatrends

directly contributing towards STI advancement thus leading to future revolutions. In short, nanotechnology will improve and revolutionise many technology and industry sectors for the benefit of society at large.

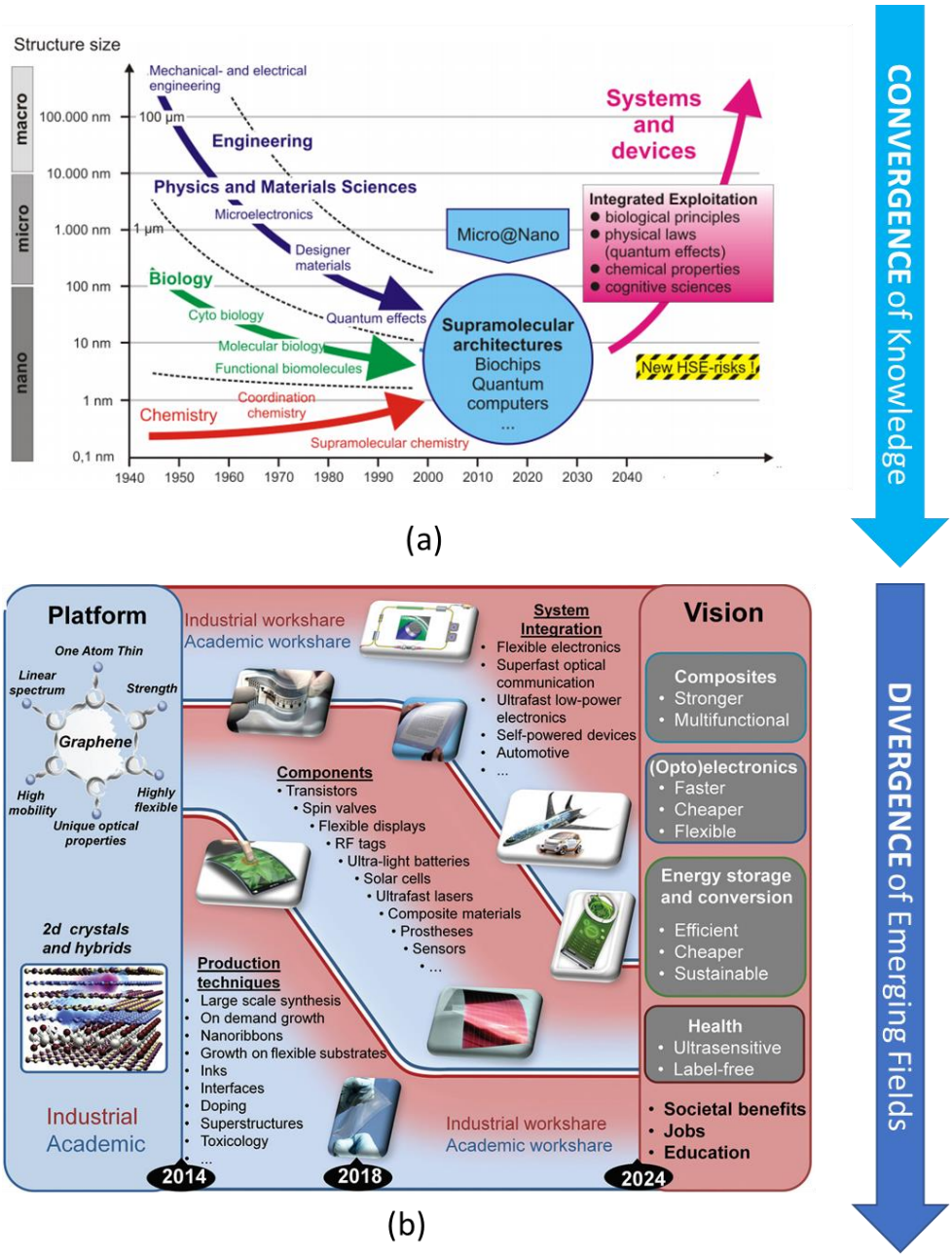


Figure 1: (a) Knowledge convergence through nanotechnology, (b) Diverging applications of nanomaterials (Graphene) in various fields.
Source: (a) Juanola-Feliu, Samitier, & Valls-Pasola, 2010, (b) Ferrari et al., 2015

Endowed with such a versatile, cross-cutting quality, nanotechnology applications are predicted to grow exponentially for the next decade. It is projected that beyond 2020, the value of the global nanotechnology market could rise between USD 2.33 billion to USD 5.76 trillion (Table 1).

Table 1: Selection of global market forecasts for nanotech-enabled products (in USD billions)
Source: Compiled from Global Nanotechnology Market Reports by ASM, 2020

Year / Source	2016	2017	2018	2020	2021	2022	2024	2025	2027
BCC (2016)	39.2				90.5				
RNCOS (2015)				75.8					
IndustryARC (2019)								121.8	
iGate (2018)							125.0		
DataBridge (2018)		7.24						24.56	
Global Industry Analysts (2020)				54.2					126.8
Allied Market Research (2019)			1.06					2.33	
Lux Research			3,680			5,760			

The exponential growth of nanotechnology through discoveries, technological transition, horizontal expansion, and its spin-off areas is expected to continue at high rates coming into 2030 and beyond. The economic estimations were currently made by valuing the commercialisation of products. However, this is not representing the overall value of nano products as the development process (know-how and technological capabilities that are changing fast towards composite and modular nano-systems) which is more valuable is not included in the economic estimations. Henceforth, a comprehensive global nanotechnology outlook would be far greater due to the cross-cutting and convergent qualities that should be capitalised in enabling further advancement in STI.

Nanotechnology Globally

Based on the global analyses, several countries especially the developed nations have aggressively embarked in nanotechnology both in research and businesses since 2000s with most of the programmes and initiatives peaking in 2010s. From this, the United States of America (USA), South Korea and Germany (Figure 2) are among the countries that have been boldly maintaining nanotechnology as one of their forefronts STI agenda going beyond 2020. Over the years, with the recognition of the trans-disciplinary nature of nanotechnology, more countries in the world have been rapidly shifting towards incorporating nanotechnology as one of the key-enabling elements for STI advancements especially in advanced materials and advanced manufacturing.

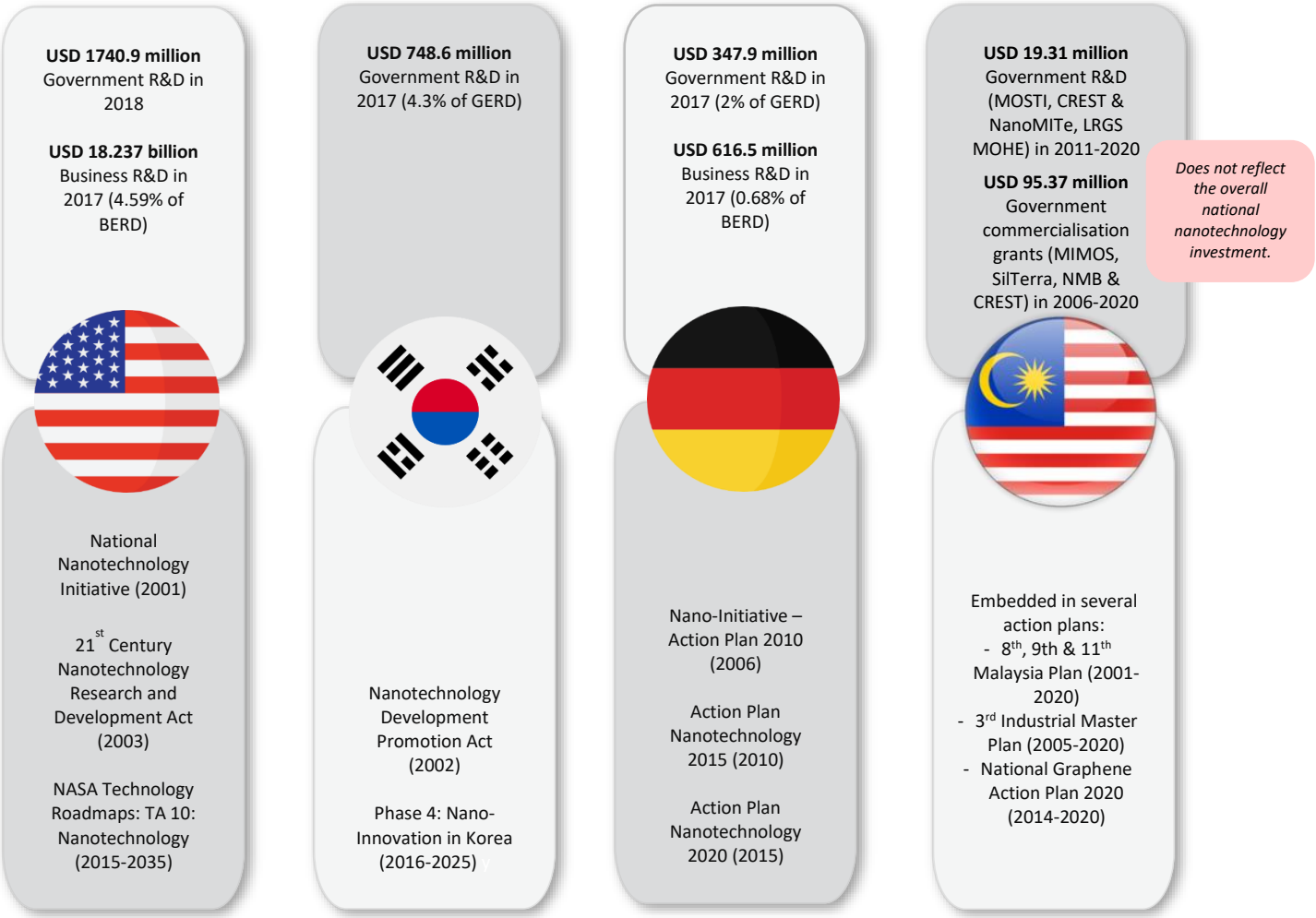


Figure 2: Nanotechnology in top developed countries and Malaysia
Source: Compiled by ASM from OECD Key Nanotechnology Indicators updated Oct 2019, NNI Supplement to the President's 2020 Budget, ASM ESET Study 2017b, NNC 2020 and NMB 2020

As one of the key elements for advanced manufacturing globally, nanotechnology is currently being pursued by the industrial-based countries such as Australia, Canada, China, France, Germany, Japan, the Republic of Korea, and USA. Advanced manufacturing is the focus of one

of the China's 16 mega-engineering programmes to 2020 and has been incorporated into Canada's revised research strategy in 2014, Seizing Canada's Moment: Moving Forward in Science, Technology, and Innovation.

It is observed that the development of nanotechnology in several leading countries in the world such as Russia and China involve a vital role of a dedicated corporation set up for this purpose. In China, Suzhou Industrial Park (SIP) launched 'Nanopolis Suzhou' initiative in 2013 to provide a complete ecosystem support for the growth of nanotechnology and its enabling industries which include focus areas; micro and nano-manufacturing technologies, energy and green technologies and nanomedicine. While in Russia, RUSNANO Group which comprising an Open Joint-Stock Company "RUSNANO" and the Fund for Infrastructure and Educational Programs are working closely to achieve common objectives in improving the competitiveness and effectiveness of the Russian nanotechnology industry.

However, the role of oversight and national level coordination, as well as facilitation of different actors in the nanotechnology ecosystem in the global is effectively carried out by a government entity or directorate responsible for the development of the technology area. This can be seen in advanced countries such as the USA, South Korea, and Germany where a dedicated national nanotechnology coordinating body plays their imperative roles in putting the direction and driving nanotechnology development of the country by aligning and embedding it in the overall technologies components and areas that is vital towards the STI development. Furthermore, the role also includes bringing the overall key players together.

A dedicated nanotechnology policy, strategy and roadmap is also important in putting the right direction and guiding all key players towards one goal of utilising and maximising nanotechnology towards STI advancement and competitiveness of their country as well as future revolution.

USA

Since the launching of the National Nanotechnology Initiative (NNI) in 2001 and its authorisation by the 21st Century Nanotechnology Research and Development Act in 2003, USA has steadfastly remained as the leader in the global nanotechnology advancements be it in terms of R&D or commercialisation efforts.

This is done through the collaboration of twenty US Federal departments, independent agencies, and commissions towards the shared vision of NNI coordinated by the National Nanotechnology Coordination Office (NNCO) under the White House (Figure 3 and Figure 4).

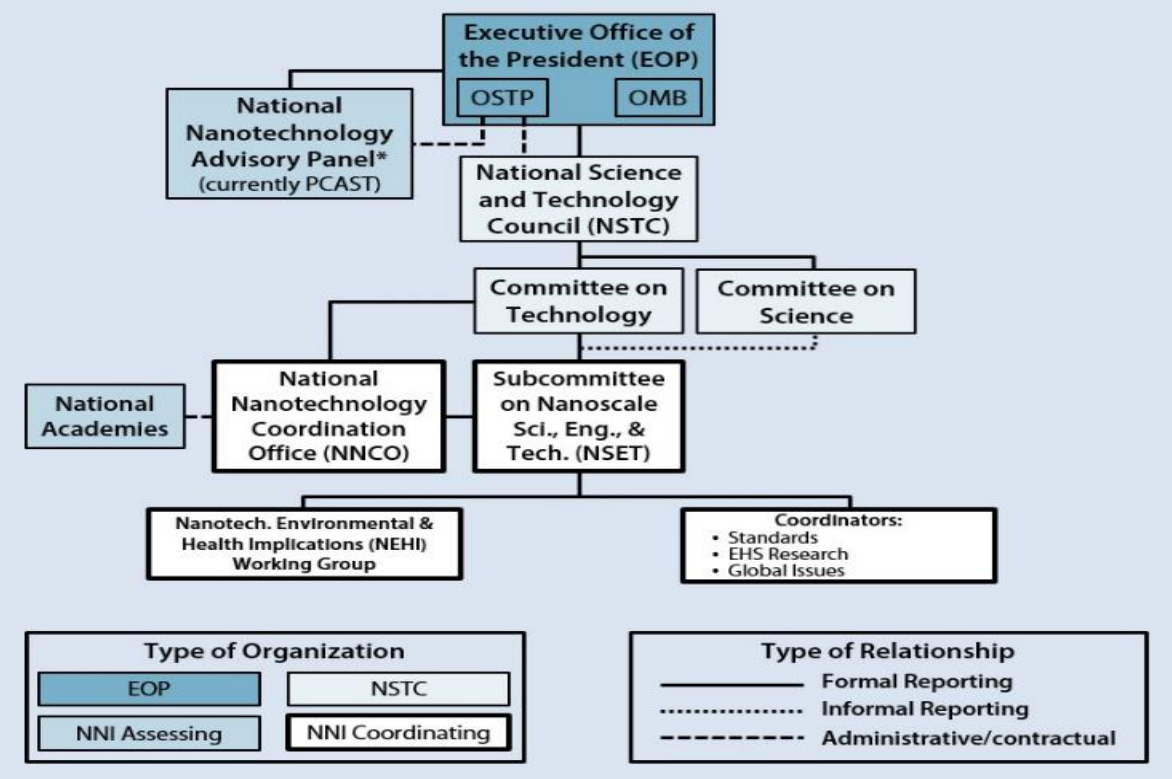


Figure 3: Coordination of US NNI
Source: NNI, 2019a

While in terms of R&D focus, USA supports upstream research and education in all areas of nanoscale science and engineering, leading to a flexible infrastructure and educational pipeline at national level. Through NNI, USA has cumulatively allocated nearly USD 29 billion from 2001 to 2019 for basic research, early-stage applied research, and technology transfer efforts that are leading to the breakthroughs of the future (NNI, 2019b). This continuous support is then mirrored by the business sector with total R&D in the USA business sector amounting to approximately USD 140.2 billion from 2010 to 2017 (OECD, 2019).

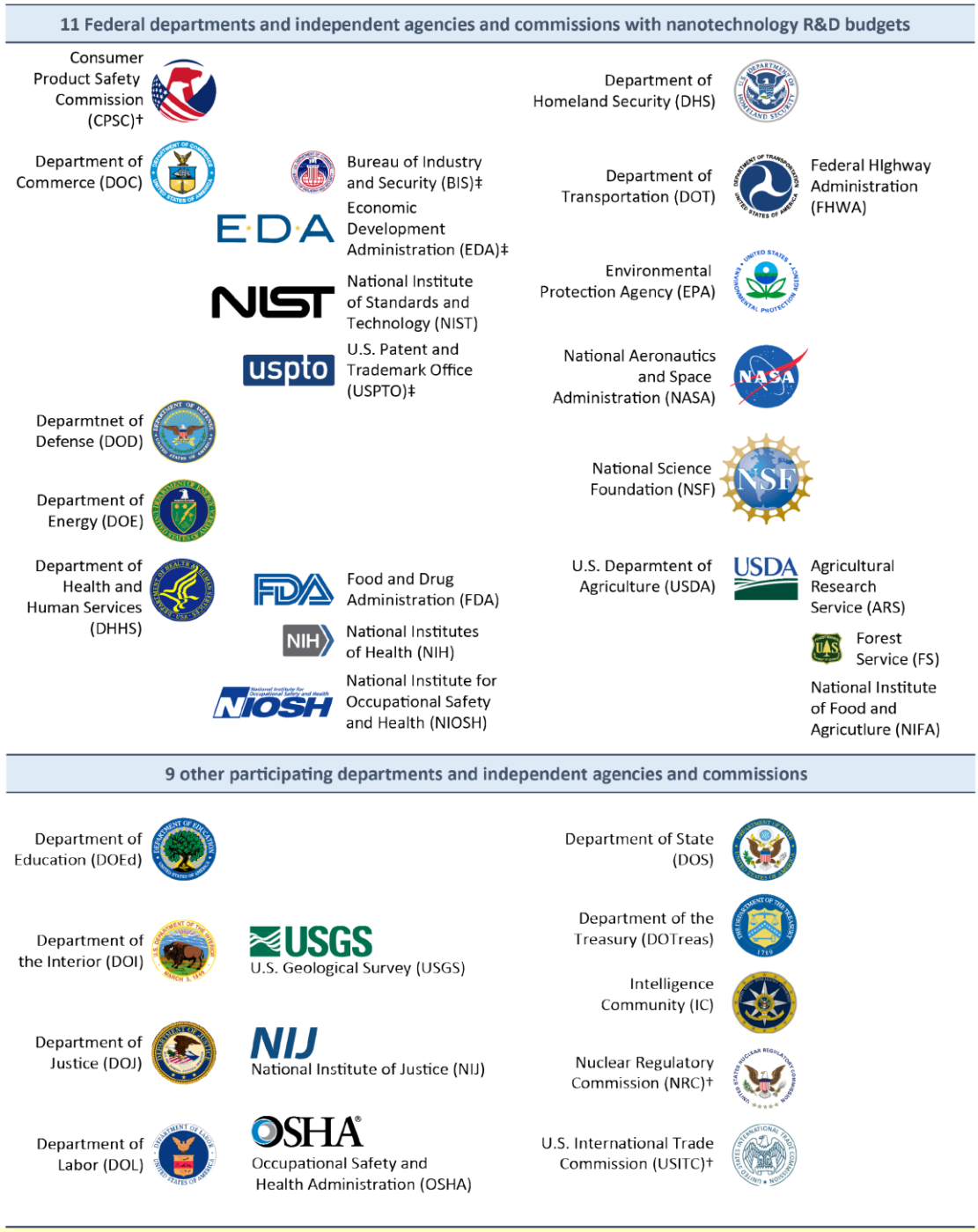


Figure 4: Participating US Federal Departments, Independent Agencies and Commissions in NNI.

Source: NNI, 2019

South Korea

South Korea's efforts into nanotechnology started through the collaboration of several ministries including Ministry of Knowledge Economy (now Ministry of Trade, Industry and Energy, MOTIE), Ministry of Education, Science and Technology (now Ministry of Science and ICT, MSIT), Ministry of Health and Welfare (MOHW), Ministry of Employment & Labour (MOEL), Ministry of Environment (ME) in 2001 to develop a ten-year master plan for the country's nanotechnology development, Nanotechnology Development Plan (NDP). The NDP was approved by South Korea's National Science and Technology Council (NSTC) leading to the launch of the Korean National Nanotechnology Initiative (NNI-K) in the same year.

In ensuring the required legal and institutional backing of NNI-K, a Nanotechnology Development and Promotion Bill and subsequently the Nanotechnology Development and Promotion Act was passed in 2002. As of 2020, four phases of NNI-K have been launched with the shift in focus in the establishment of nanotechnology infrastructure in Phase 1 (2001-2010) to the current vision of being a First-Class Country accomplishing sustainable growth through nanotechnology innovation in Phase 4 (2016-2025).

South Korea has outlined its current R&D focus in the development of 30 future core nanotechnology subjects encompassing five overarching areas namely: (1) Nano-electronics, (2) Nano-bio, (3) Nano-energy and environment, (4) Nanomaterials and (5) Process, Measurement and Equipment. From 2001 to 2016, South Korea had invested over USD 4.4 billion in nanotechnology with 81% allocated for R&D, 12.4% for infrastructure and the remaining 6.7% for human resource development.

In 2018, South Korea launched its 3rd National Nanotechnology Roadmap to chart its future path in the field of nanotechnology (Song, 2018).

Germany

Germany's nanotechnology approach involves an inter-ministerial nanotechnology action plan as a part of the government's New High-Tech Strategy (HTS) encompassing the overarching themes of Technology and Mobility, Health and Transformation and Sustainability and Environment, in which one of the targets set was the alignment of nanotechnology support to priority tasks for the future.

The Nano-Initiative Action Plan 2010 was prepared in 2006 with the document reviewed every five years leading to Action Plan Nanotechnology 2015 (2010) and Action Plan Nanotechnology 2020 (2015).

This inter-ministerial and inter-departmental approach is coordinated across seven ministries: Federal Ministry of Education and Research (BMBF), Federal Ministry of Labour and Social Affairs (BMAS), Federal Ministry of Food and Agriculture (BMEL), Federal Ministry of Health (BMG), Federal Ministry for the Environment, Nature Conservation,

Building and Nuclear Safety (BMUB), Federal Ministry of Defence (BMVg) and Federal Ministry for Economic Affairs and Energy (BMWi).

Nanotechnology R&D funding in Germany is anchored in various dedicated programmes of the Federal Government and is partly promoted as part of inter-ministerial support frameworks. In addition, there is complementary funding by the federal ministries in synergy with the activities of institutional research funding. In 2013, Germany reported that its public nanotechnology funding exceeds 600 million Euros annually (BMBF, 2016). While in 2017 alone, USD 616.5 million was invested for nanotechnology R&D in Germany's business sector (OECD, 2019).

Nanotechnology Towards Achieving Malaysia's Aspirations

Malaysia that we envisioned tomorrow is a progressive Malaysia that is harmonious, prosperous, and sustainable. The well-being of the people, success of the economy and sustainability of the development will be highly depended on the STI advancement. It is vital for STI to be placed at the forefront of its efforts in driving Malaysia forward towards socio-economic advancement, competitiveness, and future revolution.

After 63 years, Malaysia has done reasonability well in global standing related to STI (Figure 5). This is evidenced by Malaysia being ranked 33rd out of 133 countries in the Global Innovation Index 2020. However, despite doing well, there are still rooms for improvement to turn Malaysia into producers of innovative products and services as well as for us to participate in higher end of the global value chain. Malaysian innovation capacity and skills need to be strengthened to move STI-based enterprises.

Hence, as we move towards the advanced nation status, nanotechnology is crucial as the key enabler of STI advancement in every socio-economic sector. Following its ability to crosscut the entire S&T spectrum, nanotechnology is indeed important in catalysing, supporting, and realising Malaysia's aspirations through its many technology-driven efforts. Among others are the Shared Prosperity Vision (SPV) 2030, National Policy on STI (DSTIN) 2021-2030, Industry *4WRD* - National Policy on Industry 4.0, National Entrepreneurship Policy 2030 (DKN2030), National Automotive Policy (NAP) 2020, National Science, Technology, Innovation and Economy (STIE) Niche Areas 2021-2030 and 10-10 *My*STIE Framework (Figure 6).

Figure 5: Current Malaysia's position at the global STI related indexes
Source: Compiled by ASM, 2020

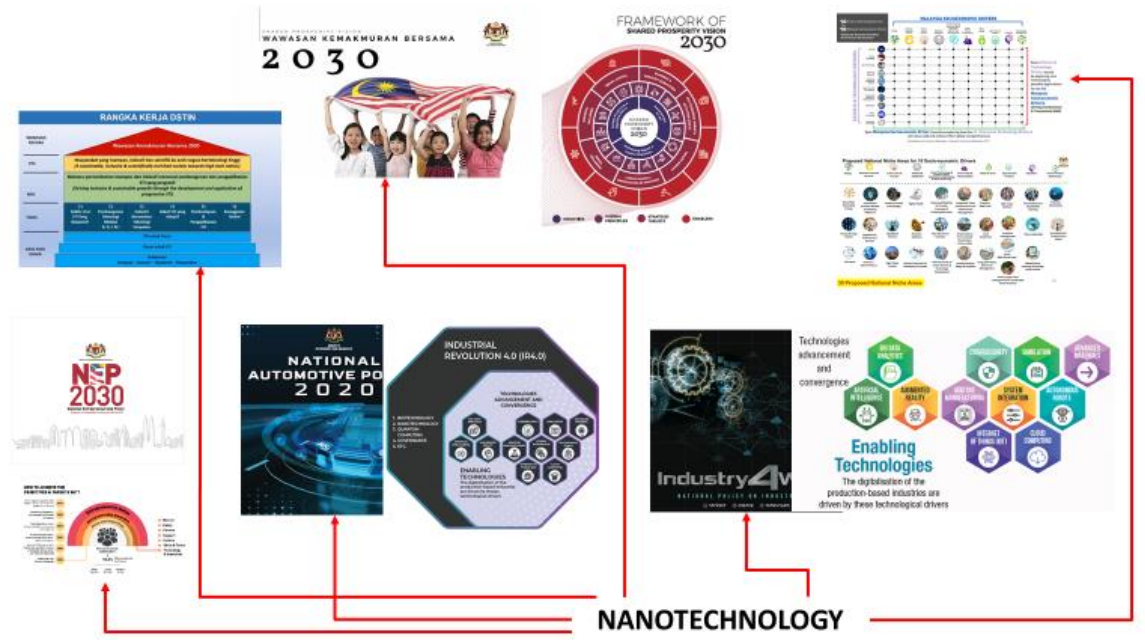


Figure 6: Nanotechnology realising Malaysia's aspirations through technology-driven efforts.
Source: Compiled by ASM, 2020

In the SPV 2030, nanotechnology is essential to play its significant role in driving technologies development in most of its strategic thrusts especially in the enhancement of business and industries ecosystem as well as development of new key economic growth activities that will be aligned with the Industry 4.0. It is crucial in driving all Key Economic Growth Activities (KEGA) as listed in Figure 7 towards realising the SPV's aim to provide a decent standard of living to all Malaysians by 2030.

Figure 7: Key Economic Growth Activities (KEGA)
Source: Shared Prosperity Vision 2030, 2019

While for DSTIN 2021-2030, Industry *4WRD* and NAP 2030, nanotechnology is predicted to play a greater role in driving all STI-driven initiatives and strategies under the policies which involving Industry 4.0 towards realising Malaysia's aspiration to become a high-tech nation by 2030 as envisioned under the DSTIN 2021-2030. Nanotechnology is undoubtedly crucial in all enabling technologies of Industry 4.0 (Figure 8) such as advanced materials and artificial intelligence where it will bring technology advancements and convergence.

Figure 8: Industry 4.0 technologies that impacting manufacturing.
Source: Industry 4WRD: National Policy on Industry 4.0, MITI, 2018

Malaysia is targeting 3.5% Gross domestic expenditure on R&D (GERD) by 2030 in which 2.06% surge from the current GERD. Thus, robust, strategic, and multifaceted efforts are crucial towards achieving this target. The Government has outlined 30 national niche areas through 10-10 *My*STIE Framework towards strategic focus for intensification of investment in STIE under the 12th Malaysia Plan to build sustainable and agile ecosystems for every industrial sector at localities across Malaysia (Figures 9 and 10). This would spur inclusive development for economic growth and societal well-being for the nation.

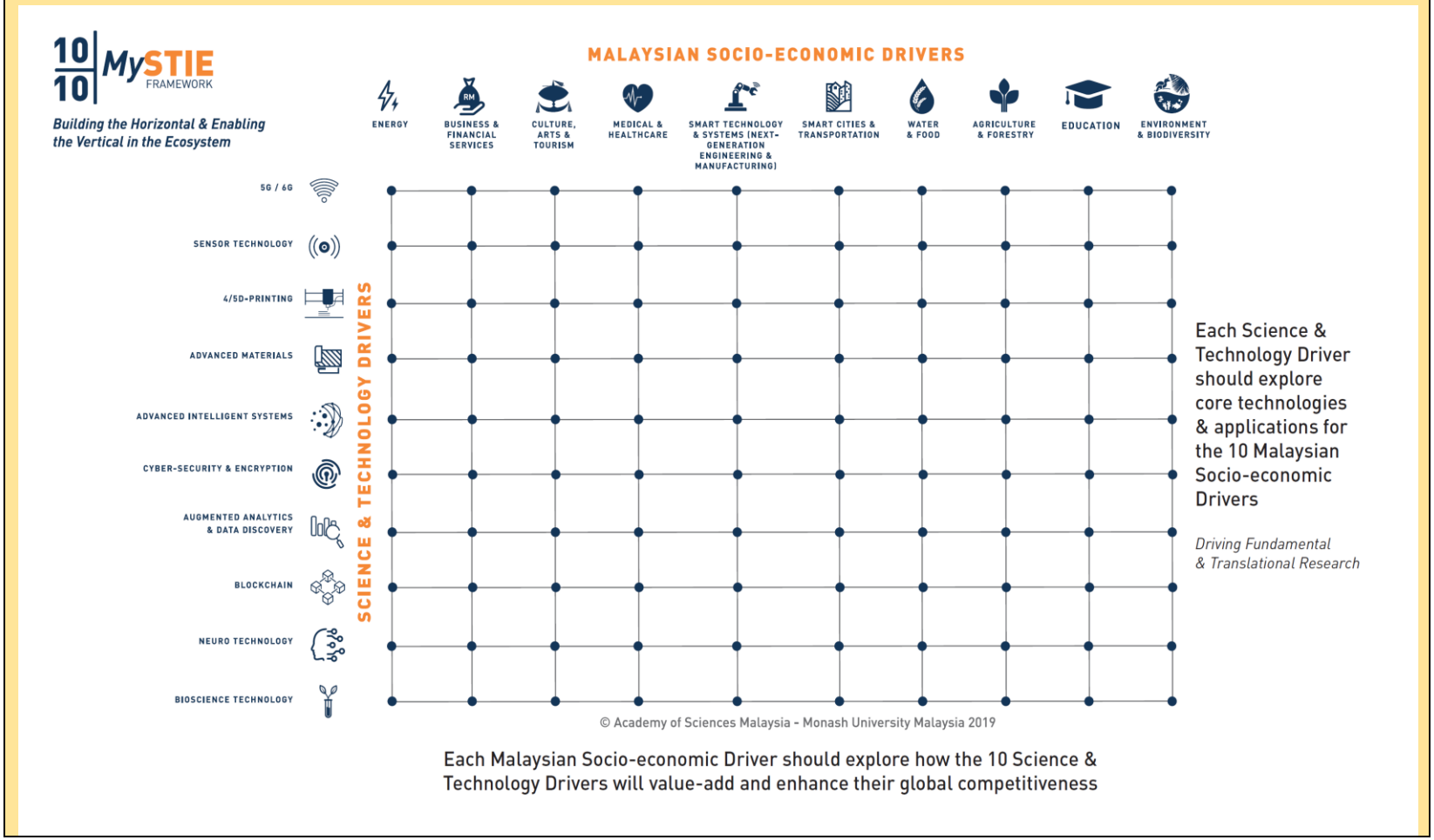
Nanotechnology will be playing significant roles in these niche areas as well as the 10 socio-economic drivers and the 10 S&T drivers of the 10-10 *My*STIE Framework as it is crosscutting all the S&T aspects. The convergence of nanotechnology with the key technologies will certainly lead our country towards STI advancements and will rapidly driving Malaysia towards achieving its 3.5% GERD target by 2030.

Therefore, it is imperative for nanotechnology to be positioned aggressively at the forefront of Malaysia's efforts that in sync with STI towards driving the nation's socio-economic advancement and competitiveness.

Figure 9: National STIE Niche Areas
Source: 10-10 MySTIE Framework, ASM, 2020

10-10 *My*STIE Framework

Figure 10. A framework that provides a systematic approach to transform Malaysia into a knowledge-intensive economy by design through the integration of 10 key Malaysia socio-economic drivers with the 10 global leading science and technology drivers aligned to Malaysia's strengths and needs. Its linking STI to socio-economic development to generate shared economic prosperity across the diverse ecosystem in the country and to move Malaysia up the global innovation value chain.



Chapter 2: Nanotechnology in Malaysia - Then and Today

Nanotechnology Journey in Malaysia

Aligned with the nanotechnology development in the world, Malaysia's journey in nanotechnology began in early 2000s with the formation of several research groups in institutions of higher learning and research institutes that embarked on nanotechnology research.

Following to the growing needs as well as the importance of nanotechnology for economic growth, the government had included nanotechnology as a strategic research theme under the Intensification of Research in Priority Areas (IRPA) programme in 2001 and as one of the research priority areas in the IRPA programme under the 8th Malaysia Plan (2001-2005).

Malaysia then took a step further on the participation of nanotechnology in the world by officially joined a nanotechnology organisation network called as Asia Nano Forum (ANF) led by Japan in 2004 where Malaysia is among the founding members. To date, 23 organisations from 17 economies in the Asia Pacific region have participated in the network with Malaysia as one of the Executive Committee members.

The key milestone of nanotechnology journey in Malaysia is the launching of National Nanotechnology Initiatives of Malaysia (NNIM) by the Deputy Prime Minister in 2006 after a declaration on the need of a national nanotechnology initiatives presented to the Deputy Prime Minister during the Malaysia Nanotechnology Forum that was organised together with ANF Meeting in 2005 and approval by the Cabinet in 2006. The initiative demonstrated the government's understanding and support on the vital roles of nanotechnology for the nation's development. NNIM drives Malaysia towards a conducive environment for nanotechnology application, development and commercialisation and it is anticipated that the government support will accelerate the progress of the development of home-grown nanotechnology into beneficial technologies.

The Malaysia Nanotechnology Association (MNA) was established in 2009 as a non-profit association to support NNIM. The association has until now plays an important role in organising nano-related events to include various key nanotechnology players of the country.

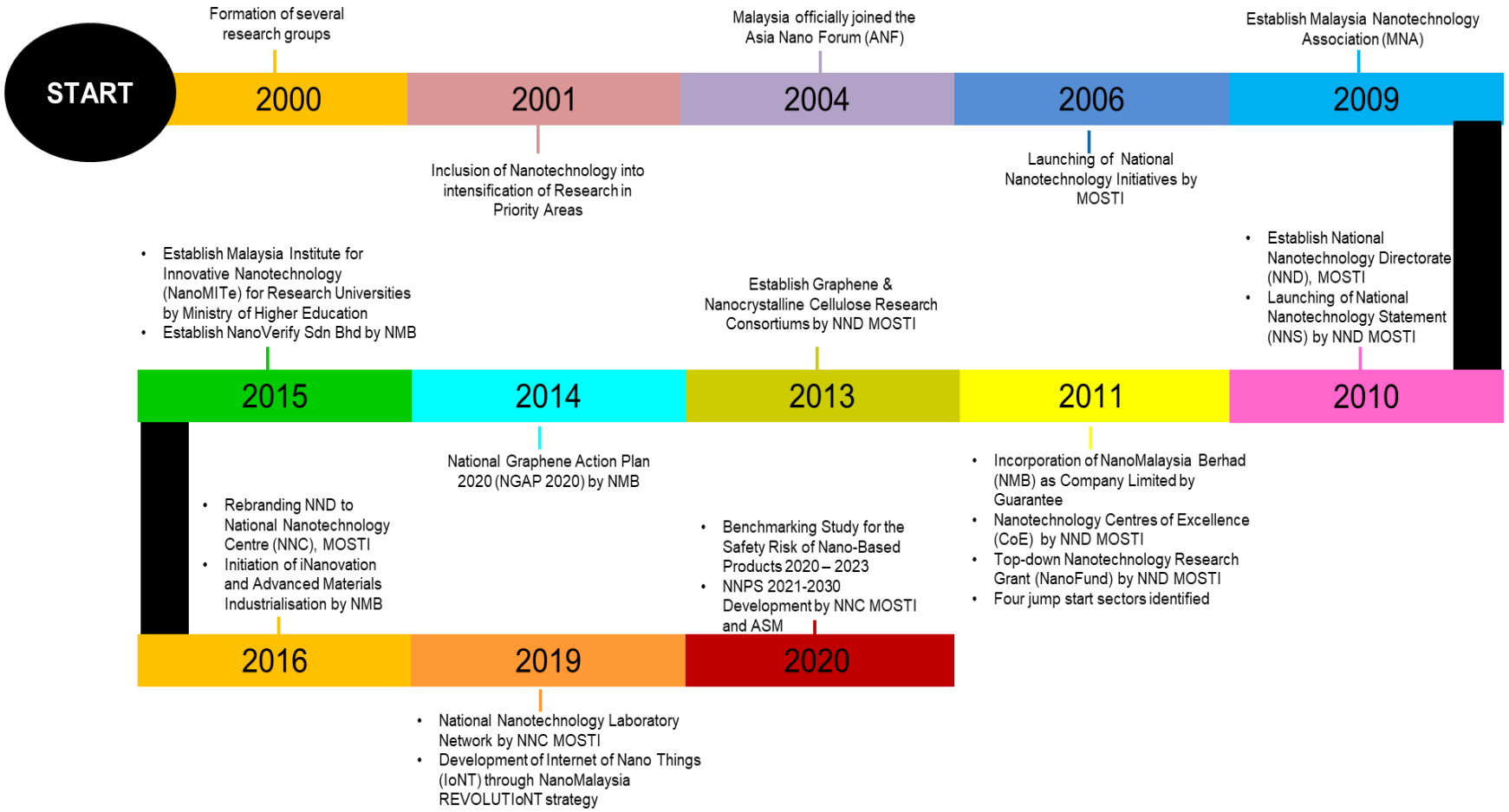


Figure 11: Nanotechnology journey in Malaysia
Source: Compiled by ASM, 2020

NNIM has also paved the way for the establishment of an important central coordination agency for nanotechnology in Malaysia which is National Nanotechnology Directorate (NND) in July 2010 under the Ministry of Science, Technology, and Innovation (MOSTI) to facilitate nanotechnology development in Malaysia by coordinating, planning, and ensuring the adoption, adaptation and application of nanotechnology innovation as well as dissemination of the technology is well infused among Malaysians.

Together with the establishment of NND, the National Nanotechnology Statement (NNS) was also launched in July 2010 with five themes that aspire to exploit nanotechnology as an enabling engine for new economic growth, sustainable development, and societal well-being. It contains a general approach to regulating nanotechnology across its value chain in Malaysia and the cornerstone of national nanotechnology strategic direction and roadmap, which is the reference document for the National Nanotechnology Policy.

Aligned with the NNS, it is undeniable that commercialisation is a major component to drive nanotechnology as the engine for economic growth. However, the difficulties in transforming research and development (R&D) outputs into revenue generating products is among the key challenges in the Malaysian innovation ecosystem. Therefore, in driving nanotechnology commercialisation and industry in Malaysia, NanoMalaysia Berhad (NMB) was incorporated as a company limited by guarantee (CLBG) in August 2011 under MOSTI to act as a company and business entity that entrusted with nanotechnology commercialisation activities.

Following to this, four key strategic jumpstart sectors: Food and Agricultural, Wellness, Medical & Healthcare, Energy & Environment and Electronic Devices & Systems have been identified to be accelerated for nanotechnology developmental programmes, by both entities, NND and NMB.

There were several initiatives initiated by NND upon their establishment in 2010. Apart from the incorporation of NMB in 2011, NND has also recognised five centres as Malaysia Nano Centre of Excellence (COEs) that aim to support nanotechnology R&D, provide shared facilities and for human capital development. A total of RM 2.5 million funding was given to Nano COEs for the centre to perform the activities.

As a part of its NanoMalaysia Programme (NMP) 2011-2020, NND has also implemented a top–down R&D grant called as NanoFund in 2011. A total of RM 7 million was allocated to support nano research towards the development of experts and excellence in nanotechnology research.

In 2013, the national nanotechnology research network was strengthened with the establishment of Graphene Wafer and Nanocrystalline Cellulose Research Consortium. A total of 5 and 9 projects were funded under the Graphene Wafer Research Consortium and Nanocrystalline Cellulose Consortium, respectively.

Starting from 2014, NMB has spreading their wings higher towards strengthening nanotechnology commercialisation and industry in Malaysia with the launching and commencement of National Graphene Action Plan (NGAP) 2020. Then, followed with the establishment of NanoVerify Sdn. Bhd. in 2015 to implement the Malaysia's first nano

certification programme known as NANOVerify Programme. While in 2016, NMB initiated iNanovation and Advanced Materials Programme. Lastly in 2018, NMB has embarked on the development of Internet of Nano Things (IoNT) through NanoMalaysia REVOLUTIoNT Strategy.

The establishment of a research consortium, by Ministry of Higher Education on nanotechnology called as Malaysian Institute for Innovative Nanotechnology (NanoMITe) in 2015 gave a new breath for collaborative research activities among the universities in Malaysia. NanoMITe brings together over 100 chemists, engineers, biologists, physicians, and business experts, to focus on application of nanotechnology to improve society and creating a synergy that essential to the progress of nanotechnology. NanoMITe programme has also embarked on collaborative network with nano-scientists from academic institutions and centres of excellence from the United States, Germany, Canada, China, and Malaysia.

In October 2016, marked a new milestone for NND when it is rebranded by the government to the National Nanotechnology Centre (NNC) following to the need of NND to become a national focal point and central coordinating body for research activities, technology, and product development as well as safety, standards and regulatory matters pertaining to the nanotechnology in Malaysia. Following to this, NNC continued their roles towards the nanotechnology development in Malaysia, among others with the implementation of survey on the formation of National Nanotechnology Laboratory Network in 2019 and initiating Benchmarking Study for the Safety Risk of Nano-Based Products in 2020.

The overall nanotechnology journey in Malaysia from 2000 until to date showed all the government and key nanotechnology players' hard work and efforts in developing and advancing nanotechnology in Malaysia and bring to where it is now. Therefore, it is appropriate for these efforts to be continued and intensified towards strengthening and advancing Malaysia's STI as well as realising its aspiration to become a developed and high-tech nation.

Nanotechnology Landscape and Initiatives: Where Are We?

Despite of many initiatives in developing nanotechnology in Malaysia have taken place from 2000 until to date, there is neither a policy on nanotechnology in Malaysia nor legal framework that provides strategic and concerted direction for nanotechnology in Malaysia. The first National Nanotechnology Policy and Strategy (NNPS) was drafted in 2012 and updated in 2016. However, to date, the policy was never published.

The National Nanotechnology Policy and Strategy (NNPS) 2021-2030 is important in putting the strategic direction and improvements needed for the nanotechnology development and advancement in the country for the next 10 years. Therefore, it is crucial to dive into the current landscape, status and impacts of nanotechnology initiatives to strategise on the way forward.

Ecosystem and Governance

In overall, the current national nanotechnology landscape has diverse players for nanotechnology and innovation ecosystem. This includes coordinating body, research institutions and institutes, industry, commercialisation bodies, standard, safety and regulation bodies, funding related bodies as well as talent and enculturation organisations.

However, the relationship of all these players is rather limited following to the nature of businesses and matters between them and some of it are rather disconnected. The roles of NNC as the coordinating body of nanotechnology in Malaysia is also limited and often seen as less importance. This landscape and ecosystem resulted to fragmented efforts between the key players in developing nanotechnology in Malaysia and slowing down the development.

While in term of governance, it is led by MOSTI in which two of its agencies NNC and NMB are both responsible as the key drivers of nanotechnology in Malaysia.

NNC as a division under MOSTI that is responsible to oversee and coordinate the implementation of national nanotechnology agenda is reporting directly to the Deputy Secretary General (Technology Development, Commercialisation and STI Services). While NMB is a company limited by guarantee under MOSTI, and hence, act as the business entity which entrusted for nanotechnology commercialisation activities is now under the purview of the NNC.

Figure 13 is based on the new MOSTI's Governance Structure (Memo MOSTI.500-2/1/1(3)), October 2020. Disconnection issues between NNC and NMB have been solved. However, it is important to have a centralised national coordinating body that given the necessary mandate in setting the direction, coordinating, and monitoring the national nanotechnology agenda.

As the national coordinating body, NNC should be given sole authority and mandate on national nanotechnology at the government level to enable them to reach and coordinate nanotechnology agendas with all nanotechnology players in the country either through the relevant ministries or directly to the respective organisations.

Direct access to central government and representation at national council are also pertinent in positioning nanotechnology as the key enabler for socio-economic benefits and engine growth as well as to be embedded in all technology sectors of the country.

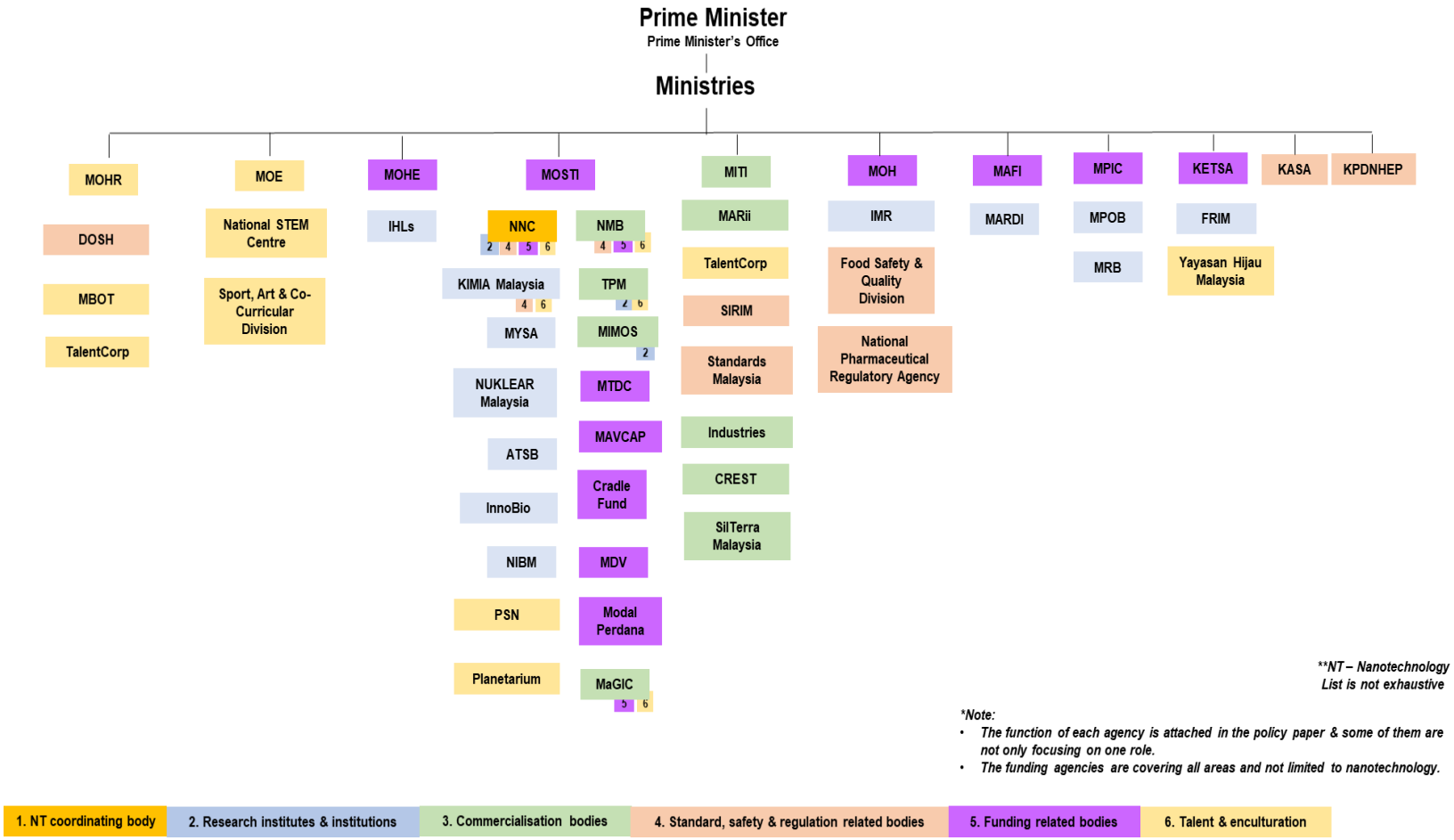


Figure 12: National nanotechnology landscape in Malaysia.
Source: Compiled by ASM, 2020

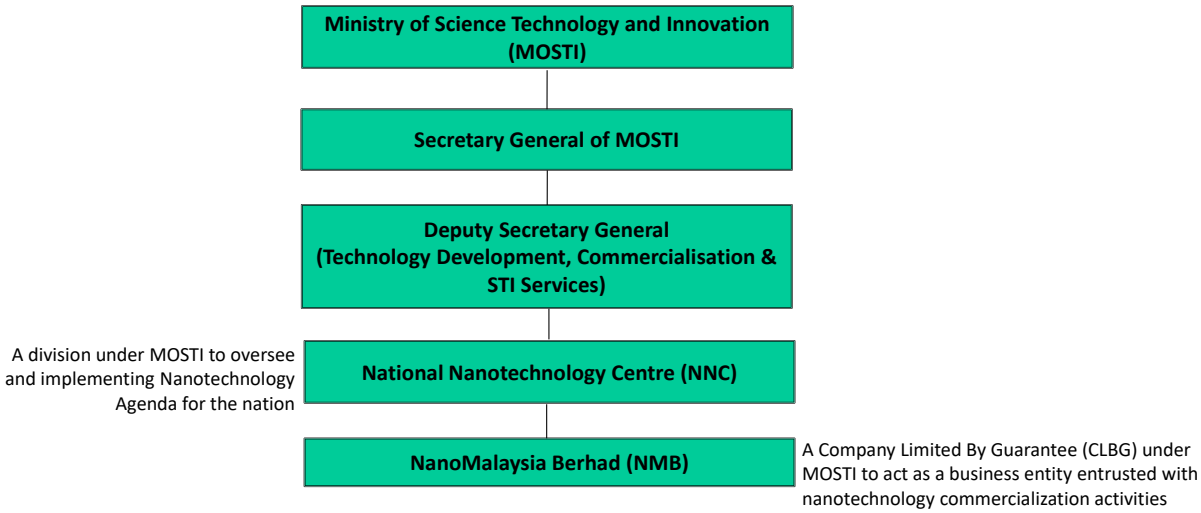
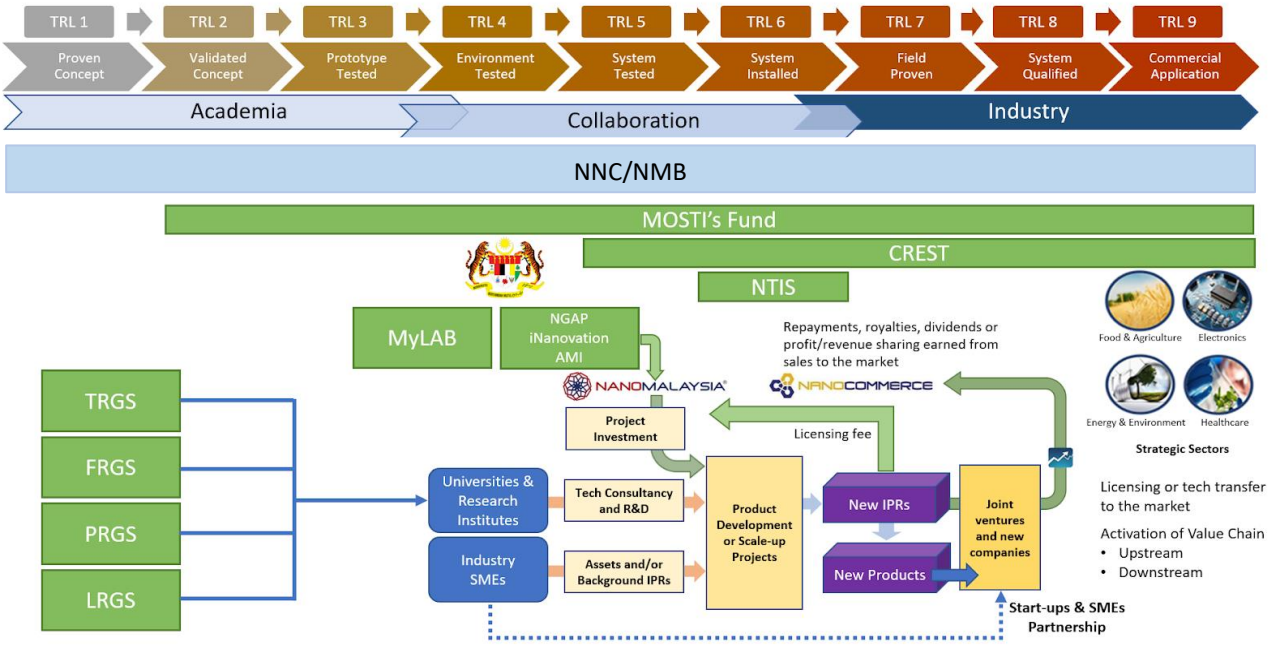


Figure 13: Nanotechnology governance structure in Malaysia.
Source: NNC, 2020

Research and Development

Nanotechnology research and development (R&D) of the country is majorly driven by scientists and researchers in institutions of higher learning (IHLs) and research institutes (RIs) towards generating new and emerging findings of nanotechnology. While in term of governance, NNC is responsible to plan, coordinate, and monitor R&D activities in Malaysia to support the government strategic aspirations in nanotechnology (Figure 14 below).



Currently, there are 31 IHLs and RIs actively involved in nanotechnology R&D and nine of them have specific nano research centres.

Research Institutes

1. Lembaga Getah Malaysia (LGM)
2. Institut Penyelidikan Dan Pembangunan Pertanian Malaysia (MARDI)
3. Institut Sistem Mikroelektronik Malaysia (MIMOS Berhad)
4. Institut Penyelidikan Perhutanan Malaysia (FRIM)
5. Agensi Nuklear Malaysia (ANM)
6. Pusat Inovasi Industri dalam Nanoteknologi (ICI Nano, SIRIM Berhad)
7. Institute for Medical Research (IMR)

IPTS

1. Universiti *Southampton* Malaysia (UoSM)
2. International Medical University of Malaysia (IMU)
3. Monash University Malaysia (MUM)
4. Universiti Nottingham Malaysia (UNM)
5. Universiti Teknologi Petronas (UTP)
6. Universiti Kuala Lumpur (UniKL)
7. Sunway University

IPTA

1. UTM
2. UKM
3. USM
4. UM
5. UPM
6. UiTM
7. UNIMAP
8. UTHM
9. UMT
10. UTEM
11. UNIMAS
12. UMS
13. UMP
14. UMK
15. UIA
16. UPNM
17. UPSI

***List is not exhaustive & not based on rank*

Figure 15: List IHLs and RIs that runs nanotechnology research and activities in Malaysia based on the National Nanotechnology Laboratory Network Survey as of August 2020 (IPTA refers to public IHLs whereas IPTS refers to private IHLs).
Source: NNC, 2020

R&D Priority Areas

Despite many government initiatives in putting nanotechnology as one of the priority areas for the country since 2001, to date, there are no standardised national priority areas for nanotechnology R&D in Malaysia. IHLs and RIs are implementing their R&D either based on their institution/ institute/ consortium's priority areas or the current global nanotechnology progress.

In 2011, NNC listed seven high impact priority areas for NanoFund programme: nano delivery system, nano sensors, nano materials, nanostructured materials, nano-lab-on-chip, health, security, and environment social impacts in nanotechnology. However, these priority areas were then not formalised as the national nanotechnology priority areas.

The absence of standardised priority areas for nanotechnology R&D in Malaysia has resulted in unstandardised R&D direction and difficulties in achieving national targets.

R&D Funding

While in term of R&D funding, the government was aggressively invested in nanotechnology during IRPA in 2001 where a dedicated R&D funding provided for nanotechnology. However, only several dedicated nanotechnology R&D funding that available, which is a one off

NanoFund by MOSTI in 2011, fund for Graphene Wafer and Nanocrystalline Cellulose Research Consortiums under MOSTI in 2013 and Long-Term Research Grant Scheme – Malaysia Institute for Innovative Nanotechnology (LRGS-NanoMITe) comprising 5 nanotechnology-based research programs by MOHE lead by a NanoMITe Consortium in 2015. The funding for nanotechnology R&D is now required to be obtained from the currently available R&D grants in various ministries and organisations either in specific or general scientific fields.

Based on the data gathered from MOSTI, NanoMITe and CREST, to date, the total funding awarded to the nanotechnology-based projects (excluding FRGS, PRGS and LRGS under MOHE except NanoMITe as well as R&D funding that available in other ministries) from 2011-2020 is RM 78.38 million (Table 2).

Table 2: R&D funding for nanotechnology-based projects from MOSTI, NanoMITe & CREST.
Source: NNC MOSTI, 2020, NanoMITe, 2020 and CREST, 2020.

No	Year	Type of Funding	Details of Funding		Amount (RM million)
1	2011-2014	Launching/Initial Grant by Government of Malaysia	NanoFund: RM7 mil 1. Renewable Energy/ Alternative Energy: RM3 mil 2. Nanomaterials/ System: RM2 mil 3. Life Science & Health Care: RM2 mil	NanoCOE: RM2.5 mil 1. COINN, UTP: RM500k 2. INEE, UniMAP: RM500k 3. MIMOS: RM500k 4. IBNUSINA, UTM: RM500k 5. IMEN, UKM, RM500k	9.50
2	2011-2019	MESTECC/ MOSTI	ScienceFund, TechnoFund, International Collaboration Fund, R&D Grant		36.40
3	2012-2020	CREST R&D Matching Grant between CREST-Industry	8 research projects		4.88
4	2013	Graphene Wafer Research Consortium: Funded by MOSTI (ScienceFund)	5 research projects		1.49
		Nanocrystalline Cellulose Consortium: Funded by MOSTI (ScienceFund)	9 research projects		1.97
5	2015-2020	Malaysia Institute for Innovative Nanotechnology (NanoMITe) by MOHE	LRGS fundings given to 5 research areas that has a total of 18 research projects		24.34
TOTAL (Note: Not including other grants such as TRGS, FRGS, PRGS, LRGS from MOHE)					78.38

From the total funding, a total of 185 R&D projects were funded under MOSTI's fund from 2011 – 2019. There is only one dedicated nanotechnology funding among the funds which is NanoFund (Table 3). While the other projects are based on the data gathered and analysed

by NNC for the projects that were fall under the nanotechnology categories from the general funding awarded by MOSTI. This indicates the importance of having a continuous dedicated nanotechnology funding in driving nanotechnology development rather than depending on general funding.

Furthermore, the highest number of nano-related projects, 144 projects are from ScienceFund (discovery of new ideas and advancement of knowledge in applied sciences) if compared to TechnoFund (fund that covers technology development up to pre-commercialisation stage) which has only 4 projects that were funded. This shows that R&D investment in experimental development is rather low to enable R&D outputs translated to market.

Table 3: Type of funding and number of funded nanotechnology-based projects under MOSTI's Fund (2011 – 2019). *Source: NNC MOSTI, 2020.*

No	Year	Type of Funding	Number of Projects	Amount (RM Million)
1	2011-2014	NanoFund	20	7.00
2	2011-2014	NanoCOEs	5	2.50
3	2011-2015	ScienceFund	144	30.02
4	2013-2016	TechnoFund	4	7.16
5	2017	R&D Grant	11	2.43
6	2019	International Collaboration Fund (ICF)	1	0.26
TOTAL			185	49.38

Table 4 shows that the highest number of projects funded is under the Electronics, Devices and Systems category and followed by Wellness, Medical and Healthcare category. This indicates the local strengths that can be leveraged to enhance and advance our industries through nanotechnology.

Table 4: Number of projects and amount funded by MOSTI/MESTECC according to nanotechnology R&D categories. *Source: NNC MOSTI, 2020.*

No	Category	Number of Projects	Amount (RM Million)
1	Electronics, Devices and Systems	56	13.26
2	Wellness, Medical and Healthcare	54	15.75
3	Energy & Environment	34	8.40
4	Food & Agriculture	19	7.16
5	Manufacture & Industry	14	3.04
6	Coating	4	0.71
7	Synthesis	3	0.89
8	Textile	1	0.18
TOTAL		**185**	**49.38**

In supporting the implementation of R&D in various fields including nanotechnology, the government through the Ministry of Higher Education (MOHE) provides several grants to help spur the knowledge development in IHLs. Among the grants are:

- Fundamental Research Grant Scheme (FRGS) – up to RM 250,000 for 2-3 years research.
- Prototype Development Research Grant Scheme (PRGS) – up to RM 500,000 for 1-2 year/s research period.
- Transdisciplinary Research Grant Scheme (TRGS) – up to RM 1.5 million for the first year and max 50% of total 3 years.
- Long-Term Research Grant Scheme (LRGS) – up to RM 3 million per year for 3-5 years of research.

MOHE has initiated grants worth RM 741 million for 2 years running under 10th Malaysia Plan for the development of country's research and innovation. Moving up the Technology Readiness Level (TRL) scale, an IHL that collaborating with industry can apply for funding with the Malaysia Laboratories for Academia-Business Collaboration (MyLAB) under MOHE. MyLAB was established as a step to realise collaboration networks between Institutes of Higher Learning (IHL) and the industry sector. MyLAB programs were intended to develop and establish product outputs from high impact research to be commercialised in strategic thrust fields, including nanotechnology. Based on the recent data extracted from MOHE's MyGRANTS by MOSTI, there are 729 nano-related projects funded by MOHE. The highest projects funded under MOHE is Graphene, 250 projects. The distribution of nano-related projects funded by MOHE is detailed in Table 5.

Table 5: Number of nano-related projects funded by MOHE as extracted by MOSTI through MyGRANTS. *Source: Extracted by MOSTI, 2020*

No.	Nano keyword	No. of projects	No. of principal investigators/ researchers
1.	Graphene	250	222
2.	Carbon Nano Tube	99	97
3.	Quantum Dots	99	93
4.	Titanium Dioxide	71	68
5.	Silver Nano	51	50
6.	Graphene Oxide	43	43
7.	Zinc Oxide	35	34
8.	Nanocellulose	27	25
9.	Nano Titania	25	25
10.	Nanotechnology	19	18
11.	Nano Catalysts	10	10
TOTAL		**729**	**685**

Moving forward, it is important for a continuous and dedicated nanotechnology R&D funding as well as increase in experimental development funding towards driving the development and advancement of nanotechnology in the country.

Talent

Based on the study performed by NNC, it was estimated around 469 nanotechnology experts in Malaysia as of 2019. Nevertheless, these data are not exhaustive and might be increasing as nanotechnology can crosscut almost every scientific area.

Facilities & Infrastructures

In overall, Malaysia at least has basic and necessary facilities and infrastructure for nanotechnology R&D in most of the IHLs and RIs. However, access to these facilities and infrastructures are mostly limited for internal usage of the respective IHLs and RIs unless there are services that provided by the institutions for accessing the infrastructure and facilities via subscription.

Therefore, National Nanotechnology Laboratory Network was initiated by NNC since 2019 through their strategic partnership with several IHL, RIs and private labs as the main platform to gauge the national capabilities of nanotechnology facilities and infrastructures. This initiative is currently ongoing and aim to bring more participation in the network in promoting sharing of facilities and infrastructures for nanotechnology research as shown in Figure 16.

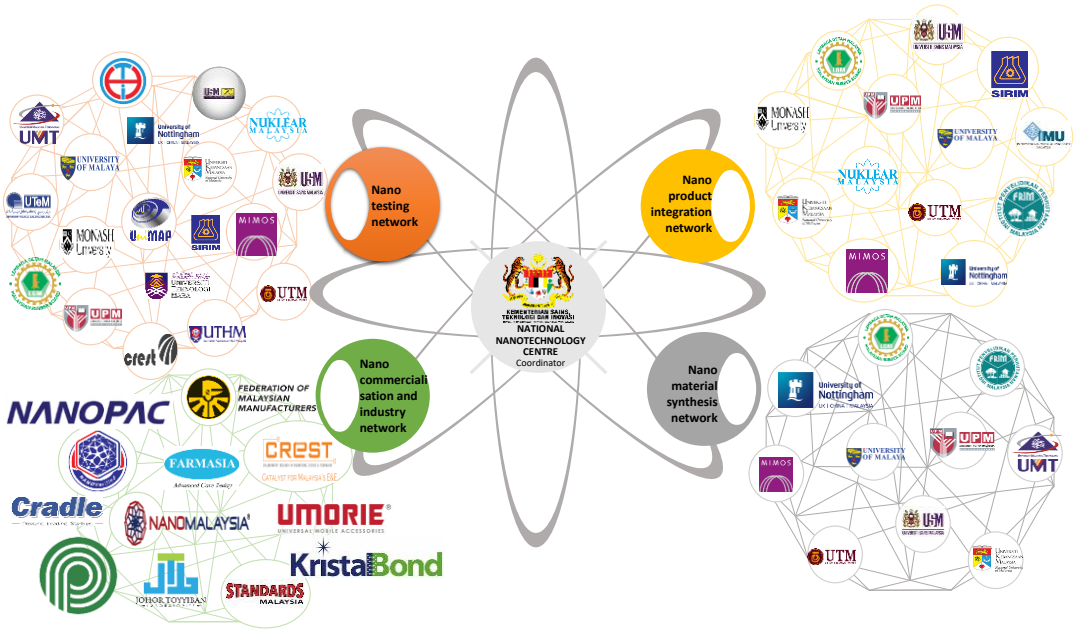


Figure 16: Framework of National Nanotechnology Network.
Source: NNC, 2020

Publications

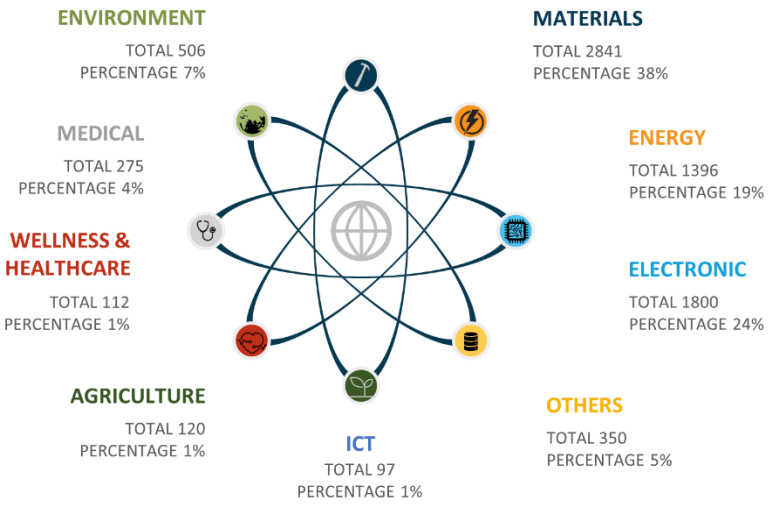


Figure 17: Research Publications in Nanotechnology from 2015 – 2019.
Source: NNC, 2020

A survey conducted by NNC also revealed on the number of publications on nanotechnology as shown in Figure 17. A total of 8,963 publications was recorded in journals, proceedings, books, and articles. The fields that researchers published on span across many areas with the most number in Materials (2,841 publications) which may include nanomaterials, nanostructured materials such as nanocellulose, carbon nanotubes, silicon nanowires and graphene. Publications on nanotechnology also covers on Environmental, Medical, Health and Wellness, Agriculture, ICT, Electronic and Energy. Nevertheless, there is still a gap to translate research knowledge into tangible research products.

Intellectual Properties

Based on a survey conducted by NNC and as shown in Figure 18, to date, a total of 328 Intellectual Properties (IPs) were filed from 2015-2019 by IHLs and RIs with a breakdown of 208 patents, 88 copyrights, 13 trademarks and 19 trade secrets. However, translating the IPs to marketable and valuable products is remain as a challenge that need to be addressed.

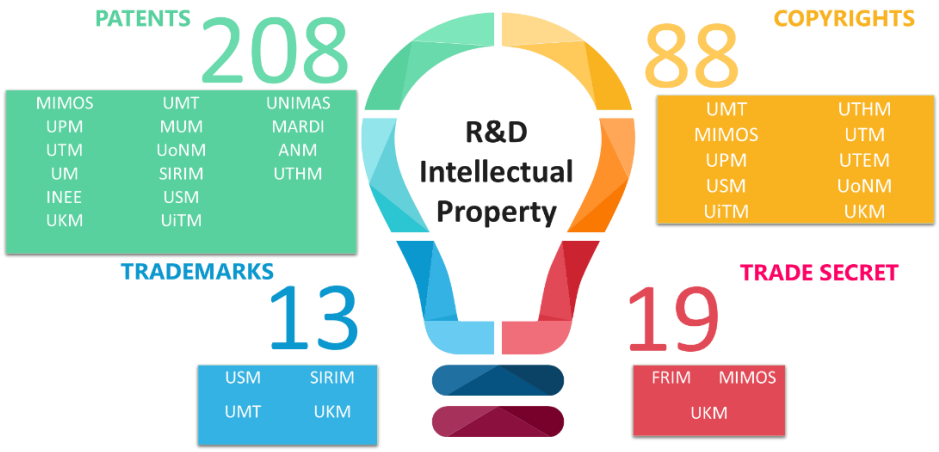


Figure 18: Intellectual Property from 2015 – 2019.
Source: NNC, 2020

Commercialisation

Nanotechnology commercialisation in Malaysia is mainly driven by NMB as the key player responsible in leading nanotechnology commercialisation and industrialisation in the country. There are several commercialisation bodies in the country such as Collaborative Research in Engineering, Science and Technology (CREST) and Malaysian Technology Development Corporation (MTDC) which is also facilitating nanotechnology industry under their commercialisation programmes.

Being the lead entity in commercialisation, NMB provides support for commercial entities within the nanotechnology industry to achieve targeted outcomes in moving towards an innovation-driven economy. The support includes global marketing activities, helping sectoral talent development, providing financial and infrastructure resources, assisting with technology and knowledge transfers, and catalysing product innovations leveraging on nanotechnology.

Throughout 9 years of its efforts in coordinating and advancing nanotechnology industry of the country, it has resulted to commendable outputs from its programmes which can be proud of in nano-products manufacturing, market, funding, certification as well as facilities and infrastructure provided.

Technology Transfer in Nanotechnology

Over the last five years, CREST has funded the Gallium Nitride on Gallium Nitride (GaN-on-GaN) program, with the intention of further accelerating the growth of the Light Emitting Diode ecosystem in Malaysia. The technology being developed by CREST is Gallium Nitride epitaxy. The total funding allocated for the program is RM123.30 million based on a matching grant with the following contribution 62.8% from CREST, 22.2% from university and 15% from industry.

Through the GaN-on-GaN research programme, CREST has brought various Malaysian academic institutes (Universiti Malaya, USM, UniMAP and Monash University Malaysia) to collaborate with University of California Santa Barbara (UCSB). The team also set up a full supply chain for Light-emitting diodes (LEDs) from the frontend epitaxy process to fabrication, packaging, and system applications for the first time in the country.

There are around 70 Malaysian GaN experts carrying out their research in UM, USM, Monash University Malaysia, and UniMAP under the programme. On top of that, the programme has also sent visiting researchers from Malaysia to UCSB as part of the knowledge transfer activities for 6 months assignment (4 researchers per year). As of now, 13 visiting researchers have completed the training and returned to Malaysia to continue the research as well as to guide the local team.

Currently, the programme has successfully replicated Nakamura's laboratories in UM and USM. These 2 laboratories are working at the forefront of research and development in the GaN epitaxy layer for the LED devices. Following to the collaboration with Shuji Nakamura, OSRAM have invested in a front-end epitaxy and provided fabrication facility in Kulim as in-kind contribution. The programme has gathered all local universities' capabilities for the GaN research activities from fabrication, packaging, testing, thin film, to surface characterisation.

Nano-Products Manufacturing

Nano-products manufacturing in four nanotechnology jump-start sectors are projected by NMB to reach RM 1-2 billion market size in 2025.

Table 6: The four jump-start sectors for nanotechnologies development.
Source: NMB 2020

Food & Agriculture	Energy & Environment	Electronic Devices & Systems	Wellness, Medicine & Healthcare
• The Malaysian trade performance for food and agricultural industry was valued at RM 157.4 billion 2019 where RM 69.6 billion stands for export and RM 7.786 billion of imported goods (DOSM, 2019). • The total nanotechnology market size in food and agriculture to reach RM 1.31 billion in 2025 (DOSM, 2019).	• The Malaysian trade performance for energy and environment was valued at RM 16.33 billion in 2019 where 66.7% (RM16.82 billion) are imported goods (DOSM, 2020). • It is expected that the nanotechnology market size in energy and environment will reach RM 2.1 billion in 2025 (DOSM, 2020).	• Electronic devices and systems in Malaysia were valued at RM 576.9 billion in 2019 where 60% (RM 346.6 billion) are exported goods (Malaysia External Trade Statistics, 2019). • It is expected that the nanotechnology market for electronic devices and systems to be estimated at RM 1.78 billion in 2025 (Malaysia External Trade Statistics, 2019).	• The Malaysian health and wellness trade performance was valued at RM 39.9 billion in 2019 where imports and exports are balanced (NMB, 2019). • The total addressable market for nanotechnology application in health and wellness is expected to reach RM 1.93 billion in 2025 (NMB, 2019).

Malaysia Market for Nanotechnology

Nanotechnology products scope is not only tradeable physical tangible products, but also refers to solutions, systems, services, and technology in the form of intellectual property.

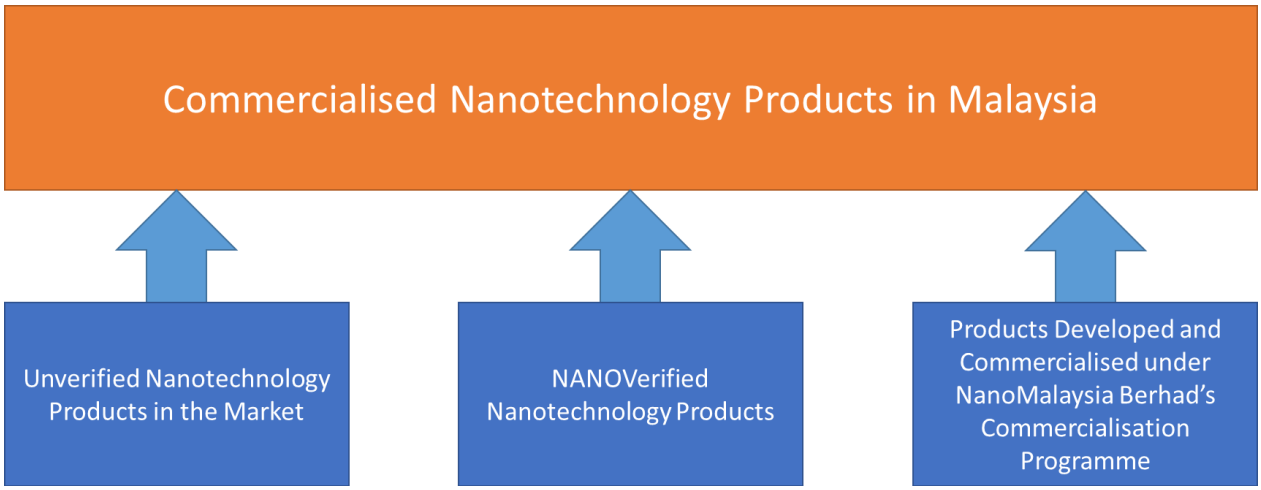


Figure 19: Commercialised Nanotechnology Products in Malaysia.
Source: NMB, 2020

Malaysian nanotechnology products market revenue was valued at RM 322.307 million in 2019 and is expected to grow steadily amid COVID-19 pandemic as nanotechnology serves as a technology-enabler to combat COVID-19. Nanomaterials play a pivotal role as disinfectant and other preventive measures from SARS-CoV-2. For these reasons, it was expected that the revenue from biotechnology, chemical, pharmaceutical, plastic and textile manufacturers to soar despite the challenges ahead.

It was expected that the local nanotechnology scene to reach Compound Annual Growth Rate (CAGR) of 10.9% for the forecast period of 2020-2025 where pharmaceutical and plastic products will dominate the Malaysian market with each of them registering RM 249.46 million and RM 234.72 million, respectively (NMB, 2020).

As the number of verified companies increase through NANOVerify Programme over the next 5 years, it was expected that the revenue and participation from more sectors will be increasing.

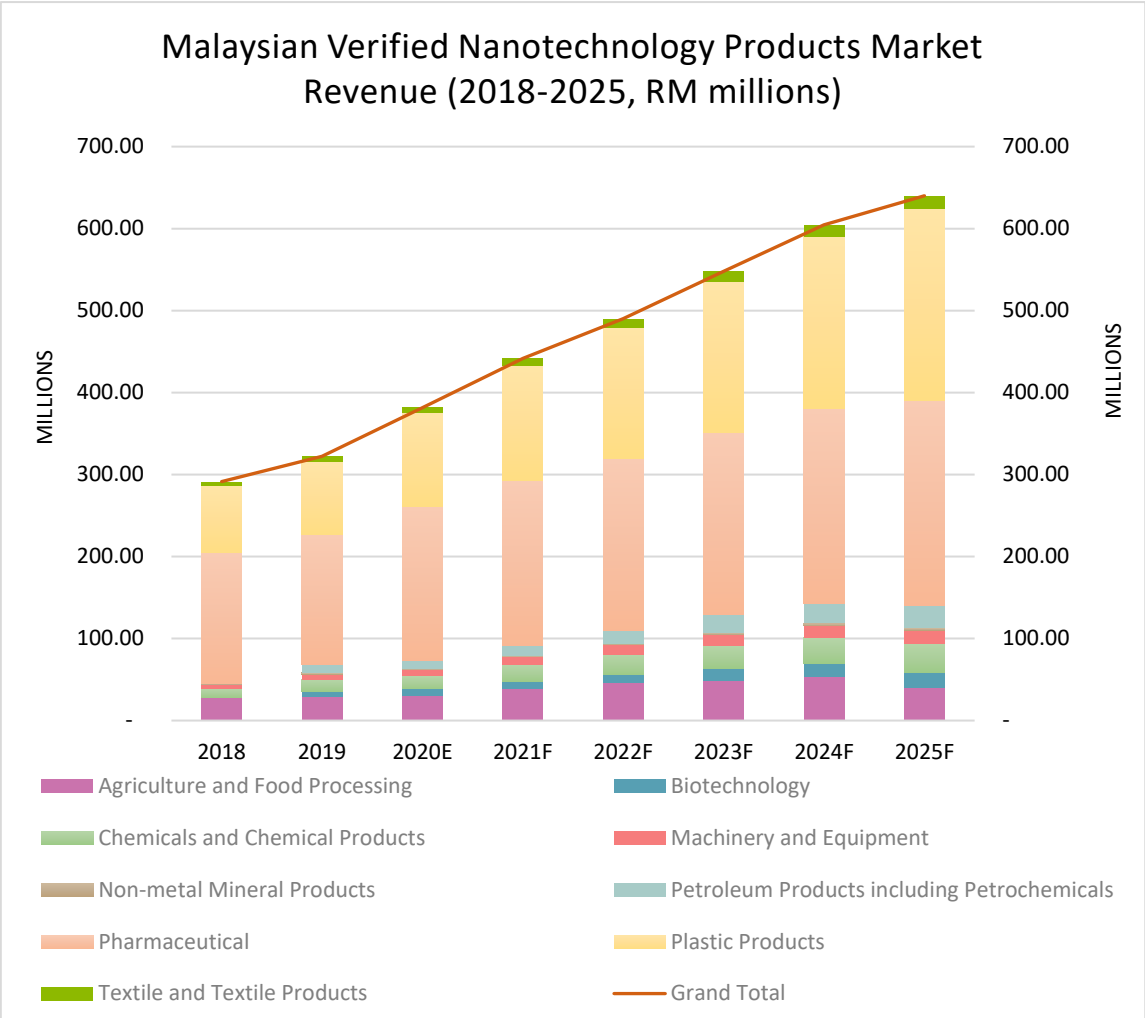


Figure 20: Malaysian Verified Nanotechnology Products Market Revenue.
Source: NMB, 2020

The leading nanotechnology products in Malaysia is currently cosmetics and personal care that covers 63.1% from the overall nanotechnology products.

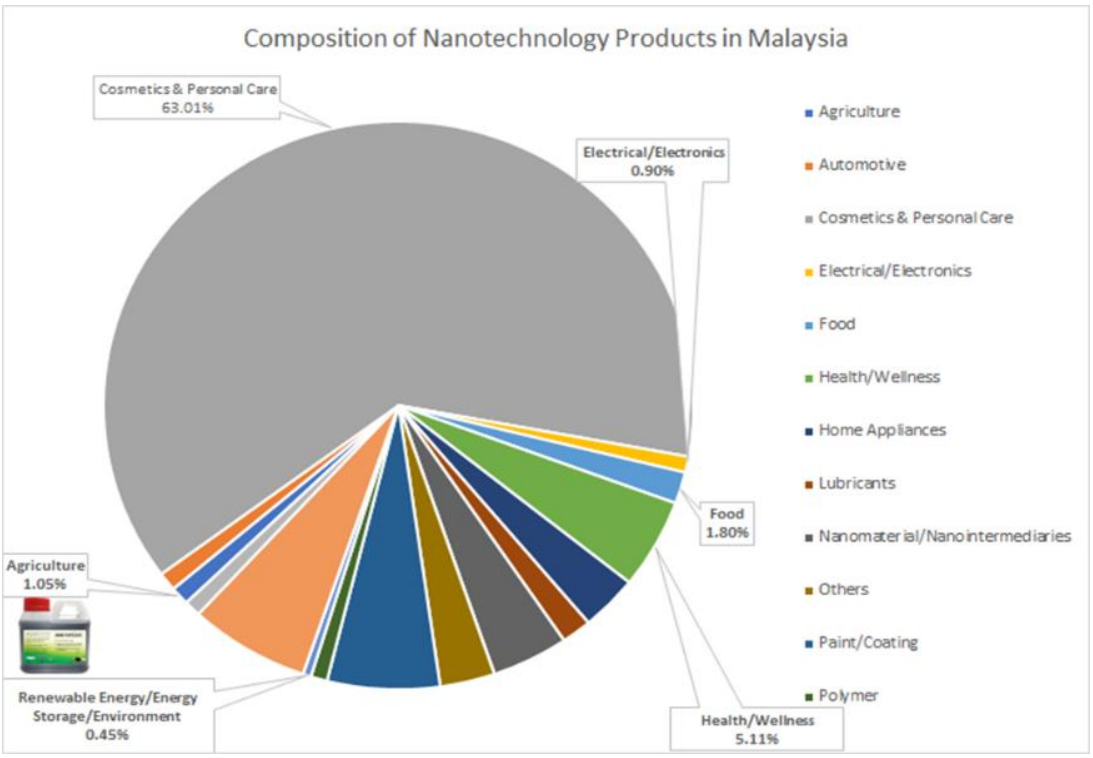


Figure 21: Composition of Nanotechnology products in Malaysia.
Source: NMB, 2020

Several products, services, and technologies were successfully commercialised through NMB programmes which now has reached 87 commercialised products, services, and technologies. From the 87 products, services, and technologies, several companies contributed to more than one Key Jump Start Sector.

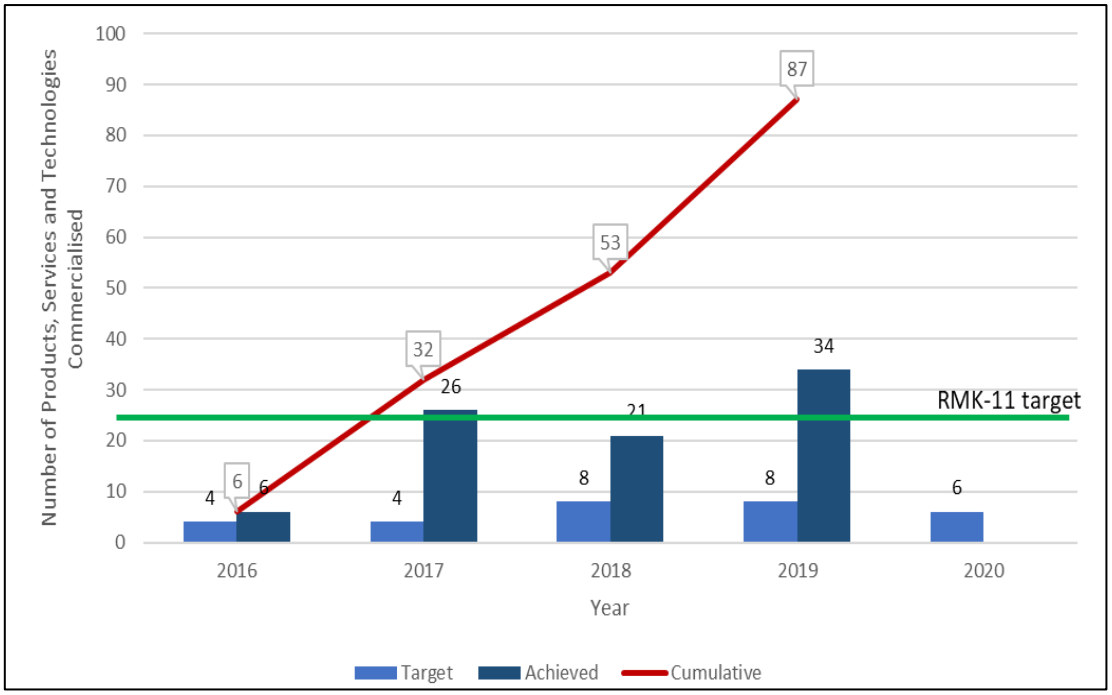


Figure 22: Number of products, services and technologies commercialised.
Source: NMB, 2020

Figure 23 shows the total commercialised product, services, and technologies by the Key Jump sector from NMB, MIMOS and SilTerra Malaysia Sdn. Bhd. Based on the breakdown, the highest products, services, and technologies commercialised is from the wellness, medical and healthcare sector.

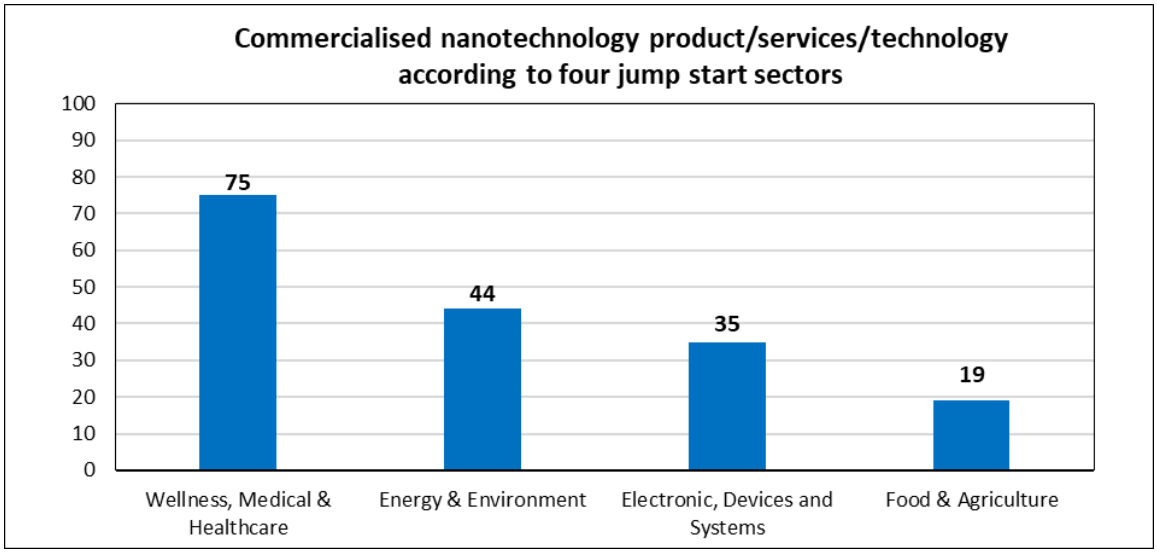


Figure 23: Commercialised nanotechnology products, services, and technologies.
Source: NMB, 2020; MIMOS, 2020 and SilTerra Malaysia Sdn. Bhd., 2020

Commercialisation and Innovation Intellectual Property (C&I IP)

Intellectual Properties (IPs) developed by NMB for commercialisation purposes are the fundamental instruments used to drive NMB's nanotechnology commercialisation agenda.

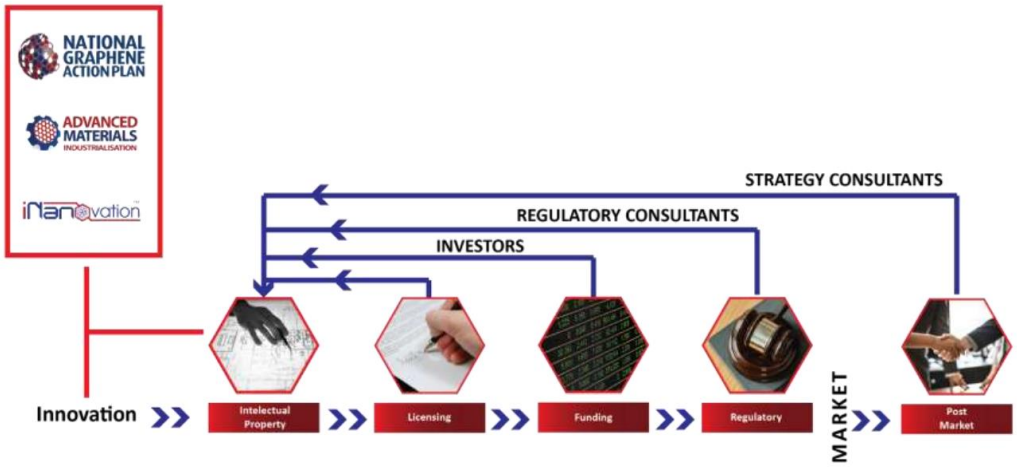
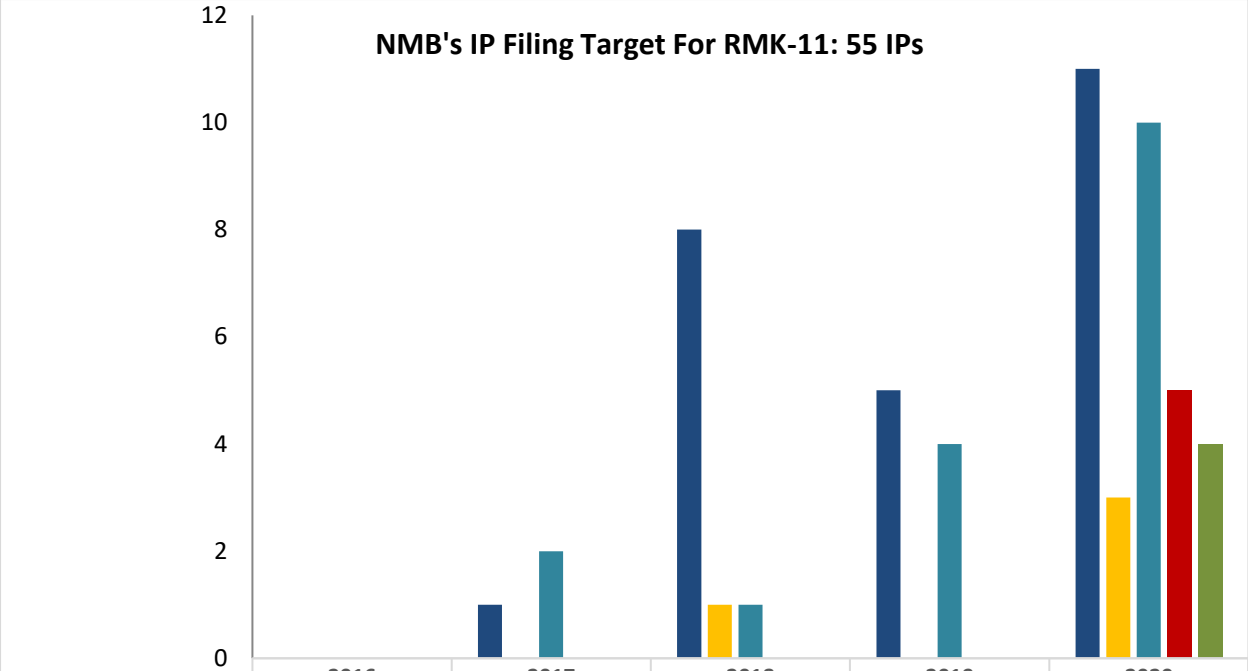


Figure 24: Development of C&I IP by NMB.
Source: NMB, 2020

By developing and protecting the IPs produced from the product development and some scale-up projects, NMB can use these IPs for creation of business opportunities in joint venture exercises through licensing and assigning in consideration for shares, generating income for SMEs through royalty payments and licensing fees, as background IP for developing new, more valuable foreground IPs, and as a form of collateral for project investment.

Through the 11th Malaysia Plan, nanotechnology commercialisation programmes, National Graphene Action Plan, iNanovation and Advanced Materials Industrialisation, NMB has thus far managed to develop and filed 55 IPs.



	2016	2017	2018	2019	2020
Patent	0	1	8	5	11
Utility Innovation	0	0	1	0	3
Copyright	0	2	1	4	10
Trademark	0	0	0	0	5
Trade Secret	0	0	0	0	4

Figure 25: Intellectual Properties filed by NanoMalaysia Bhd. with MyIPO.
Source: NMB, 2020

Funding

NMB's nanotechnology commercialisation programme funding is available to industry, including university spin-off companies and private start-ups. In a typical product development project, NMB will fund up to RM 500,000, and for scale-up projects, the limit is RM 1 million.

Further investment by NMB will be depending on the type, scale, and complexity of the project, with the industry partner being the beneficiary of the project to commercialise the resulting product or technology. Upon recouping the investment sum over the years or through joint ventures and other repayment methods, NMB will assign the developed IP to the industry partner for their further exploitation. NMB will then take a venture builder approach in which NMB co-ideates and co-creates the innovation and the business entity required as well as develop corresponding ecosystem to successfully commercialise the end-product.

In 11th Malaysia Plan, the government has invested RM 80 million through MOSTI and MITI for 5 years NMB nanotechnology commercialisation programmes.

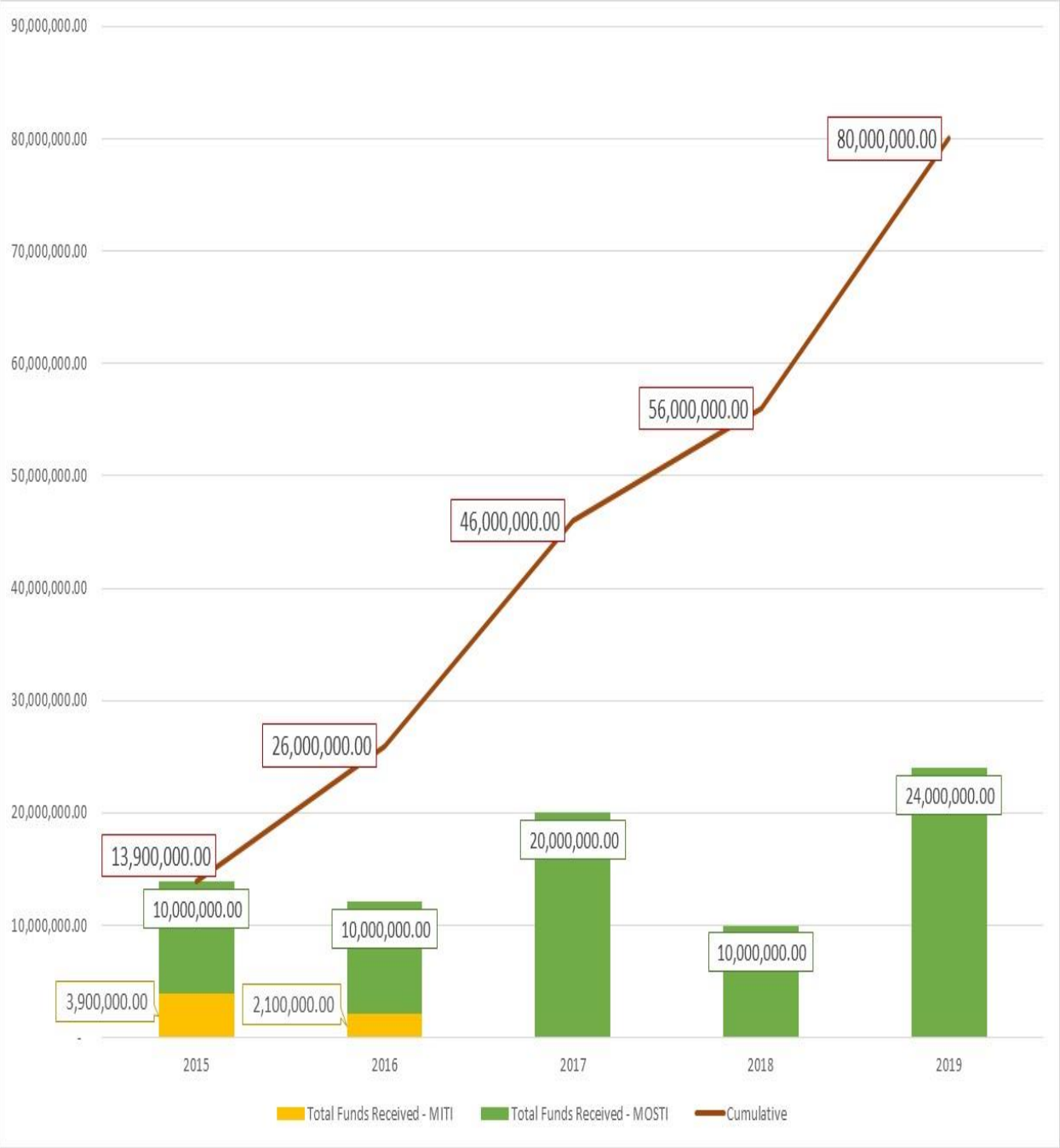


Figure 26: Funding amount for commercialisation for NanoMalaysia Berhad programmes
Source: NMB. 2020

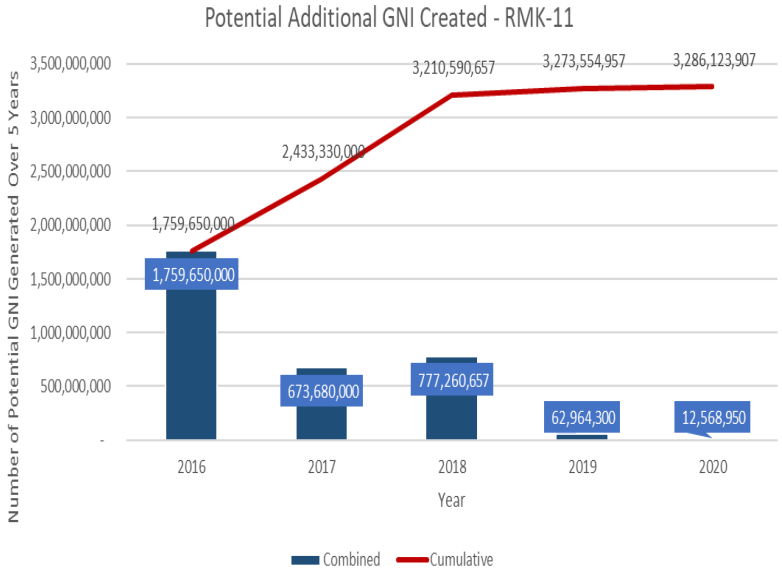
Besides NMB, MIMOS and SilTerra Malaysia also has received fundings to commercialise their nanotechnology products. The fundings received by NMB, MIMOS, SilTerra Malaysia, and CREST are shown in Table 7.

Table 7: Type of funding and number of commercialised product/ services / technologies from 2006 – 2020.
Source: NMB, 2020, CREST, 2020, SilTerra Malaysia, 2020, and MIMOS, 2020

No.	Year	Details of funding	Number of Commercialised product/ services/ technologies	Amount (RM million)
1.	2006 - 2020	The fundings are given for 4 MIMOS Commercialisation programmes: a) Nanoelectronics b) Ubiquitous NEMS-based Sensor Network & Solution c) Graphene Platform for Advanced & Flexible Nanoelectronics d) Establishment of National Nanoelectronics Shared Infrastructure	23	143.86
2.	2015 – 2019	NanoMalaysia Berhad: In RMK-11, NMB received fundings from MOSTI and MITI	144	80.00
3.	2015 – 2020	SilTerra Malaysia: Domestic Investment Strategic Fund from MIDA	6 products under the Electronic, Devices and Systems that has application in the other 3 jumps start sectors as well.	40.00
4.	2016 – 2020	CREST: Gallium Nitride on Gallium Nitride (GaN-on-GaN) program. Project funding breakdown: (62.8% from CREST, 22.2% from university and 15% from industry)	Project under product development phase.	123.3
Total			**173**	**387.16**

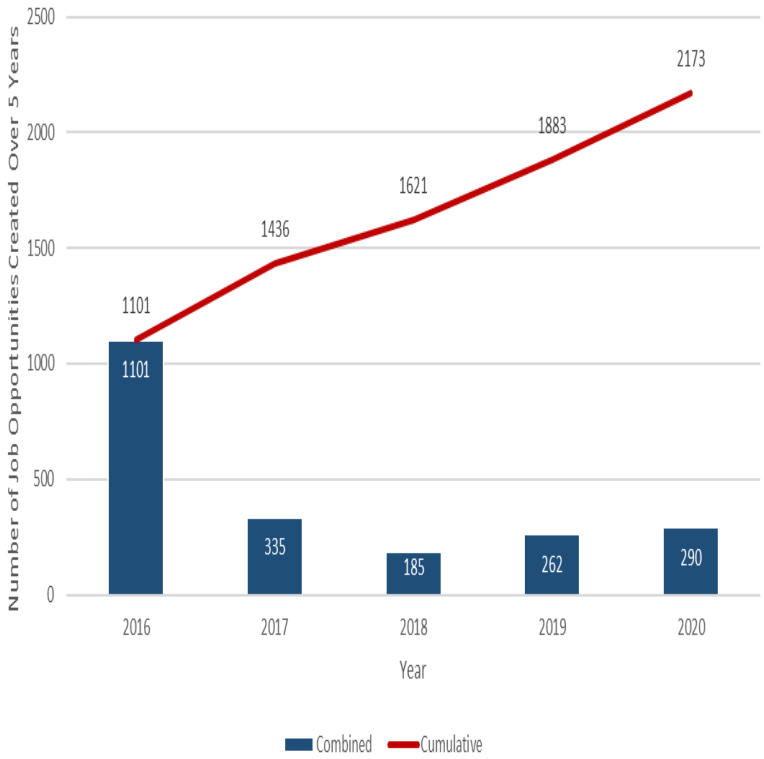
From the investment, NMB has surpassed the targeted key performance indicators (KPIs) where it has generated RM 3,286,123,907 potential additional Gross National Income (GNI) and created 2,173 potential job opportunities over the 5 years of its programme implementation. Furthermore, its NANOVerify programme has increased the company's revenue to RM 126.2 million and reach 13 % local market penetration.

While for SilTerra Malaysia, around 20 % extra capacity were gained to develop, and mass produce fabricated wafers for the global market. The annual revenue of SilTerra Malaysia fluctuates between RM 400 million and RM 600 million. Therefore, estimation of the contribution from the grant of RM 40 million between 2015 – 2020 to SilTerra's annual revenue translated to about RM 24 million – RM 36 million a year (6 %) from total revenue.



Direct from Projects	National Graphene Action Plan (MYR)	iNanovation (MYR)	Combined (MYR)
2016	1,266,500,000	493,150,000	1,759,650,000
2017	660,000,000	13,680,000	673,680,000
2018	771,077,557	6,183,100	777,260,657
2019	53,800,000	9,164,300	62,964,300
2020	tbd	12,568,950 (as of 12 Sep 2020)	12,568,950 (as of 12 Sep 2020)
TOTAL (as of 12 Sep 2020)	**2,751,377,557**	**534,746,350**	**3,286,123,907**

Figure 27: Potential additional GNI over 5 years as identified by industry.
Source: NMB, 2020



Direct from Projects	National Graphene Action Plan	iNanovation	Combined
2016	985	116	1,101
2017	297	38	335
2018	177	8	185
2019	177	85	262
2020	tbd	290 (as of 12 Sep 2020)	290
TOTAL	**1,636**	**537**	**2,173**

Figure 28: Potential job opportunities over 5 years as identified by industry.
Source: NMB, 2020

Figure 29: Achievement of NANOVerify programme
Source: NMB, 2020

Facilities & Infrastructures

In term of facilities and infrastructures, NMB offers four facilitation programmes to help nanotech companies, start-ups, and SMEs to develop and commercialise their nanotech-based products, services, systems and technology. The current progress and achievements are as detailed in Table 8.

Table 8: Progress and Achievements of NMB Facilitation Programmes

National Graphene Action Plan	iNanovation	Advanced Materials Industrialisation	NANOVerify
• Commercialisation programme focusing on graphene applications and a high value-add manufacturing enabled by graphene. • IPs in five application areas which are lithium-ion battery anodes / ultracapacitors, conductive inks, rubber additives, plastic additives, and nanofluids. • From 2016 until 2019, there were 29 completed projects and 15 ongoing projects under the NGAP facilitation programme. • In 2020, the NGAP programme has extended into new applications, e.g: nanosensors, radio frequency (RF) devices, lasers, etc.	• Provides enterprises and start-up companies in the nanotechnology space with the support they require to grow their business. • Achieved through the introduction of new nanotechnology-enabled processes and materials, to enable the transformational shift from conventional industries to nanotechnology-enabled industries.	• Creates technology platforms and industrial laboratories for Small, Medium and Large Enterprises to improve their products by adopting advanced materials and primarily for the E&E sector. • Operated over two years (from 2016 to 2017), the programme uses an open innovation platform to create new IPs that could be easily pivoted from one sector to multiple other sectors, for instance, a battery management system was developed for an electric scooter which could be easily deployed in various applications that require remote monitoring of battery condition.	• Ensure nanotechnology products and applications developed by SMEs in Malaysia adhere to global best practice expectations and requirements. • NanoMalaysia has collaborated with SIRIM QAS International, and is aligned with the requirements set by Standards Malaysia in conducting the voluntary nanotechnology certification programme known as NANOVerify

As for physical infrastructure, NMB does not own laboratories or research centres, but leverages on assets and equipment at universities and research institutes via contract research arrangements, and also utilise assets, IPs and resources from the technology recipient in a project framework where the contribution of the industry partner (or technology recipient) is acknowledged as in-kind contribution into the project, smoothening the process to embark on new projects and form joint ventures or Special Project Venture (SPV).

As seen from Figure 30 below, NMB and NNC provide the joint Coordination and Governance over the activities for nanotechnology commercialisation – NNC is focused on fundamental research in universities and research institutes, while NMB carries output of that said research into the market.

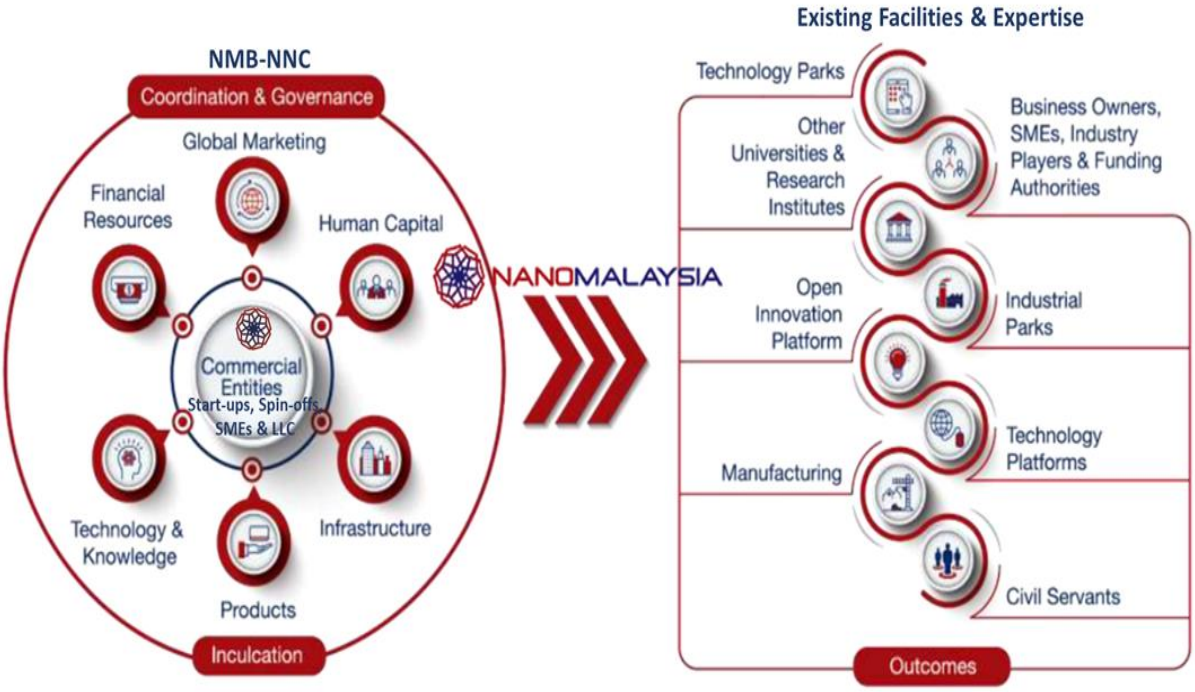


Figure 30: NanoMalaysia Berhad commercialisation ecosystem
Source: NMB, 2020

Despite the current success of NMB programmes, there are room for further improvement in nanotechnology commercialisation of the country. Among others that highlighted by stakeholders especially industries are lacking in local nanotechnology products demand and requires more vibrant investment and facilitation for nanotechnology commercialisation.

Standard, Safety and Regulation

Malaysia is committed towards the responsible use of nanotechnology to ensure prosperity, general well-being, and security for the *Rakyat*. Under the 11th Malaysia Plan, MOSTI embarked on a National level Benchmark Study for the Safety Risk of Nano-Based Products (2020-2023) which is a 3-year project to gather safety data on nano-based products in the local market. This project aims to a establish a benchmark towards risk assessment of nano-based products which will ensuring sustainable development of nanotechnology industry in Malaysia.

From this project, NNC also aims to establish an inventory of nano-based products in the local market which will be made accessible to the public. This inventory will also function as a database that provide information on health, safety and environmental aspects that lead to risk assessment of the nano-products. Analysis will be done based on four economic sectors: Food and Agriculture; Energy and Environment; Wellness, Medical and Healthcare; and Electronics, Devices and Systems. Findings from this project will be used to assist the relevant regulatory authorities on the proposals for benchmarking.

The NNC will continue to follow the development of Nanosafety practice in the developed countries and will play a role in harmonising the practice across ASEAN.

Nanotechnology has influenced a broad range of processes and occupational settings. In 2018, the Department of Occupational Safety and Health (DOSH) has published a Guideline on Control and Safe Handling of Nanomaterial to provide guidance and recommendations on safe handling and control of nanomaterials at workplace. This guideline is expected to minimise or help eliminate occupational illness due to hazards associated with the nanomaterials. This guideline also provides basic information on the toxicity of nanoparticles and potential hazard of nanomaterials to the safety and health of employers and workers. To ensure that nanotechnology products and applications developed by SMEs in Malaysia adhere to the global best practice expectations and requirements, NMB has collaborated with SIRIM QAS International in conducting the voluntary nanotechnology certification programme that aligned with the requirements set by Standards Malaysia known as NANOVerify.

Malaysia has been actively participating in ISO/TC 229 Nanotechnologies meetings since its formation in 2005. This technical committee comprising of 37 participating member and 18 observing member countries have published a total of 81 ISO standards on nanotechnologies with additional 34 standards that currently under development. Malaysia has adopted 3 ISO standards on nanotechnology as: MS ISO/TS 10867:2012 (Nanotechnologies - Characterization of single-wall carbon nanotubes using near infrared photoluminescence spectroscopy), MS ISO/TS 11251:2012 (Nanotechnologies - Characterization of volatile components in single-wall carbon nanotube samples using evolved gas analysis/gas chromatograph-mass spectrometry) and MS ISO/TS 13830:2018 (Nanotechnologies - Guidance on voluntary labelling for consumer products containing manufactured nano-object).

Standards Malaysia has since 2019 managing 25 National Standard Committees (NSC). Nanotechnology was placed under the Chemicals and Materials (NSC B) category known as the TC/B/15 Nanotechnologies. The 4 working groups under TC/B/15 Nanotechnologies are responsible in looking at Terminology and Nomenclature, Measurement and Characterization, Health, Safety and Environmental Aspects of Nanotechnologies, and Material Specifications. To date, there are 562 Malaysian Standards developed under NSC B. National standards are usually developed and published by the Standards Malaysia upon request by industries. Application of standards by industries, businesses or consumers are on voluntary basis. Compliance to a standard will only become mandatory when it is included in any act or technical regulation. Once the standard become mandatory, the relevant regulatory authorities are responsible in ensuring the implementation and compliance of the standard by industry, business, and government.

Malaysia has also submitted 2 proposals to lead national standard at ISO level which is the ISO/TC 229/WG 3 Nanotechnologies – Health, Safety and Environment aspects and ISO/TC 229/WG 5 Nanotechnologies – Cosmetics. The project is expected to be registered in 2021. The draft ISO document will be reviewed by experts on safety, health, and environment aspects of nanotechnology.

In 2006, the OECD established a programme to promote international co-operation in human health and environmental safety aspects of manufactured nanomaterials. Accepted in the OECD Mutual Acceptance of Data (MAD) system, Malaysia has since 2016 began attending the OECD Working Party on Manufactured Nanomaterials (WPMN) meetings and committed to continue participation in the programme to ensure responsible development of nanotechnology in the country.

Nanotechnology and manufactured nanomaterials have been listed among the eight emerging policy issues under UNEP's Strategic Approach to International Chemicals Management (SAICM). The Ministry of Environment and Water (KASA) that represents Malaysia in SAICM meeting and MOSTI as the national focal point for the meeting are responsible in updating issues pertaining to nanotechnology and manufactured nanomaterials at the national level. Besides that, NNC is also responsible to take mitigation steps to ensure policy issues on nanotechnology are addressed according to the international practices.

NNC and NMB are among the 13 organisations across nine countries that involved in the setting- up of Asia Nano Forum (ANF). The member countries have collaborated through 4 working groups: Standardisation; User-facility Network; Nano Safety and Risk Management; and Commercialisation in advancing nanotechnology industry of respective country.

NNC also participated in the 3rd Eu-Asia Dialogue on NanoSafety in Thailand. Through this event, experts from Asia and Europe were gathered to share knowledge on the safety of nanotechnology and establish thematic collaborations.

The collaborations had enabled NNC to organise events with international partners that targeted at regional collaborations, namely the Seminar on the Management of Chemicals and Nanomaterials (with OECD EHS & WPMN, September 2016), Nanotechnology for Safe and Sustainable Development Conference (UNESCAP Asian and Pacific Centre for Transfer of Technology, May 2017), Nanosafety Seminar (during ANF Summit Meeting, August 2017) and Nanosafety Course (UN Institute for Training and Research, November 2018).

Currently the issues concerning to the standard, safety and regulation in nanotechnology are:

1. **Lack of awareness on standards, safety, and regulation specific for Nanotechnology**
   Industries that manufacture nano-related products have low awareness on the importance of nano-related standards for their products. Most of them are hesitant in adopting and implementing the standards due to the perception it will complicate their manufacturing process, increase the manufacturing costs and make their products less price competitive. They were also of the view that non-compliance to the standards will potentially affect their product certification that led to the problem in product acceptance and market penetration. Most of them are not familiar on the commercialisation benefits that comes together with the nano-related standards and certification. Therefore, this has contributed to the low adoption or application of nanotechnology standard and certification. Without demand from industries, Standards Malaysia will not be able to develop nano-related standards as the standards will only be developed upon request from industries.

   While on consumers' part, they need to be educated on the health and safety impact of nanomaterials in products. Certified nano-products which comply to nano-related standards provides assurance to the consumers on the safety and benefit of the products. This implies on the need to educate both manufacturers and end-users on the importance of nano-related standards.

2. **Lack of robustness for nanotechnology certification in leveraging on the advantages of certification for country's revenue generation**
   In Malaysia, the current certification is limited to certifying the presence and size of nanomaterials in products. Concerns on health, safety, environment, and regulatory issues have emerged as key barriers to the commercialisation of nanotechnology-based products. While Occupational Safety and Health Act only covers nanomaterials or activities involving nanomaterials at workplace. To date, there is no act that cover the whole spectrum of nanotechnology activities especially on the standard, safety and regulation. Therefore, it is important for nano-related standards, safety and regulations to be included in the relevant acts to address the ecological, health and safety aspects for environment and consumers. At the same time, it is timely for this nanotechnology certification opportunities to be leveraged for revenue generation for the country.

Issues and Challenges

From the stakeholder engagements organised by the NNC, the issues and challenges that were raised are revolve around the main issues that were also mentioned in STI of the country. Among others, the governance of national nanotechnology, innovation ecosystem, funding and commercialisation of local nanotechnology products, services, and technologies.

In overall, the main issues and challenges that need to be addressed on national nanotechnology to drive the national economy agenda of the country towards 2030 are as follows:

1. Disconnected ecosystem and unclear governing and coordinating body in setting the direction, coordinating, and monitoring the national nanotechnology agenda. This leads to weakness in terms of governance systems that is mandated in managing the resources efficiently and raise the return of investment (ROI).
2. The pathways from laboratory research to successful commercialisation remained a challenge due to barriers such as absence of a standardised priority areas, dedicated funding, monitoring process on the progress of the project till it is taken up by industry for commercialisation.
3. Disconnected information between the main key players that involve in the supply chain. Most of research that funded by the government are not taken up by the industry for commercialisation. While information from market analysis and feedback is not shared to researchers to ensure the technologies and products developed are aligned with market needs. This resulted to most of research unable to be commercialised and industry remained lack of competitiveness due to low technology adoption.
4. While in term of standards, safety, and regulation, the issues are mainly due to the lack of awareness on standards and lack of robustness in leveraging nanotechnology certification for country's revenue generation.

Table 9: Summary issues and challenges raised in stakeholder engagements organised by NNC. *Source: NNC, 2020*

Ecosystem & Governance	Research & Development	Commercialisation
• Disconnected ecosystems in supporting the overall nanotechnology implementation, development, and innovation ecosystem. • Unclear governing and coordinating body in setting the direction, coordinating, and monitoring the national nanotechnology agenda.	• No standardised and strategic priory areas for nanotechnology at national level in guiding the direction of R&D&C&I in the country. • Low R&D commercialisation and technology acquisition due to lacking in commercial viability, involvement of industry at the of innovation process as well as failure in meeting the market and industry's need. • Lack of dedicated nanotechnology R&D&C&I funding in driving nanotechnology agenda of the country. • Lack of sharing and improving R&D facilities and infrastructures towards a world class facility and infrastructure for nanotechnology R&D&C&I. • Lack of partnership and collaboration in R&D&C&I nationally and internationally as well as with industries.	• Industrial R&D ecosystem lacks strategic focus, has weak linkages between key stakeholders, poor knowledge sharing culture, and weakness in technical education and training ecosystem that limits their adaptive and innovative capabilities. • Lack of vibrant investment and facilitation of nano-technopreneurs and start-ups. • Lack of novelty of new products from both services and manufacturing sectors since majority of industries are SMEs that not innovators. • Lack of demand for Malaysian nanotechnology products and services both nationally and internationally. • Lack of strategic marketing platform in driving penetration of markets.
Talent	**Standard, Safety & Regulation**	**Promotion & Enculturation**
• Lack of total S&T talent planning and development to move STI agenda that also affecting nanotechnology's talent pool and the demand. • Lack of effective approach in developing and attracting nanotechnology talent.	• Lack of awareness on standards, safety, and regulation for commercialisation. • Lack of robustness for nanotechnology certification in leveraging on the advantages of certification for country's revenue generation.	• Lack of appreciation and awareness on nanotechnology in all levels of community.

Chapter 3: National Nanotechnology Policy and Strategy

Background of the Policy

The National Nanotechnology Policy and Strategy (NNPS) 2021-2030 is a long-term strategy document designed to drive the national socio-economy agenda of the country towards 2030.

To fulfil this aspiration, a dynamic nanotechnology ecosystem will be established to ensure all segments of the governance, research institutions, universities and industries can benefit from it and explore their potential in nanotechnology.

Policy Statement

"Malaysia: Shaping the High-Tech Nation 2030".

Vision

- Nanotechnology: Shaping the High-Tech Nation 2030

Mission

- Mainstreaming nanotechnology in daily life.
- Nanotechnology as an enabler in a multidisciplinary field in support of a broad-based technology to reach mass use by 2030.
- Nanotechnology to enhance societal and environmental well-being.
- Nanotechnology for sustainable national development of science, technology, industry and economy.

Objectives of the Policy

1. To enable cross-sectorial and sustainable development through nanotechnology.
2. To increase nanotechnology's economic contribution via dedicated research, technology and product development, talent and commercialisation activities.
3. To facilitate the growth of the local nanotechnology industry through specific programmes and action plans.
4. To establish a comprehensive safety and regulatory framework for the development of nanotechnology.

The Policy and Strategy

NNPS 2021-2030 outlines 4 strategic thrusts and 15 strategies towards providing strategic direction and strengthening national nanotechnology of the country.

Strategic Thrust 1: Strengthening Ecosystem and Governance

Strategy 1.1 - Nurturing and developing a conducive and connected nanotechnology and innovation ecosystem.

The ability to innovate and contribute to value creation through a robust nanotechnology ecosystem is a key indicator of competitiveness of the nation and will feature more prominently over the next decade. Nanotechnology has the potential to propel the socio-economic status as it is an enabler for cross-sectorial and sustainable development of the nation. As such, it is imperative that we both define and strengthen the role that nanotechnology can play in socio-economic development. To achieve this, collaboration, partnerships, and networks are powerful mechanisms for sharing expertise and strategies. Hence, there is a need to identify and redesign a complete nanotechnology ecosystem by adopting a collaborative network strategy (***Figure 31***)

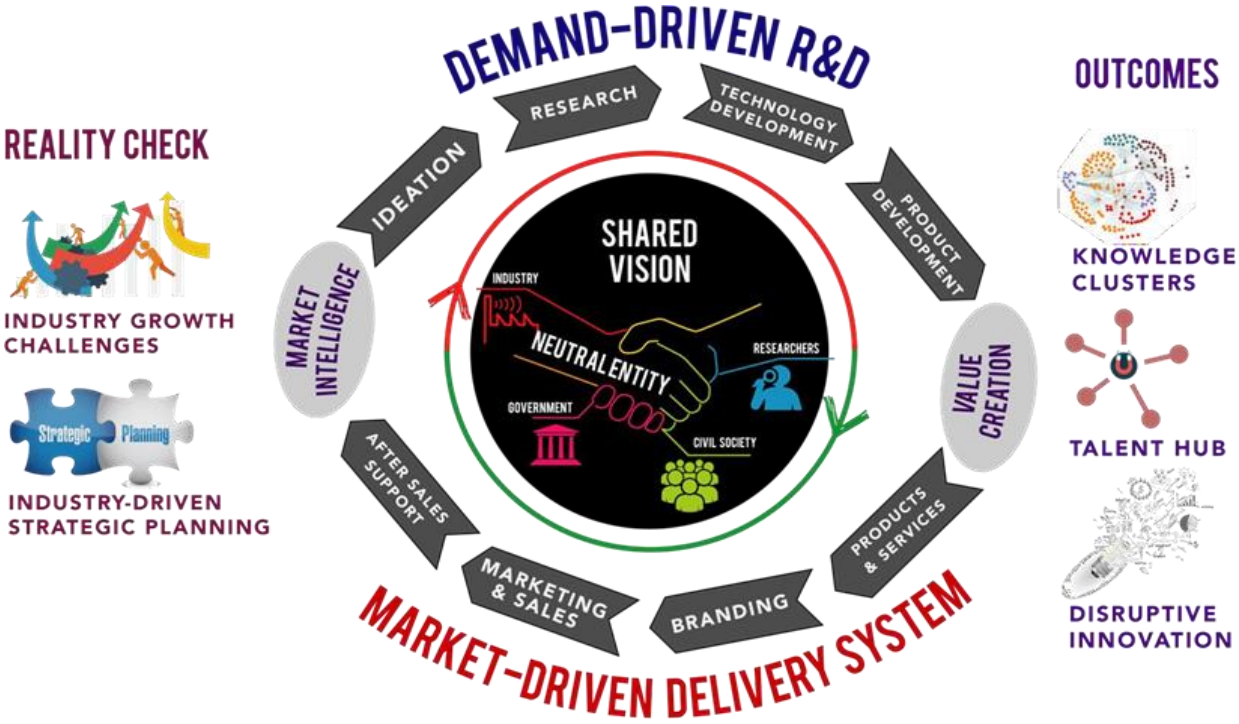


Figure 31: The collaborative network
Source:ASM, 2017a

The collaborative network is an alliance of several quadruple helix organisations that are essentially independent, geographically dispersed, and heterogeneous in terms of their operating environment, culture, social capital, and priorities, but will work together to help achieve shared or compatible goals. There needs to be a well-defined collaboration network to serve emerging markets and expand global reach.

The core of collaborative network is a shared value that forms a conducive ecosystem for disruptive innovation. Drivers who are industry players and researchers will be connected to enablers among the government regulatory bodies, institutions of higher learning and civil society to catalyse the genesis of ideas leading to disruptive innovations at a very dynamic pace.

This collaborative network will make it possible for market information as well as nanotechnology knowledge to be applied creatively to realise value and result in products and services that are unique and differentiated. This collaboration will also enable risk sharing and thereby lowering the risks and barriers faced by each player. This also reduces reluctance to participate in innovative initiatives and makes it easier to enter new global markets.

Dynamic industry-led, people-driven interactions will give rise to knowledge clusters and a talent hub. Malaysia will not only be able to create demand for local high-skilled talent and knowledge workers but also be able to tap into talents throughout the region. Gathering the right talent is vital to realise the full potential of the collaborative network.

This collaborative network will enable Malaysia to effectively realise demand-driven R&D and offer an enhanced value proposition to customers based on data-driven market intelligence. This collaborative network will also enable Malaysian industries to incorporate rich nano-based knowledge content into their products and services, make Malaysia a knowledge hub, and draw global talent into our innovation ecosystem.

This hub will finally have exceptional capacity to turn creative ideas rapidly into useful innovations. As the collaborative network brings together players from R&D and the market, two mutually reinforcing activities take place. The R&D community brings value creation which is brought to the market as knowledge-based, high value products and services, while market intelligence from market players feed into the R&D community for demand-driven R&D.

The above self-sustaining ecosystem will complement collaborate network to perpetuate innovation and growth. Each identified element is expected to complement each other. This synergy will be critical to move nanotechnology and the nation forward in the face of a highly challenging global environment.

The next step would be to weave the elements of the ecosystem into a coherent series of action plans and manage their interactive dynamics.

Figure 32: Components of National Nanotechnology Ecosystem
Source: National Nanotechnology Centre (NNC), MOSTI

The National Nanotechnology Ecosystem integrates various components for optimal growth. Therefore, to develop the industry in an integrated manner, we must understand the role of each component within the ecosystem as shown in Figure 32.

Global Marketing

Malaysia must market its companies, products, solutions, and capabilities globally to ensure an optimal spread of risks and revenue streams. To an extent, we can emulate the global marketing strategies adopted by the MPOB (palm oil) and PETRONAS (oil and gas) and adapt them to promote nanotechnology. Malaysia can be a global leader in green nanotechnology by leveraging upon its huge natural biodiversity and plantation industries. This should be complemented with technologies from traditionally strong sectors such as electronics, ICTs and services. It is suggested that Malaysian-based technologies must therefore be synonymous with premium green nanotechnology products and services.

Commercial Entities

We need commercial entities that will support our global nanotechnology goals. These will be new companies created through various initiatives such as:

- Nanotechnology Entrepreneur Development Programme
- GLC Investment Programme
- MNC Investment Programme

These programmes will ultimately ensure that the right nanotechnology products are developed and commercialised by companies either based in Malaysia or owned by Malaysians.

Products

The development, commercialisation and marketing of niche nanotechnology products should be supported by proven Research & Technology / Product Development (R&TPD) capabilities in key sectors such as:

- Agriculture and Food
- Energy and Environment
- Electronics, Devices and Systems; and
- Wellness, Medical and Healthcare.

The success of the national nanotechnology agenda will depend on initial momentum and these sectors are poised to provide it.

Technology and Knowledge

Nano-products must be generated from either indigenously developed technology (make-some concept) or through strategic acquisitions (buy-some approach). To translate this into reality, two key initiatives are required:

- The National Nanotechnology R&D Programme; and
- The Nano Technology Acquisition Programme.

Both these initiatives balance local strategic imperatives and the need to develop local products and technologies in the shortest possible time.

Infrastructure

Local nanotechnology facilities and laboratories that undertake research and development activities need to match the best in the world, as they will determine the success of niche Malaysian products, industries and markets. For this, National Nanotechnology Laboratory Network has been selected to be the main platform to perform latest and high-end research on nanotechnology in Malaysia. Universities, research institutions and industries will be the key players in undertaking research and development activities. The National Nanotechnology Centre (NNC) is proposed to be established as a nanotechnology excellence hub for the nation.

Human Capital and Talent Development

As a knowledge-driven area, it is important to invest in qualified personnel as well as develop training and educational programs in nanotechnology. Nanotechnology professionals need to be creators as well as adaptors of new technologies. This requires a paradigm shift. Our local expertise may have to build a network with foreign counterparts through various tech-based incentives to maintain a global level of competence.

Financial Resources

Adequate financial resources will maintain growth momentum in the nanotechnology sector. Financial resources will be especially needed for:

- R&D Funding (for R&D and infrastructure)

- Investment (for commercial development)
- Governance (planning, coordination, monitoring, regulatory compliance, health, and safety).

It is proposed for the direct connection and involvement of National Nanotechnology Coordinating Body with Research Management Centre (RMC) that is currently managed by the government to ensure strategic and sustainable funding for nanotechnology in Malaysia both in R&D and commercialisation.

Coordination and Governance

A strong national planning, coordination, monitoring, and enforcement authority is needed to lead nanotechnology development in Malaysia. It must be empowered with clear mandates on legal and regulatory matters and powers to develop a competitive and resilient sector. It is also must be adequately financed to enable and accelerate any necessary strategic transformation for Malaysia.

Regulatory and Safety

Nanotechnology is a field that involves particles, structural arrangements, functionality, and systems that cannot be visualised by the naked eyes. It is inevitable that many issues concerning health, safety, and environment (HSE) will be raised with regards to the use of nanomaterials. Industry players and personnel must be trained, certified, and monitored to ensure that HSE issues are inclusively and comprehensively addressed. As such, an inclusive and comprehensive Health, Safety and Environment Management Framework must be established with full statutory, regulatory and enforcement powers.

Inculcation

There is a need to create general awareness on nanotechnology and nanoscience to optimise its benefits. This will enable every Malaysian to appreciate nanotechnology as a:

- Everyday reality
- Business sector
- Career choice
- Fundamental science
- Evolutionary Technology
- Safe solution to socio-economic challenges.

This awareness needs to be communicated in a sustained manner through a conscious plan, so that Malaysians will embrace nanotechnology, just as they have done with ICT.

Collaboration and Smart Partnership

Smart Partnerships deliver win-win outcomes for nanotechnology. Nearly every national nanotechnology master plan advocate integrated cross-sectoral and cross-border collaborations and partnerships. This fulfils respective national nanotechnology agendas and the flourishing of nanotechnology industries in the speediest and most cost-efficient manner.

Finally, developing the local pool of knowledge and expertise will support home-grown innovations to address national priorities and ultimately allow Malaysia to compete globally both in commercial and scientific terms. As it is known, innovation requires collaboration,

ideation, implementation and value creation. Therefore, a collaborative network between government, academia, industry and civil society needs to be implemented to develop and promote home-grown, high-value innovations. This will create shared value for stakeholders to deliver an economic and social return on investment and differentiate Malaysia as one of the preferred destinations for nanotechnology-related innovations.

Strategy 1.2 - Institutionalising and strengthening the national nanotechnology governance.

The National Nanotechnology ecosystem can be strengthened through the institutionalisation of nanotechnology governance structure, which covers legislative and regulatory aspects, ministerial level, coordinating and supporting bodies as well as the R&D performers by formulating and forming national nanotechnology governance.

The nanotechnology landscape is complex and includes a variety of public and private entities. This intricate landscape requires re-organisation of these major nanotechnology entities for better coordination, monitoring and evaluation. All parties or entities across the national nanotechnology ecosystem must work together within a collaborative network.

Having a robust institutional framework enables efficient nanotechnology governance and management. A well-defined monitoring and evaluation mechanism eliminate lapses, duplications, and obsolete elements in the national nanotechnology landscape. Introducing legislative and regulatory support in the structure ensures sustained commitment by the government. Ultimately, effective nanotechnology governance sets the stage for a dynamic and empowering nanotechnology ecosystem.

In order to have a clear and overarching national strategic direction for nanotechnology with integrated actions across ministries, agencies, industries and communities, there is an urgent need for the re-organisation of the current nanotechnology governance structures. For this to happen, we should empower a centralised nanotechnology co-ordination and monitoring body that will transcend all ministries to create greater stakeholder participation, integrated implementation, evidence-based decision making and national level monitoring and evaluation of nanotechnology. It is proposed for the governance framework as per detailed in Figure 33.

National Science Council (NSC)

NSC is chaired by YAB Prime Minister Malaysia and Division of Strategic Data and Foresight Technology Division (DSF), MOSTI as the secretariat. The function of NSC is to set the direction of science, technology, and innovation policies in national development strategies.

High Technology Nation Council

This council is chaired by YB Minister MOSTI while DSF, MOSTI and ASM are the secretariat. The function of High-Tech Nation Council is to provide strategic direction on the current and future technology developments that have the potential to be developed in Malaysia.
Term of references for the council are as follows:

1. To provide strategic direction on the current and future technology developments that have the potential to be developed in Malaysia

2. To coordinate planning and development of local technology applications in line with the STIE niche areas based on the 10-10 STIE Framework
3. To provide advisory on technological feasibility, suitability, usability, security, and investments to the National Science Council
4. To drive collaboration on technology development at national level.

It is proposed for nanotechnology representatives in the High-Tech Nation Council consisting of representatives from nanotechnology industry, nanotechnology expert, NNC and NMB. Direct access to central government and representation at High Technology Nation Council are pertinent in positioning nanotechnology as the key enabler for socio-economic benefits and engine growth as well as to be embedded in all technology sectors of the country.

International Advisory Panel

The function of International Advisory Panel is to provide advice on technology strategy and emerging technology based the global development.

Tech-Expert Panel

Tech-Expert Panel is chaired by KSU MOSTI with TKSU (T) MOSTI as the co-chair. The secretariat for the panel is DSF, MOSTI and ASM. This panel will identify future technology developments that have the potential to be developed in Malaysia.

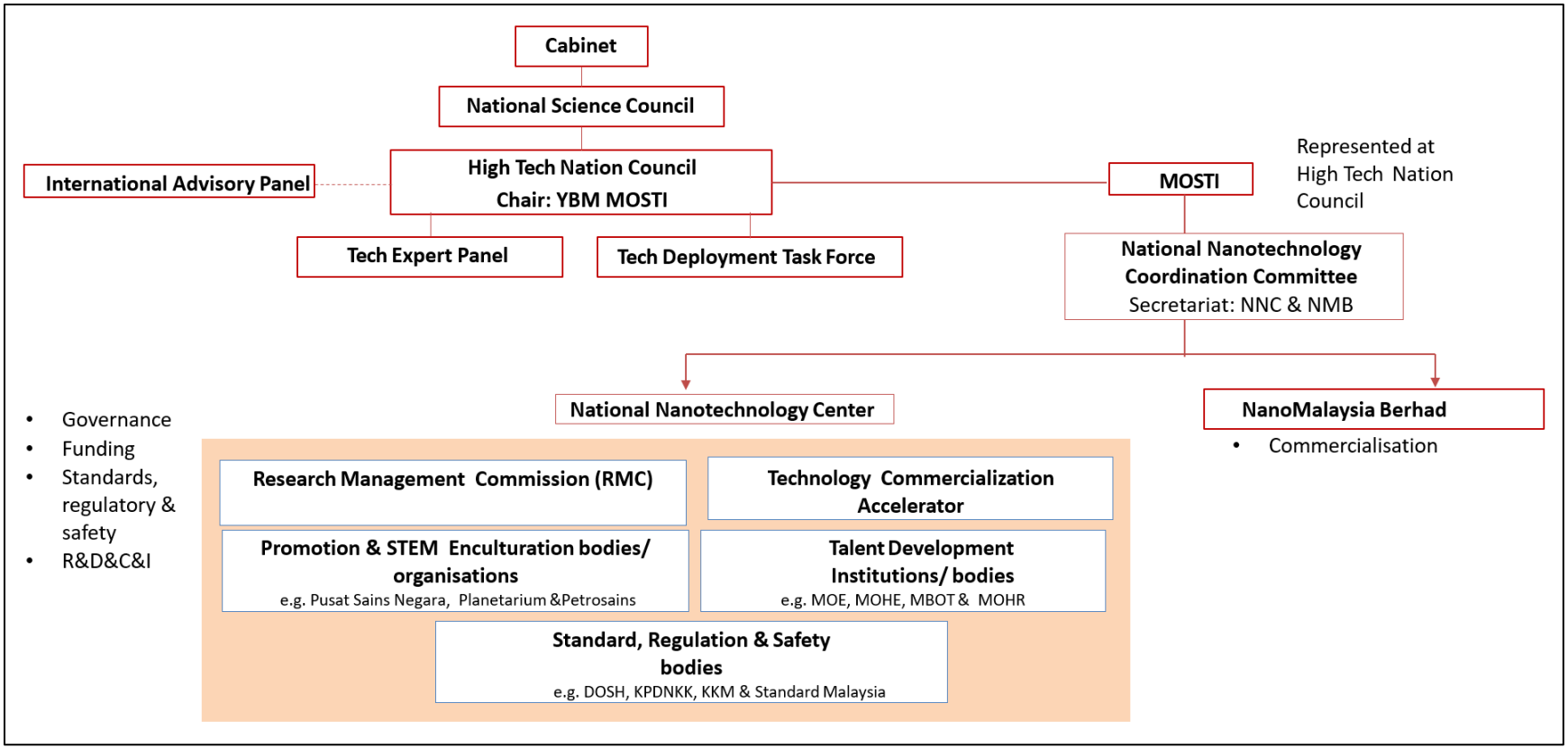


Figure 33: Proposed Governance Framework Structure

Tech-Deployment Task Force

The Task Force is chaired by KSU MOSTI and TKSU (T) MOSTI will be the co-chair. The secretariat involved in the Task Force is Strategic Technology and S&T Applications Division, MOSTI and Malaysian Industry-Government Group for High Technology (MIGHT). The purpose of the Task Force is to coordinate the planning and development of local technology applications in line with the STIE niche areas based on the 10-10 STIE Framework.

National Nanotechnology Coordination Committee (NNCC)

National Nanotechnology Coordination Committee should be empowered as a centralised nanotechnology co-ordination and monitoring committee that will transcend all ministries to create greater stakeholder participation, integrated implementation, evidence-based decision making and national level monitoring and evaluation of nanotechnology. The committee to be managed by both National Nanotechnology Centre (NNC) and NMB as secretariat. The committee will also be represented by the quadruple helix which are the universities, research institutions, industry, civil society, and government. A comprehensive Term of Reference needs to be developed for this committee in ensuring the committee will be able to deliver the dynamic needs required as the coordinating body for the country's national agenda of nanotechnology.

National Nanotechnology Centre (NNC)

National Nanotechnology Centre (NNC) are given absolute authority to coordinate and manage national nanotechnology agendas for the nation. Other than that, NNC will also be responsible in increasing awareness by building a conducive environment that encourages nanotechnology invention, innovation and technology development in community. The function of NNC is to:

1. Develop and strengthen the national capability and capacity through the development and implementation of policy, supporting infrastructure and physical facilities; in tandem with early education in nanoscience in effort to develop the human capital;
2. Plan, coordinate, conduct/ execute and monitor Research, Technology and Product Development; and Commercialisation activities in Malaysia to support the Government strategic aspirations;
3. Plan, coordinate and monitor activities contributing to the development of nanotechnology-based industry as sources of economic growth;
4. Facilitate positioning of the Malaysia's nanotechnology related industry players and products in the global supply and value chain; and
5. Foresighting activities to identify key future developments in nanotechnology.

NanoMalaysia Berhad (NMB)

NMB is a Company Limited by Guarantee (CLBG) under MOSTI, mandated with nanotechnology commercialisation and industrial development activities. Through its venture builder model, NMB forms the nexus of industry, universities, research institutes and society to jointly develop and commercialise viable nanotechnology-based solutions in the forms of products and services supported by the creation of relevant industrial ecosystems. NMB should work closely with NNC to connect fundamental and applied R&D to market and societal demands.

Effective from 9 July 2020, NMB was placed under the coordination of NNC as per Minister of the Federal Government (No. 3) Order 2020 to:

1. Act as a business entity under MOSTI which entrusted to focus on the commercialisation and industrial technology development of nanotechnology.
2. Plan and coordinate the commercialisation of R&D of nanotechnology in high-impact areas of focus such as electrical and electronics, food and agriculture, energy and environment, and healthcare and medicine.
3. Plan and manage activities that contribute to the development of nanotechnology-based industries.
4. Strategise the positioning of nanotechnology industry of Malaysia in the global supply and value chain.
5. Facilitate investment in nanotechnology commercialisation.
6. Facilitate the development of human capital (scientists and engineers, researchers and professionals) for the nanotechnology industry.

Strategic Thrust 2: Advancing Research and Development (R&D)

Strategy 2.1 - Identifying and aligning strategic nanotechnology priority areas with the national priority and niche areas to drive as well as supporting the country's socio-economic development and increase competitiveness.

Malaysia must be strategic in how it invests in science, research and innovation. In the absence of national priorities for nanotechnology-related research, the country will not be able to guide research expenditure, negotiate with partners for targeted funding and long-term efforts, nor stimulate human resource development for research. A national research and innovation system require four critical elements: focus – priorities – targets – milestones; without which development would be blind. With clear priorities in place, the science and innovation sectors can flourish to support the country's socio-economic development and increase global competitiveness.

In relation to this, there is a need to formulate strategic nanotechnology priority areas that are aligned with the national priority and niche areas, which are at the same time, holistic and cross-disciplinary. As illustrated in Figure 34, four key sectors have been identified to "jump-start" Malaysian nanotechnology:

(1) Food and Agriculture,

(2) Energy & Environment,

(3) Electronic Devices & Systems, and

(4) Wellness, Medical & Healthcare.

These "Jumpstart" priority areas, developed through a wide stakeholder consultative process, are designed to help focus government investment for science and research to address important and fundamental societal challenges. The overall goal is to increase productivity, achieve sustainable economic growth and improve the well-being of the nation. These 4 main jumpstart sectors would be able to cover other important sub-sectors, for example under the Energy and Environment, there would be involvement of Forestry and Biodiversity sectors.

Figure 34: Jump Start Sectors in Nanotechnology.

To forge a dynamic national innovation system, the nanotechnology priority areas will be implemented and adopted across all STI areas. In 2019, a science, technology, innovation, and economy (STIE) ecosystem framework, called the 10-10 *My*STIE Framework was established (Figure 10). The framework integrates the 10 technological drivers and 10 socio-economic drivers to raise the dynamic capability (absorptive, adaptive and innovative capabilities) of the Malaysian economy. Nanotechnology is associated with all the socio-economic and technological drivers in the 10-10 STIE framework, which includes the four identified "Jumpstart" sectors. Having a systematic and focused STIE policy framework is crucial in boosting the nation's socio-economic development in response to an increasingly challenging global economy.

Malaysia's R&D landscape has grown tremendously over the last decade. The country has dedicated serious efforts in improving its research, technology and product development, and innovation activities. Nevertheless, neither the government nor the industry can afford to invest in every single field of nanotechnology-related research. Therefore, it is necessary to strategise, synchronise and coordinate R&D funding for research projects that are aligned with the national priority and niche areas according to 10-10 MySTIE Framework.

The 10-10 MySTIE Framework is an integration of 10 key Malaysian socio-economic drivers with 10 global leading science and technology drivers aligned to our strengths and needs. This Framework provides a systematic approach to transform Malaysia into a knowledge-intensive economy by design. It aims to generate shared economic prosperity across the diverse ecosystems in the country and shift Malaysia up the global innovation value chain. This Framework will enable key sectors of the economy to become more knowledge intensive and innovation driven. This will enhance the competitiveness and sustainability of Malaysian industries. It is designed to enhance the quality of life of the Rakyat.

Aligning nanotechnology R&D funding with the identified areas not only facilitate the technology transfer of indigenously developed technology and products to the industry, but also improve the competitiveness needed to transform Nanotechnology into a new growth engine. Therefore, the strategic investment in the priority areas that can lead to impactful outcomes is a way forward, and this includes the funding to support basic research, applied research, experimental development, and commercialisation. According to Science and Technology Foresight 2050: Emerging Science, Engineering & Technology by ASM 2017, among top 5 emerging technologies in nanotechnology are Nanomaterials, Photovoltaic cell, Nanosensors IoT, Nano based drug delivery system, and Fuel cell.

Another issue with the current national STI landscape is the multitude of "actors" and funding agencies that have become self-competing. This in turn results in the dilution of available funding and resources. It is suggested that the National Nanotechnology Centre (NNC) be given the mandate and suitable authority to coordinate the funding for nanotechnology-related research in the strategic areas and work together with the government Research Management Centre (RMC) to drive the nanotechnology agenda of the country.

Setting the priorities for nanotechnology research is absolutely critical to streamline research activities, bridge knowledge gaps, and to maximise the country's resources. Therefore, one of the initiatives involves establishing a dedicated contestable fund for the priority R&D areas with funds coming from both government and alternative sources. As discussed earlier, the investment needs to be focused and targeted to ensure that the country increases its regional and global competitiveness and become a RM3 trillion economy by 2030-2032.

Strategy 2.2 - Enhancing nanotechnology R&D and promoting effecting partnering in research collaboration for high-value output, high-impact outcomes, and innovation.

Nanotechnology is widely regarded as an extremely promising technology domain with regards to business opportunities in various industries, particularly in the context of pressing societal challenges relating to sustainable energy, environment, food, wellness and healthcare. An increasing number of groups is actively involved in nanotechnology R&D in Malaysia, the majority of which are from the government research institutions and higher learning institutions. However, the world is changing rapidly given the challenges of the 21st century which include the global economic crisis and disruptive technologies. Therefore, a comprehensive foresight process for R&D can both enhance performance and steer the broader organization through such a turbulent marketplace. Being aware of such information can also assist us in leveraging future opportunities and mitigating possible risks.

As highlighted in Chapter 2, the country's low percentage of experimental development funds clearly indicates the lack of potential to translate R&D outputs to the market. Consequently, only a small fraction of research can be developed into market-ready products and/or services. To avoid this, increased funds should be dedicated for experimental development, and encourage more collaboration between research institutions, universities, and industries towards demand-driven research. Studies by ASM, focusing on the Malaysia 2050 agenda

through a compendium of several strategic studies since 2009, one of which is the Emerging Science, Engineering and Technology (ESET) study. The first key output from this study is Malaysia's Emerging Technology Timeline towards 2050 that showcases 95 emerging technologies relevant to Malaysia's future STI proficiency, economic growth and societal well-being (Figure 35(a)). As can be seen from the figure, Nanotechnology, which is represented in orange, constitutes a large portion of the roadmap over the 35-year period (2015 – 2050). The technology timeline also reinforces that as we progress towards the future, more and more technology convergence is anticipated to occur. Even today, technological advances are largely attributed to multi-disciplinary platforms. For instance, nanomaterials-based sensors that improve sensitivity and specificity are already being integrated with digital technology to give rise to nanoscale environmental surveillance known as smart dust networks. The second key output of the S&T Foresight Study, as depicted in Figure 35(b), is a technology tree that comprises 21 Impactful Emerging Technologies to realise six envisioned outcomes for a Progressive Malaysia 2050 that is harmonious, prosperous and sustainable. It is undeniable that at every step of the way, nanotechnology plays a critical role in elevating Malaysia's well-bring, wealth creation and governance.

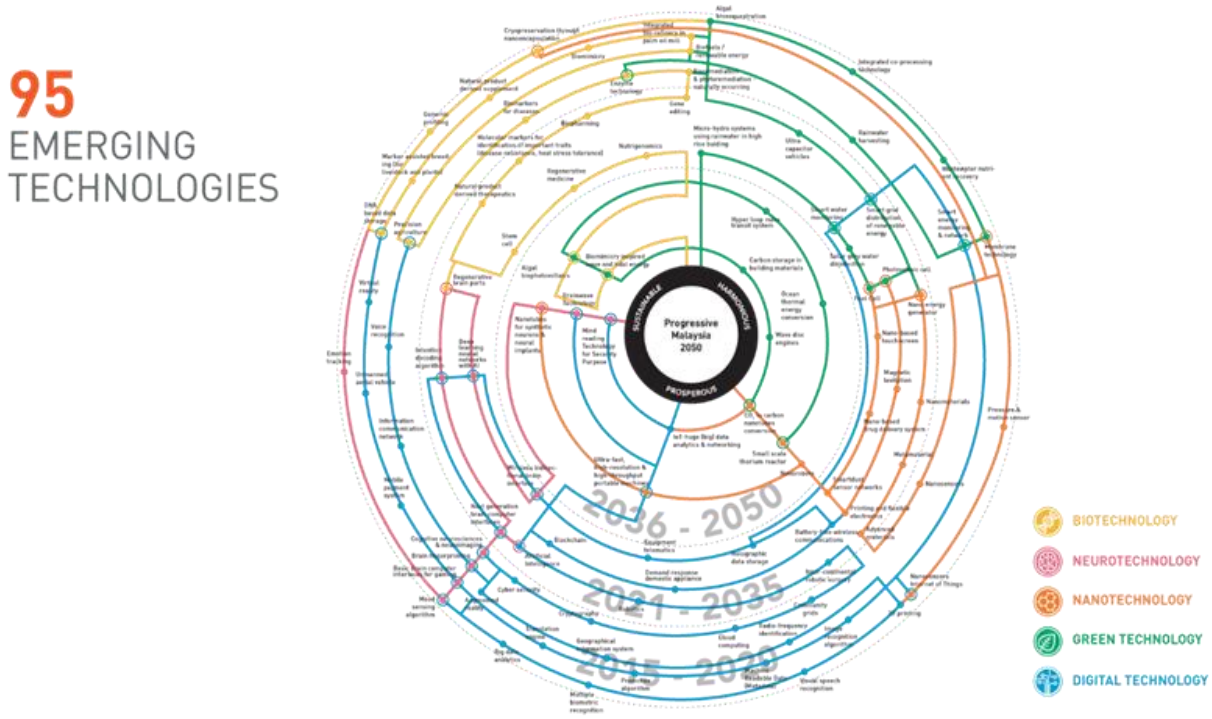


Figure 35: (a) Malaysia's Emerging Technology Timeline towards 2050;

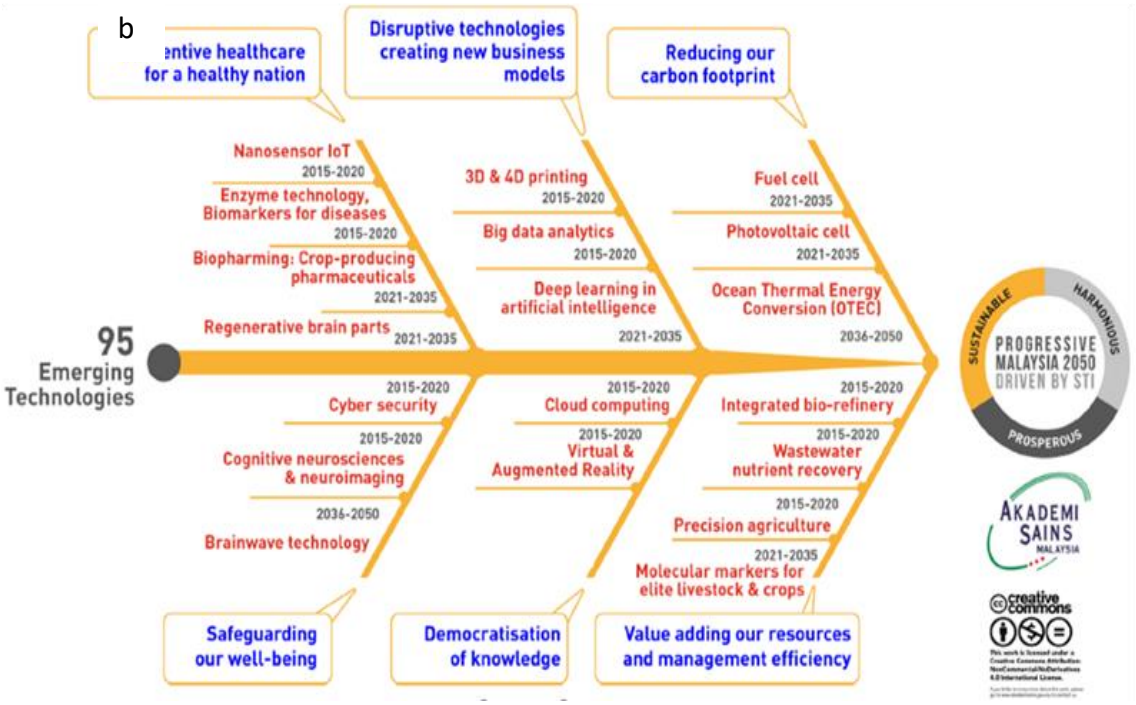


Figure 35: (b) Impactful ESET for Malaysia's Wealth Being, Wealth Creation & Governance
Source: ASM, 2017b

The adoption of collaborative network in the potential focus areas will enable Malaysian industries to become more nanotechnology-based and innovative using domestic technologies. Connecting NMB as the key player of nanotechnology in Malaysia with the Technology Commercialisation Accelerator (TCA), an industry-led statutory body that to be established and institutionalised by MOSTI. TCA will facilitate collaborative commercialisation by focusing on both demand-driven R&D and a market-driven delivery system between R&D and the industry.

To ensure that a responsive knowledge-driven innovation ecosystem is in place, other key parties such as researchers, the government and the private sector need to play their respective roles in the collaborative network, moderated by a trusted neutral entity in collaboration with the founding members. The neutral entity must possess a strong understanding of the landscape and players for the identified focus areas. The most important factor in driving the collaborative network is that the neutral entity should not have vested interest in any of the participating parties in order to create an environment of trust.

Collaborative network funding mechanism which is matching fund between the industry and the government should be adopted, where industry contributes at least half of the project cost. This common fund for R&D will ensure commitment from both parties to fund demand-driven R&D and facilitate commercialisation.

The dynamic features of a collaborative network will foster industry-led, people driven interactions that create knowledge clusters and a hub for talent. The hub will consist of a satellite lab, teaching factory, and integrated data sharing platform.

Malaysia will not only be able to create demand for our highly skilled talent and knowledge workers but also be able to tap into talent throughout the region. Gathering the right talent is vital to realise the full potential of the collaborative network.

Ultimately, the benefits of collaboration networks are limitless. The collaborative network approach enables Malaysian industries to offer market-driven products and services through integration of rich nanotechnology-based knowledge content.

Strategy 2.3 - Promoting sharing and improving existing R&D facilities and infrastructures towards building world class R&D facilities.

Research infrastructure is a vital component of high-level, competitive research. It is the collective term for a wide variety of equipment, laboratory facilities, resources, databases, supercomputers and other tools used by scientists to carry out their research and to deliver innovation in their respective fields. Today, the sharing of publicly funded R&D resources has become more important than ever owing to the very high cost of the sophisticated equipment and facilities to support nanotechnology research and nanomaterials characterisations. To accelerate nanotechnology research and innovation, initiatives need to be formulated to effectively maintain, sustain and encourage the sharing of research infrastructures among all nanotechnology players.

One of the current initiatives is the National Nanotechnology Laboratory Network under the coordination of NNC as depicted in Figure 33. The primary aim of the network is to leverage on the existing research infrastructures, laboratory facilities and strengths to form a supporting ecosystem, thereby increasing the research capability of the nation to champion in nanotechnology-driven STI. The platform or network provides opportunities for multidisciplinary research among scientists from various disciplines and from different research sectors (e.g. academia, industry and research institutions) to work on cutting-edge research projects that address the national priorities and global issues. Moreover, such multidisciplinary research not only gives rise to advances in knowledge, but also fosters relationships that help spearhead the transition of basic research results to market-ready products and services.

Other than that, the National Nanotechnology Centre (NNC) is proposed to be established as a nanotechnology excellence hub in Malaysia. The NNC's major roles include:

1. Provide world-class nanotechnology laboratories and facilities for R&D and pre-commercialisation activities
2. Develop core capabilities in nanotechnology advancement
3. Provide expertise for technology development and technical consultations to support commercialisation of nanotechnology products and nanotechnology-based industries

Key goals of the NNC are to:

1. Position Malaysia as a hub for nanotechnology knowledge and applications;
2. Promote commercialisation activities by local companies; and

3. Collaborate with the relevant authorities in areas such as education and expertise development, and research.

It is envisaged that the establishment of NNLN will facilitate and support research and commercialisation including product development and testing. This will also create a critical mass of entrepreneurs as well as facilitate the creation of new nanotechnology-based firms contributing to national economic growth.

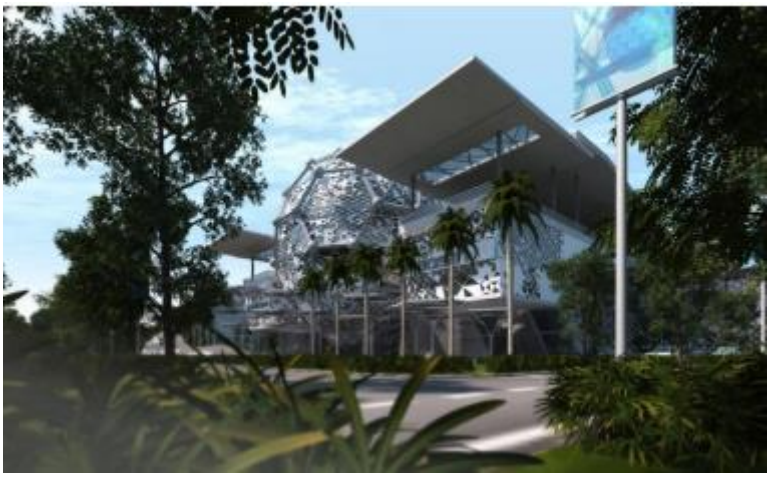


Figure 36: Artist Illustration of the National Nano Centre
Source: NNC, 2016

Strategy 2.4 - Building a competent and adaptive nanotechnology talent with effective and fun STEM education integrating nanotechnology component.

Ensuring a pool of skilled nanotechnology talent is a vital component of the strategic planning that is aimed at increasing the number of nationally and internationally competitive scientific and technological developments in the nation.

Supply and demand data for nanotechnology talent is useful for decision making and strategic planning related to the future workforce of the nation. In Malaysia, the supply of nanotechnology talent can be measured according to the National Education Code (NEC) Manual by the Ministry of Education, whereas the data on employment by occupation is under the purview of the Ministry of Human Resource (MoHR) using the Malaysia Standard Classification of Occupations (MASCO). The MASCO list follows the International Standard Classification of Occupations (ISCO) set by the International Labour Organisation. According to the data on employment by occupation, the nature of the work performed in relation to characteristic tasks, defined for various skill-levels, takes precedence over formal educational qualifications. On the other hand, the measures set out in the NEC manual are based on qualifications, which call for further alignment to the MASCO list. A structured collection of data on supply and demand of nanotechnology talent and occupations in the nation is therefore necessary for comprehensive analysis and strategic planning. Such credible data

would then enable the matching of supply and demand and allow strategic projections of the quantity and quality of nanotechnology talent and skill sets required in the future.

As Malaysia enters Industry 4.0, the nanotechnology workforce needs will increase drastically, along with the pressure to develop talent armed with the new skills (e.g. programming, cyber security, and data science) required to meet the evolving needs of industries. An integrated approach to national nanotechnology talent planning would be best undertaken under the auspices of an overseeing governance entity which can take a more strategic perspective. At the same time, a complete mapping of nanotechnology occupations with details of job descriptions, associated qualifications, competencies and technical skills, as well as remuneration packages would help raise awareness about nano-related career paths and opportunities. Thus, a centralised national planning for nanotechnology talent is crucial to define the way forward for nanotechnology talent in research and development.

Other than that, STI education provides students with a myriad of future employment and economic advancement pathways. It is important that students be provided with a solid foundation in STEM so that they can make informed decisions about these pathways and their future.

However, there have been reports of a general downward trend in terms of student participation in scientific subjects, and the government is concerned about this relative lack of interest. Statistics show that the percentage of STEM students increased from 2001 to 2016 but fell back again in 2017 (Table 10). Two of the major reason students avoid STEM subjects are their inherent difficulty and theoretical nature. Therefore, it is important for promoting and nurturing critical thinking skills among the students to increase their mastery and performance in STEM.

Promoting critical thinking in students will require individuals to be exposed to effective developmental teaching programmes through appropriate pedagogy. This is where teachers and trainers have an important role to play. They should do their best to make STEM teaching and learning fun, experimental and effective from pre-school to tertiary levels. It is hoped to raise the overall quality of teaching through training and continuous professional development for STEM teachers. Parents and school counsellors are also important figures in shaping a student's life, so incentives will be used to persuade parents to encourage their children to pursue STEM studies.

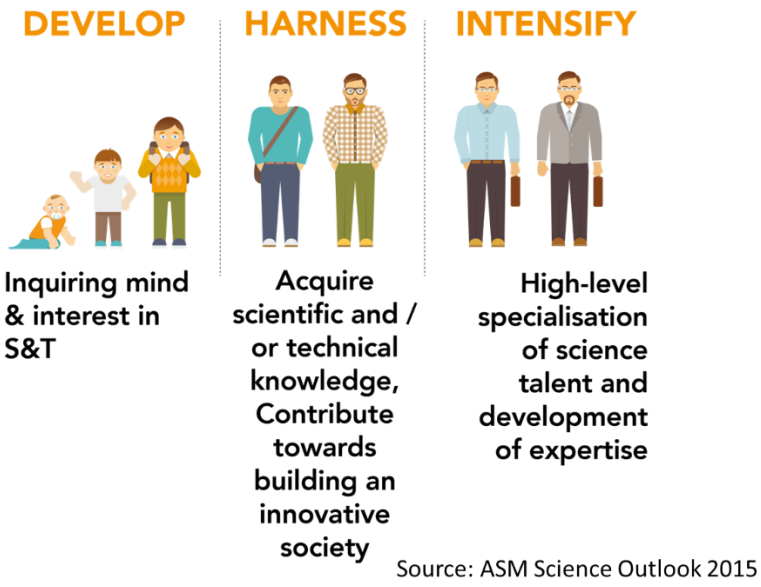


Figure 37: STEM Talent Value Chain

Table 10: Number of students enrolled in form 4 and 5, in stem and non-stem streams in government schools

Source: Extracted and analysed by ASM, 2017 from various McE statistical reports

	STEM (%)	Non-STEM (%)
Target	**60.00**	**40.00**
1986	31.00	69.00
1993	20.00	80.00
2001	29.00	71.00
2014	46.33	53.67
2016	47.82	52.18
2017	45.74	54.26

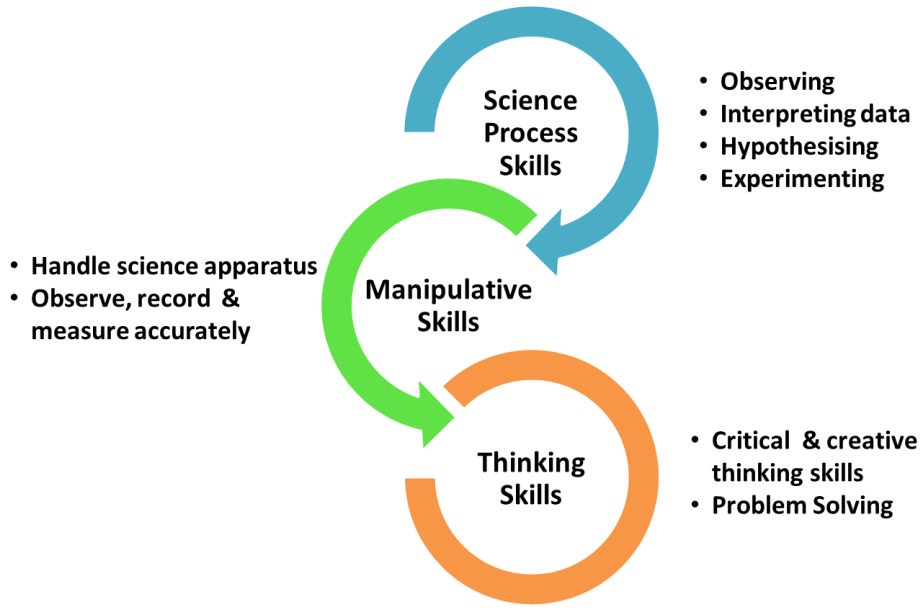


Figure 38: Inquiry-based Science Education (IBSE) Skills Component
Source: ASM, 2012

Strategy 2.5 - Increasing effective nanotechnology outreach and science communication.

The Malaysian government firmly believes that inquisitive and informed citizens are crucial for Malaysia to become a high-income and high-tech nation. MOSTI continuously promotes STI through nationwide activities like the National Innovation & Creative Economy Expo and Minggu Sains Negara and provides funds that help transform ideas into products and services. Organising effective nanotechnology outreach will help to increase the knowledge and information of nanotechnology.

There have also been numerous STI programmes implemented independently by various ministries, agencies and stakeholders. In solidifying commitments of the various nanotechnology promotion activities and programmes for all levels of society, periodic review of nanotechnology initiatives by the quadruple helix (government, academia, industry and society) representatives is desirable to ensure efficacy. Strengthening coordination, monitoring and evaluation not only helps integration, but also consolidates strengths to deliver tangible outcomes and long-term impact. It is proposed for all nanotechnology programmes to be coordinated and leveraged the existing STI enculturation platform that available for higher impacts for example collaboration programmes with the National Science Centre (PSN).

Science communication is also essential to disseminate knowledge to a wide range of audiences. Using media to heighten public awareness and appreciation of nanotechnology involves the expansion of nanotechnology content in media. Effective nanotechnology communication should be comprehensible to both scientists and the public.

Nanotechnology-related news helps make nanotechnology a part of people's daily lives beyond the classroom and makes clear the relevance and applicability of nanotechnology in an everyday context. Teachers often also make use of nanotechnology-related news to illustrate certain scientific concepts or to highlight socio-scientific issues to promote critical thinking. The media can be a positive force to promote nanotechnology and help the public make more informed decisions.

It is proposed for the existing science communication platforms to be leveraged for nanotechnology for example platform that is available in Science Media Centre.

Strategic Thrust 3: Enhancing Commercialisation and Energising Industries

Strategy 3.1 - Shifting towards high-value-added and high-technology industries by fostering adoption nanotechnology to drive economic growth.

The global Fourth Industrial Revolution (4IR) market size will be growing in an exponential trend in 2021 until 2025. The market revenue of the global market was valued at USD 87 billion in 2019 and is expected to grow with a CAGR of 32.1% over the forecast period of 2020-2025.

Nanotechnology itself and nanotechnology-based advanced materials are positioned to be an important enabler for all 4IR technology areas, but the applications are complex and require a multidisciplinary and comprehensive research, development, commercialisation and industrialisation strategy and approach in nanotechnology involving government, industry, academia and the public.

The respective roles are as follows:

Role	Function
Government	• Policymakers • Coordination • Catalytic funding
Industry	• Product development • Technology Development through adoption or adaptive approaches • Assets, infrastructure and network • Manufacturing • Job creation
Academia/Research Institutes	• Fundamental and application technology development • Testing • Talent development
Public	• End user of technology • Product, services and technology adopters • Talent pool

Nanotechnology as an emerging field in Malaysia requires significant risk mitigation for industry to embrace the shift into incorporating nanotechnology into their products and businesses. Without government intervention, the rate of industry adoption of nanotechnology will not position Malaysia strategically in the emerging 4IR global supply chain, and as such, NMB's existence as a Company Limited by Guarantee under MOSTI, is to create the connector between the government, industry, academia and society to enable the

entire nanotechnology commercialisation ecosystem to grow, generate revenue and create jobs.

From the positive results and experience of deploying the quadruple helix strategy in propagating nanotechnology into products, solutions and services, it is imperative that this approach continues moving forward from day 1 of the proposed policy implementation.

With nanotechnology commercialisation programmes such as the National Graphene Action Plan and *iNanovation* under NMB, SMEs are provided with the avenue, information and ability to shift their business into adopting nanotechnology in their products and services. This prepares them for a world that is transforming around them under the light of 4IR – increasing their competitiveness locally and within the global supply and value chain.

To rapidly amplify and broaden the reach of this transformative effect, the policy must address strengthening the talent and capability of public and private research in universities, research institutes and in-house innovation functions within industry. This upstream component is crucial for sustainable supply of economically viable intellectual properties. Commercially rewarding collaboration between academia and industry facilitated by NMB can provide the added boost required to propel Malaysia into the forefront of the region's 4IR race.

The innovation development model as detailed in Figure 15 is to be adopted by this policy.

As NNC and NMB are both entities focusing on the whole value chain of R&D&C&I for nanotechnology in Malaysia, the ecosystem is a collaborative one across the Technology Readiness Level (TRL) spectrum:

Nanotech innovations mainly fall into two categories:

1. Push – when innovation comes from fundamental and application research starting from TRL 1 in universities and research centres and moving their way towards TRL 9 where the innovation becomes commercially available likely through university spin-offs and private start-ups.
2. Pull – when industry players like private start-ups, SMEs and large local companies (LLC) are actively seeking some innovation to spur their business and creates the demand for such innovation to be pulled upwards from a lower TRL into the market.

Figure 15 shows how in Malaysia, innovation is distinctly divided into two categories:

(1) Research and technology/product development (R&TPD) and

(2) Commercialisation and industrialisation (C&I).

In the Malaysia nanotechnology scene, R&TPD falls within the domain of the NNC, and C&I is the responsibility of NMB.

The Malaysian Collaborative Network Platform for Disruptive Innovation initiative (i-Connect) is another example of a programme that implements an industry-led collaborative network mechanism (quadruple helix framework: industry, research community, government and civil

society). Both NNC and NMB should be appointed as the neural entities under one of its four strategic sectors that is Manufacturing: Industry 4.0.

The objectives of all these programmes in i-Connect are to increase disruptive innovation (new products/services/business models) in strategic sectors, develop knowledge clusters and talent hub and enable demand-driven R&TPD and market-driven delivery system – All for the purpose of enhancing Malaysian industries to become an innovation-led economy and to venture into new and emerging global markets. Funding demand-driven R&TPD by researchers and its contribution to be matched with either monetary or in-kind from the industry ensures a collaborative network is achieved and an overall innovation ecosystem is created.

Strategy 3.2 - Improving international networks and demand for Malaysian nanotechnology products and nanotechnology services.

The global nanotechnology market for nanotechnology products is worth USD 3 trillion in 2020, we see high investments in developing and producing nanotechnology-based products and services. Nanotechnology enables performance and abilities that are characteristics of high- value products which are sought after by the global market.

Collaborations between companies and governments of different countries are rapidly growing as technology and intellectual property are traded and shared to create new, exciting products. The need for regulating the nanotech market grows as well to ensure high confidence in the economic potential. These collaborations come in various forms:

Regional platforms such as the Nanotechnology Business Creation Initiative (NBCI) and the Asia Nano Forum offer countries and companies to share notes and create opportunities of collaborative projects and market access. In addition to NMB's access to these platforms, it has established collaborative relationships with the following parties: (i) Innovation Alliance of the Graphene Industry (CGIA), (ii) RUSNANO from Russia, (iii) NanoCanada, (iv) NanoNextNL from the Netherlands, (v) UK's National Graphene Institute, (vi) USA's National Nanotechnology Coordination Office, (vii) Nanotech Indonesia, (viii) Nanotech Thailand, and others. Malaysia's access to these markets allows for local SMEs and entrepreneurs to expand their offerings abroad.

The world's largest annual nanotech exhibition and convention in Tokyo, called "Nano Tech" provides opportunities to see what the rest of the world is working on in nanotech innovation, upping the game for Malaysia's businesses targeting the global market. NMB intends to leverage on this opportunity by continuing to be present in these events and other significantly important events to promote Malaysia's nanotech companies, products and services.

Presence of both, NNC and NMB as working group members in the ISO TC229 "Nanotechnologies" working group, allows for strategic injection of standards and terms that

will help smoothen the path for Malaysian nanotech innovators to commercialise their offerings abroad.

NANOVerify, a programme under Nano Verify Sdn. Bhd; a subsidiary under NMB, is the current Malaysia's only nanotech validation and certification programme. To date, NANOVerify Programme has a cross-country certification arrangement with NanoMark in Taiwan, a similar programme in that economy. Future plans include similar cross-country collaboration with Iran, Russia, South Korea and the UK. Building these international connections smoothens the entry for Malaysian nanotech products and innovation to enter these economies.

A very important activity that need to be focused on in this policy is to improve branding and positioning of local nanotechnology innovations through savvy marketing strategies and approaches, to broaden the appeal of the products and innovations that consumers will associate with 4IR.

It is important for Malaysia to also focus on improving the demand of local nanotechnology products. The key factor for driving the demand for nanotechnology products and services in Malaysia is awareness and trust. To foster this, a series of comprehensive engagements need to be carried out with the following stakeholders:

- Ministries e.g., MITI, KPDNHEP, MEA, MoH
- Regulatory bodies e.g., NPRA, JAKIM
- Industry associations e.g., Federation of Malaysian Manufacturers, CTFA Malaysia
- Consumer associations e.g., FOMCA, CAP
- General public

These engagements are aimed at educating the respective stakeholders on the unique selling propositions of nanotechnology products and processes when applied to their respective sectors. Unique Selling Propositions which are common across nanotechnology products and processes include:

- Increased cost effectiveness e.g., lower cost per application
- Additional/enhanced functionality e.g., increased strength, antifungal, antibacterial
- Increased product performance e.g., higher electrical conductivity

To further bolster confidence of industry and consumers, certification of nanotechnology products and processes needs to be stepped up to validate the authenticity of the said nanotechnology input. Currently, the NANOVerify Programme under NMB, intended to cover the following certifications:

- Characterisation - validation of nanoelement size as per ISO TC229 definition
- Functionality - validation of mechanical, surface and electrical property enhancement because of nanomaterial incorporation.

Strategy 3.3 – Provide facilitation and incentives to the company that producing nano related products.

SMEs will be supported in strategic areas through provision of funds, incentives and collaborative initiatives to embrace nanotechnology innovations into their products, solutions and services. In this regard, facilitation such as funding will be provided for product development, scaling-up and certification activities to promote nanotechnology product and application research, development, production and commercialisation amongst SMEs. The proposed fund will leverage on NanoMalaysia's RevolutIoNT Programme to finance start-up and SME's R&D&C&I activities carried out primarily in Malaysia. Funding will also be provided for genuine product certification through the NANOVerify Certification Programmes.

Besides that, tax incentives for companies that adopt local nanotechnology products will trigger a multiplying chain effect on the local industry, thereby encouraging more technology adoption. This will drive SMEs to be more proactive in using these incentives provided by the government to accelerate the adoption of nanotechnology. Leveraging the existing STI related incentives would be a more feasible model to enable the following incentives for SMEs:

i. Lower interest rate for contract financing and scale-up of production
ii. Export tax incentives for Malaysian nanotechnology products going overseas
iii. Tax incentives for SMEs that invest into adopting nanotechnology (R,D,C&I) into their product, solutions and services
iv. Incentives and support to market and distribute new products domestically and in the export market
v. Financing for SMEs to provide a fair value of IPRs based on their existing and potential future market values to determine the licensing model which includes licensing fees and royalty
vi. Financing and incentives for products and services that has been certified through the NANOVerify Programme.

Strategy 3.4 - Intensifying demand and attracting more and better talent to participate in the nanotechnology workforce.

In most advanced countries, skilled STI workers make up about 30% of the total workforce as compared to Malaysia's 20% with STEM background. Malaysia must do all that it can to attract more talent to the STI workforce because a strong talent foundation in STI is a major prerequisite for innovation. This is especially important for nanotechnology talents as nanotechnology is a cross-cutting key enabler in driving the growth of the Fourth Industrial Revolution.

In general, there needs to be an improved career path inclusive of remuneration to make STI a preferred career choice if Malaysia wants to draw and groom top notch talents in the field of nanotechnology. This is essential to bridge the gap of supply and demand for nanotechnology workforce to fuel a sustainable growth for the nanotechnology ecosystem from the development of highly functional materials; development of high value product, applications and solutions; process and product transfer for manufacturing and

commercialisation; testing and characterisation services; and product/process certification and safety. This includes improving schemes for researchers, scientists, engineers and technologist (RSET), inclusive of technology transfer officers, research managers and commercialisation managers. Hence, having global competitive salary and remuneration packages for nanotechnology talents is essential.

It is also important to strengthen public-private partnerships to further intensify demand for skilled nanotechnology talent. This includes partnerships in co-funding scholarships, internships, apprenticeship or knowledge transfer with industries supporting talented young students, researchers, technologists and potential entrepreneurs working in the field of nanotechnology. In addition to having a deep understanding of scientific theory and laboratory practices, graduates need to be able to translate their ideas into the marketplace. Nanotechnology being relevant to all industry sectors, the academic training approach should infuse specialization in pre-existing higher education programmes and not as stand-alone. At present, researchers in Malaysia are concentrated in higher learning institutes where they focus on basic and applied research and development activities, as compared to technology transfer and pre-commercialisation activities.

Cultivating entrepreneurship skillsets will enable more talent participation where nanotechnology researchers and technologists are able to be more market-driven and commercialise their innovations and know-how through application value creation, technology transfer and IPR licensing. A culture of creativity, innovation and entrepreneurship encourages risk-taking and rewards market-driven ideas. As the world is shifting towards a knowledge paradigm, more work flexibility will be needed as compared to the traditional 9 am to 5pm daily jobs.

The industry leveraging on nanotechnology as key enablers can also play an active role in ensuring that both trainees and trainers understand the needs of the industry, so that the right skillsets and up-to-date knowledge can be imparted to new talents entering the workforce. This initiative can be further supported through the establishment of technical societies or associations to share and explore specific areas of expertise, so knowledge and expertise can be disseminated back into respective workplace.

Maximising from the current pool of STI talents, upskilling is needed to ensure talents respond effectively to change and able to adapt to the use of nanotechnology. This is because skills for nanotechnology workforce will continue to be relevant and up to date for research, development and commercialisation. Therefore, it is essential to develop cross fertilisation programmes to retrain, reskill & upskill existing STI workforce to focus on nanotechnology. To meet industries' specific skills requirements, industrial driven upskilling and reskilling programmes needs to be established. Policy makers in STI should also not be left behind with policy makers to undertake advance training specifically to understand the nanotechnology environment and ecosystem.

In ensuring genuine and competent nanotechnology talents with relevant knowledge on research and development, production, manufacturing processes, safety, rules and regulation, product certification are available throughout the ecosystem, nanotechnology

professionals and technologists can be certified through the existing bodies such as Malaysian Board of Technologists (MBOT).

Strategy 3.5 - Mainstreaming science communication for promoting nanotechnology.

One of the key success factors to gaining local market acceptance of local nanotechnology products is the clear and concise communication strategy of what nanotechnology is, and what it is not, to avoid reputation damage or stigma from sub-standard products that merely label themselves as having nanotech. To this end, the efforts of the NANOVerify programme has been increasingly successful and should further continue to be leveraged on to educate the masses and industry. The NANOVerify programme does not only validate the authenticity and performance of the products under their mark, but also help to promote and educate the public on nanotechnology in general.

Public communications about rapid deployment of endogenous market-ready game-changer technologies aligned to 4IR will be prioritised through an assessment of unique selling proposition, applicability to Malaysia's economic advantage and relevant markets size aligning to Key Economic Growth Areas and global trends for expedited investments, IPRs protection and strategies, and market penetration facilitation which includes customisation, testing and certification.

Existing suitable national platforms or programmes, for example the RMK-12 Nanotechnology Commercialisation Programme (REVOLUTIoNT) shall be activated and leveraged on to push this initiative to jumpstart Malaysia's 4IR game plan. Locally developed first-to-market (FTM) nanotechnology enhanced on-board hydrogen generation fuel cell is going to position Malaysia uniquely in the global Hydrogen Economy at a much lower deployment cost and Graphene-based remote (contactless) wireless charging system is expected to disrupt consumer electronics, electric vehicles and mass transportation sectors. Printable advanced nano-based sensors and communication devices for Internet of Things are other examples of market-ready home-grown innovations offering technological and economic advantages over competitions. Our biomass industry is poised to experience a revolutionary shift with the intervention of proven locally developed nanotechnology-based zeolite catalyst for conversion of biomass into jet fuel to meet emerging market demands. The aviation industry has committed to reducing carbon emissions by 50% from their 2005 level by 2050. It is anticipated that biofuels reaching around 10% of aviation fuel demand by 2030, and close to 20% by 2040.

These are some of the progress and roadmaps that must be incorporated and highlighted in the policy to ensure that success stories are properly communicated for the public and industry to further embrace nanotechnology innovations. Importantly, nanotechnology should be highlighted as a key value-add in relevant policies, blueprint, roadmaps, and action plans to further mainstream its inherent sustainable and transformative effects across the sectors.

Strategic Thrust 4: Strengthening Standard, Safety and Regulation

Strategy 4.1 - Promoting the adoption of standards, safety, and regulation among industries towards increasing the value of nanotechnology products.

The successful exploitation of new ideas is crucial for a business to improve its processes, bring new and improved products and services to market, increase its efficiency and, most importantly, improve its profitability. Innovation through design is one of the ways that can generate value by creating products that are desirable, useable and feasible.

Eventually, quality becomes more important than quantity. Product innovation measures a country's ability to develop new products and integrate new technology. Making our domestic products high quality and alluring for both domestic and global markets is the most important challenge. By improving aesthetics, we will have greater success commercialising our products and services.

One of the ways to promote the adoption is to develop a comprehensive database that function as an inventory of nano-based products in the local market and generate nanosafety data. The development of the inventory for nano-based products in the local market is necessary as this will provide the consumer with the necessary information of the nano products. The data of the nano products and the scientific data of the nano products will help to assist in protecting the consumers and the environment. This inventory will also be updated as new nano products enter the market. For example, Danish Ecological Council and Danish Consumer Council in Denmark have established their own inventory for the nano products and provide the risk categories for each of the product. Furthermore, this inventory can be readily accessed throughout the world. In the long run, this inventory should be maintained and updated, or industry association can take over the system to fully utilise the inventory. Lastly, this inventory can be expanded to include the ASEAN markets.

With only two ISO standards being adopted by Malaysia, Malaysia should either adopt more relevant ISO-based standards or to develop relevant ISO Standards through ISO TC 229 Nanotechnologies Working Group, to support local industries. Nevertheless, it would be better if Malaysia able to develop its own national indigenous standards that are tailor-made for Malaysian local industries. These standards are vital to elevate the value of local nano products. These standards can be then brought to international level for adoption internationally, through relevant ISO Technical Committees, such as ISO TC 229 Nanotechnologies Working Groups. For this development to be successful, the industry must work together with the relevant parties to ensure the new standards are able to be realised. Furthermore, inventory data on nano safety and standard from industries are also required to be included in the above-mentioned database to develop national standards.

Adoption of standards is usually voluntary engagement from the industry. Industries must work collectively for the adopted standards to be well-presented and to add value to their product. Awareness among the public and industry on the health, safety and environment

issues related to nanotechnology is important to ensure the sustainability of the nano products. As the government is committed towards positioning Malaysia as a responsible renowned global player in the field of nanotechnology, the government needs to reach out to nanotechnology sceptics and proponents alike through multi-stakeholder engagements. There is a need to raise awareness and disseminate information on health-safety and regulatory aspect of nanotechnology products and activities. Another important activity is gathering, disseminating information and the latest results of research in the field of health-safety and standards. This must be a continual and non-restrictive process to allow the inculcation of nanotechnology within the community. The key activities on promoting societal dialogue and public forum on Nanotechnology-Health, Safety and Environment (HSE) include:

1. Organise dialogue and forum to create awareness among the public and stakeholders on the health, safety, and environmental issues related to nanotechnology;
2. Development of a Guidebook on Nanotechnology HSE Risk and Risk Management Process;
3. Sustainable awareness campaign on the use, storage, distribution and manufacture of nanotechnology products and materials;
4. Developing and publishing informational and educational materials for informing the public at large and professional directly involved in nanotechnology activities;
5. To disseminate information and educate the public and stakeholders on HSE Regulatory Standards through media platform;
6. Encourage participation in international forum and international efforts on HSE related on nanotechnology.

Strategy 4.2 - Integrating nanotechnology in regulation.

Nanotechnology will enable many exciting new products and solutions. It will be a major driver over future IR4.0. However, introduction of any new technology always attracts debate about potential social, environmental and health impacts. Thus, nanotechnology is no different. It may pose risks that will need to be managed as we go for wide scale development, commercialisation and adoption.

For Malaysia to move up in term of demand for Malaysian nanotechnology products and services, it is essential for the standard, safety and regulation to be adopted by the industries. Thus, it is important for us to have relevant STI based legislation or regulation, in ensuring the adoption of the standard, safety, and regulation.

Before integrating nanotechnology guidelines/standard into existing regulation, Regulatory Impact Assessment (RIA) needs to be conducted. This to ensure how the industry, stakeholders, and consumer react to the integration into existing regulation. Suitable guidelines for nano-product will be made available once the RIA have been conducted. Along the way, a new guideline will follow suit and this will further help to integrate the nanotechnology into existing regulation. As a long-term effort, harmonisation of the regulatory on nano products across ASEAN is important to further improve the integration of nanotechnology in existing regulations.

The Regulatory Impact Assessment (RIA) need to be in line with act such as Personal Data Protection Act 2010 [Act 709], Copyright Act 1987 [Act 332] and Patents Act 1983 [Act 291] before any data or information related to private individuals or organisations is disseminated to the public to avoid misused of data and information in the future. Other than that, there is a requirement of local regulators to be in place in Technical and Steering Committee that involve nanosafety projects to advice on applicability in reference to existing Acts and Regulations such as Control of Drugs and Cosmetics 1984, Food Act 1983, Medical Device Act 2012, CLASS Regulation 2013, Pesticide Act 1974, Consumer Protection Act 1999 and Environment Quality Act 1974.

The information on Environmental, Health & Safety of the nano-engineered materials are still not well established. Therefore, funding allocated for research related to nanosafety and talent on standard, safety and regulation are needed to be emphasised.

Strategy 4.3 - Re-strategising nanotechnology certification in attracting more adoption towards increasing nanotechnology products' value.

Certification of the nano products usually involves voluntary engagement from the industry. Malaysia needs to re-strategise nanotechnology to include more than just certification of nano presence in the products. Product Criteria Requirements (PCR) is necessary to ensure each product meets the requirement and provide a standard way to certify the nano products. Hence, certification of the product should be integrated with the PCR thus increasing the nanotechnology products' value. Certification of a nanotechnology product shall be in line with the requirements set in standards documents observed by the NANOVerify Programme. The standards will cover, among others, nano size characterisation, functionality testing and toxicity testing. Moving forward, collaboration and certification opportunities within ASEAN are also necessary to further increase the value of the nano products. Regulatory Impact Assessment on nano products should be conducted before making the certification of nano products compulsory to industries especially on product registration.

Chapter 4: Moving Forward

As moving forward, the following action plan of NNPS 2021-2030 that detailing the initiatives, planning and targets under its 15 strategies and covers the overall important components from the governance and ecosystem; R&TPD; commercialisation; talent; standard, safety and regulation; to enculturation are specially formulated towards the national nanotechnology development and progress that will bring high impact values to the country.

STRATEGIC THRUST 1: STRENGTHENING ECOSYSTEM AND GOVERNANCE

ISSUES & CHALLENGES			
1. Disconnected ecosystems in supporting the overall nanotechnology implementation, development, and innovation ecosystem.			
STRATEGY			
1.1 Nurturing and developing a conducive and connected nanotechnology and innovation ecosystem.			
INITIATIVES	**SHORT-TERM (2021-2022)**	**MEDIUM-TERM (2023-2025)**	**LONG-TERM (2026-2030)**
1.1.1 Identifying and redesigning a complete nanotechnology ecosystem by adopting collaborative network strategy.	A complete nanotechnology ecosystem framework and planning.		
1.1.2 Forming and implementing collaborative networks in strategic nanotechnology industry areas that led by industry towards developing home-grown and high-value innovations.	Formation of collaborative networks in 4 strategic industry areas through strategic partnership 7 new collaborative project per year.	Formation of collaborative networks in another 2 strategic industry areas through strategic partnership 12 new collaborative projects per year.	Formation of collaborative networks in another 2 strategic industry areas through strategic partnership 16 new collaborative projects per year.
PLAYERS			
Lead by: i. MOSTI ii. NNC		**Supported by:** i. Relevant ministries and research institutions/ institutes/ organisations ii. NMB iii. FMM	

<table>
<tr><th colspan="4">ISSUES & CHALLENGES</th></tr>
<tr><td colspan="4">2. Unclear governing and coordinating body in setting the direction, coordinating, and monitoring the national nanotechnology agenda.</td></tr>
<tr><th colspan="4">STRATEGY</th></tr>
<tr><td colspan="4">1.2 Institutionalising and strengthening the national nanotechnology governance.</td></tr>
<tr><th>INITIATIVES</th><th>SHORT-TERM
(2021-2022)</th><th>MEDIUM-TERM
(2023-2025)</th><th>LONG-TERM
(2026-2030)</th></tr>
<tr><td>1.2.1 Formulating and forming national nanotechnology governance.</td><td>Formulation and formation of national nanotechnology governance.</td><td colspan="2"></td></tr>
<tr><td>1.2.2 Representation of nanotechnology representatives in High-Tech Nation Council.</td><td colspan="3">Involvement of 6 nanotechnology representatives (industries, experts, NNC & NMB) in High-Tech Nation Council.</td></tr>
<tr><td>1.2.3 Empowering and strengthening NNC and NanoMalaysia Berhad (NMB) to become national nanotechnology coordinating body.</td><td>NNC and NMB performing its joint-role as national nanotechnology coordinating body through National Nanotechnology Coordination Committee</td><td colspan="2">NNC performing its role in national nanotechnology coordination committee with has complete representation from quadruple helix.</td></tr>
<tr><th colspan="4">PLAYERS</th></tr>
<tr><td colspan="2">Lead by:
i. MOSTI
ii. NNC</td><td colspan="2">Supported by:
NMB</td></tr>
</table>

STRATEGIC THRUST 2: ADVANCING RESEARCH AND DEVELOPMENT (R&D)

<table>
<tr><th colspan="4">ISSUES & CHALLENGES</th></tr>
<tr><td colspan="4">1. No standardised and strategic priory areas for nanotechnology at national level in guiding the direction of R&D&C&I in the country.
2. Lack of dedicated nanotechnology R&D&C&I funding in driving nanotechnology agenda of the country.</td></tr>
<tr><th colspan="4">STRATEGY</th></tr>
<tr><td colspan="4">2.1 Identifying and aligning strategic nanotechnology priority areas with the national priority and niche areas to drive and support country’s socio-economic development and increase competitiveness.</td></tr>
<tr><th>INITIATIVES</th><th>SHORT-TERM (2021-2022)</th><th>MEDIUM-TERM (2023-2025)</th><th>LONG-TERM (2026-2030)</th></tr>
<tr><td>2.1.1 Formulating strategic nanotechnology priority areas that are aligned with the national priority and niche areas, holistic and cross-disciplinary.</td><td>Formulation of nanotechnology priority areas.</td><td colspan="2"></td></tr>
<tr><td>2.1.2 Implementation and adoption of nanotechnology priority areas in all STI areas.</td><td colspan="3">Implementation and adoption of nanotechnology priority areas in all STI areas.

Local nanotechnology scene to reach Compound Annual Growth Rate (CAGR) of 10.9% for the forecast period of 2020-2025 and 14.3% by 2030.

Pharmaceutical and plastic products to dominate the Malaysian market with each of them registering RM 249.46 million and RM 234.72 million by 2025.</td></tr>
<tr><td>2.1.3 Establishing a dedicated contestable fund on strategic nanotechnology R&D priority areas.</td><td>Establishment of a dedicated fund.

At least 10 strategic nanotechnology R&D projects funded annually.</td><td colspan="2">At least 10 strategic nanotechnology R&D projects funded annually.</td></tr>
<tr><th colspan="4">PLAYERS</th></tr>
<tr><td colspan="2">Lead by:
i. MOSTI
ii. NNC</td><td colspan="2">Supported by:
i. NMB
ii. Research Management Agency (RMA)
iii. Relevant ministries and research institutions/ institutes/ organisations.</td></tr>
</table>

<table>
<tr><th colspan="4">ISSUES & CHALLENGES</th></tr>
<tr><td colspan="4">3. Low R&D commercialisation and technology acquisition due to lacking in commercial viability, involvement of industry at the of innovation process as well as failure in meeting the market and industry’s need.
4. Lack of partnership and collaboration in R&D&C&I nationally and internationally as well as with industries.</td></tr>
<tr><th colspan="4">STRATEGY</th></tr>
<tr><td colspan="4">2.2 Enhancing nanotechnology R&D and promoting effecting partnering in research collaboration for high-value output, high-impact outcomes and innovation.</td></tr>
<tr><th>INITIATIVES</th><th>SHORT-TERM
(2021-2022)</th><th>MEDIUM-TERM
(2023-2025)</th><th>LONG-TERM
(2026-2030)</th></tr>
<tr><td>2.2.1 Establishing and increasing of a dedicated experimental development funding for nanotechnology.</td><td>Establishing a dedicated experimental development funding for nanotechnology.

1% dedicated experimental development fund for collaborative network in nanotechnology annually from the overall R&D funding.</td><td>2% dedicated experimental development fund for collaborative network in nanotechnology annually from the overall R&D funding.</td><td>3% dedicated experimental development fund for collaborative network in nanotechnology annually from the overall R&D funding.</td></tr>
<tr><td>2.2.2 Enhancing industry-academia research collaboration through collaborative networks.</td><td>Formation and implementation of collaborative networks in 4 strategic industry areas through strategic partnership with neutral entities in i-Connect.</td><td>Formation and implementation of collaborative networks in another 2 strategic industry areas through strategic partnership with neutral entities in i-Connect.</td><td>Formation and implementation of collaborative networks in another 2 strategic industry areas through strategic partnership with neutral entities in i-Connect.</td></tr>
<tr><th colspan="4">PLAYERS</th></tr>
<tr><td colspan="2">Lead by:
i. NNC</td><td colspan="2">Supported by:
i. NMB
ii. RMA
iii. Relevant ministries and research institutions/ institutes/ organisations.</td></tr>
</table>

<table>
<tr><th colspan="4">ISSUES & CHALLENGES</th></tr>
<tr><td colspan="4">5. Lack of sharing and improving R&D facilities and infrastructures towards a world class facility and infrastructure for nanotechnology R&D&C&I.</td></tr>
<tr><th colspan="4">STRATEGY</th></tr>
<tr><td colspan="4">2.3 Promoting sharing and improving existing R&D facilities and infrastructures towards building World Class R&T/PD Facilities.</td></tr>
<tr><th>INITIATIVES</th><th>SHORT-TERM (2021-2022)</th><th>MEDIUM-TERM (2023-2025)</th><th>LONG-TERM (2026-2030)</th></tr>
<tr><td rowspan="2">2.3.1 Establishing research consortium for sharing of R&TPD facilities and infrastructures through National Nanotechnology Laboratory Network (NNLN).</td><td colspan="2">Establishment of National Nanotechnology Laboratory Network (NNLN).</td><td></td></tr>
<tr><td>5% increase in participation in NNLN consortium.</td><td>5% increase in participation in NNLN consortium.</td><td>5% increase in participation in NNLN consortium.</td></tr>
<tr><td>2.3.2 Strategising and coordinating improvements to the existing nanotechnology R&TPD facilities.</td><td>Improvement planning.

Improvements to at least 5 existing nanotechnology R&D facilities.</td><td>Improvements to another 5 existing nanotechnology R&D facilities.</td><td>Improvements to another 5 existing nanotechnology R&D facilities.</td></tr>
<tr><th colspan="4">PLAYERS</th></tr>
<tr><td colspan="2">Lead by:
i. MOSTI
ii. NNC</td><td colspan="2">Supported by:
i. Relevant ministries and research institutions/ institutes/ organisations.
ii. NMB</td></tr>
</table>

<table>
<tr><th colspan="4">ISSUES & CHALLENGES</th></tr>
<tr><td colspan="4">6. Lack of total S&T talent planning and development to move STI agenda that also affecting nanotechnology's talent pool and the demand.
7. Lack of effective approach in developing and attracting nanotechnology talent.</td></tr>
<tr><th colspan="4">STRATEGY</th></tr>
<tr><td colspan="4">2.4 Building a competent and adaptive nanotechnology talent with effective and fun STEM education integrating nanotechnology component.</td></tr>
<tr><th>INITIATIVES</th><th>SHORT-TERM
(2021-2022)</th><th>MEDIUM-TERM
(2023-2025)</th><th>LONG-TERM
(2026-2030)</th></tr>
<tr><td>2.4.1 Centralising national planning for nanotechnology talent development.</td><td>A national planning for nanotechnology talent development.</td><td colspan="2">A structured collection of data on supply and demand of nanotechnology talent including the career and jobs opportunity.

50% talents in nanotechnology from the overall STI talents of the country by 2030.

At least, 44,238 nanotechnology talents (high, semi & un-skilled workers) by 2030.</td></tr>
<tr><td>2.4.2 Making nanotechnology in STEM teaching and learning fun, experimental and effective from pre-school to tertiary levels.</td><td>A national planning of nanotechnology in STEM teaching and learning.

At least 3 specialised nanotechnology modules or programmes in STEM teaching and learning are developed and implemented.</td><td>Improvement and implementation of at least 3 specialised nanotechnology modules or programmes in STEM teaching and learning.</td><td>Improvement and implementation of at least 3 specialised nanotechnology modules or programmes in STEM teaching and learning.</td></tr>
<tr><th colspan="4">PLAYERS</th></tr>
<tr><td colspan="2">Lead by:
i. MOSTI
ii. NNC</td><td colspan="2">Supported by:
i. Pusat Sains Negara
ii. Planetarium Negara
iii. Petrosains
iv. Malaysia Board of Technologists (MBOT)
v. Ministry of Education (MOE)
vi. Ministry of Higher Education (MOHE)
vii. Ministry of Human Resources (MOHR)
viii. Yayasan Hijau Malaysia
ix. National STEM Centre
x. Other relevant ministries and organisations</td></tr>
</table>

<table>
<tr><th colspan="4">ISSUES & CHALLENGES</th></tr>
<tr><td colspan="4">8. Lack of appreciation and awareness on nanotechnology in all levels of community in research and development area.</td></tr>
<tr><th colspan="4">STRATEGY</th></tr>
<tr><td colspan="4">2.5 Increasing effective nanotechnology outreach and science communication.</td></tr>
<tr><th>INITIATIVES</th><th>SHORT-TERM (2021-2022)</th><th>MEDIUM-TERM (2023-2025)</th><th>LONG-TERM (2026-2030)</th></tr>
<tr><td>2.5.1 Formulating and organising effective nanotechnology outreach programmes.</td><td>A national planning of nanotechnology outreach programmes.

At least 5 strategic nanotechnology outreach programmes are developed, implemented and monitored.</td><td>At least 5 strategic nanotechnology outreach programmes are implemented and monitored.</td><td>At least 5 strategic nanotechnology outreach programmes are implemented and monitored.</td></tr>
<tr><td>2.5.2 Developing and executing strategic science communication initiatives/ programmes to inspire society on nanotechnology.</td><td>A national planning of nanotechnology science communication programmes.

At least 5 strategic nanotechnology science communication initiatives/ programmes are developed, implemented and monitored.</td><td>At least 5 strategic nanotechnology science communication initiatives/ programmes are implemented and monitored.</td><td>At least 5 strategic nanotechnology science communication initiatives/ programmes are implemented and monitored.</td></tr>
<tr><th colspan="4">PLAYERS</th></tr>
<tr><td colspan="2">Lead by:
i. MOSTI
ii. NNC</td><td colspan="2">Supported by:
i. Pusat Sains Negara
ii. Planetarium Negara
iii. Petrosains
iv. National STEM Centre
v. Science Media Centre
vi. MOE
vii. MOHE
viii. ASM
ix. Other relevant ministries and organisations</td></tr>
</table>

STRATEGIC THRUST 3: ENHANCING COMMERCIALISATION AND ENERGISING INDUSTRIES

ISSUES & CHALLENGES

1. Industrial R&D ecosystem lacks strategic focus, has weak linkages between key stakeholders, poor knowledge sharing culture, and weakness in technical education and training ecosystem that limits their adaptive and innovative capabilities.
2. Lack of vibrant investment and facilitation of nano-technopreneurs and start-ups.
3. Lack of novelty of new products from both services and manufacturing sectors since majority of industries are SMEs that not innovators.

STRATEGY

3.1 Shifting towards high-value-added and high-technology industries by fostering adoption nanotechnology to drive economic growth.

INITIATIVES	SHORT-TERM (2021-2022)	MEDIUM-TERM (2023-2025)	LONG-TERM (2026-2030)
3.1.1 Developing and implementing strategic national nanotechnology commercialisation planning towards high-value-added and high-technology industries.	A strategic national nanotechnology commercialisation planning. Implementation of national nanotechnology commercialisation planning.	Implementation of national nanotechnology commercialisation planning. Malaysian market in nanotechnology to reach RM 640 million in 2025.	Implementation of national nanotechnology commercialisation planning. Malaysian market in nanotechnology to reach RM 1.25 trillion in 2030.
3.1.2 Increasing investment and facilitation of nano-technopreneurs and start-ups through strategic nanotechnology commercialisation programmes.	1% increase in the investment and facilitation of nano-technopreneurs and start-ups through strategic nanotechnology commercialisation programmes.	2% increase in the investment and facilitation of nano-technopreneurs and start-ups through strategic nanotechnology commercialisation programmes. *52 nano technopreneur and start-ups by 2025.*	3% increase in the investment and facilitation of nano-technopreneurs and start-ups through strategic nanotechnology commercialisation programmes. *82 nano technopreneur and start-ups by 2030.*

PLAYERS

Lead by:
i. MOSTI
ii. NNC

Supported by:
i. NMB
ii. Malaysian Global Innovation & Creativity Centre (MaGIC)
iii. Malaysia Venture Capital Management Berhad (MAVCAP)
iv. Ministry of International Trade & Industry (MITI)
v. Technology Park Malaysia (TPM)
vi. MIMOS Berhad
vii. Malaysia Automotive Robotics & IoT Institute (MARii)
viii. CREST
ix. Ministry of Domestic Trade and Consumer Affairs (KPDNHEP)
x. Other relevant ministries, organisations & industry players

<table>
<tr><th colspan="4">ISSUES & CHALLENGES</th></tr>
<tr><td colspan="4">4. Lack of demand for Malaysian nanotechnology products and services both national and international levels</td></tr>
<tr><th colspan="4">STRATEGY</th></tr>
<tr><td colspan="4">3.2 Expanding international networks and demand for Malaysia nanotechnology products and nanotechnology services.</td></tr>
<tr><th>INITIATIVES</th><th>SHORT-TERM (2021-2022)</th><th>MEDIUM-TERM (2023-2025)</th><th>LONG-TERM (2026-2030)</th></tr>
<tr><td>3.2.1 Enhancing national and international strategic nanotechnology collaboration and engagement for commercialisation and trade towards increasing demand in local nanotechnology products.</td><td>A national nanotechnology collaboration and engagement planning for commercialisation and trade.

Implementation and participation at least 5 international collaboration/ engagement networks and programme for commercialisation and trade.</td><td>Implementation and participation at least 6 international collaboration/ engagement networks and programme for commercialisation and trade.</td><td>Implementation and participation at least 7 international collaboration/ engagement networks and programme for commercialisation and trade.</td></tr>
<tr><td>3.2.2 Implementing strategic nanotechnology commercialisation & demand programmes/ initiatives.</td><td>Implementation of at least 2 strategic nanotechnology commercialisation & demand programmes/ initiatives.</td><td>Implementation of at least 3 strategic nanotechnology commercialisation & demand programmes/ initiatives.</td><td>Implementation of at least 4 strategic nanotechnology commercialisation & demand programmes/ initiatives.</td></tr>
<tr><th colspan="4">PLAYERS</th></tr>
<tr><td colspan="2">Lead by:
i. MOSTI
ii. NNC</td><td colspan="2">Supported by:
i. NMB
ii. MaGIC
iii. MITI
iv. TPM
v. MIMOS Berhad
vi. CREST
vii. Other relevant ministries, organisations & industry players</td></tr>
</table>

<table>
<tr><th colspan="4">ISSUES & CHALLENGES</th></tr>
<tr><td colspan="4">5. Lack of strategic marketing platform in driving penetration of markets.</td></tr>
<tr><th colspan="4">STRATEGY</th></tr>
<tr><td colspan="4">3.3 Provide facilitation and incentives to the company that producing nano related products.</td></tr>
<tr><th>INITIATIVES</th><th>SHORT-TERM
(2021-2022)</th><th>MEDIUM-TERM
(2023-2025)</th><th>LONG-TERM
(2026-2030)</th></tr>
<tr><td>3.3.1 Providing facilitation to the local companies that producing and commercialising nano related products.</td><td>Implementation of at least 3 facilitation programmes for the commercialisation of nano related products.

Facilitation for 50 companies.</td><td>Implementation of at least 3 facilitation programmes for the commercialisation of nano related products.

Facilitation for 60 companies.</td><td>Implementation of at least 3 facilitation programmes for the commercialisation of nano related products.

Facilitation for 70 companies.</td></tr>
<tr><td>3.3.2 Leveraging the existing STI related incentives to the local companies that producing and commercialising nano related products.</td><td>Implementation of at least 2 incentive programmes for the commercialisation of nano related products.

50 companies benefitted from the incentives.</td><td>Implementation of at least 2 incentive programmes for the commercialisation of nano related products.

60 companies benefitted from the incentives.</td><td>Implementation of at least 2 incentive programmes for the commercialisation of nano related products.

70 companies benefitted from the incentives.</td></tr>
<tr><th colspan="4">PLAYERS</th></tr>
<tr><td colspan="2">Lead by:
i. MOSTI
ii. NNC</td><td colspan="2">Supported by:
i. NMB
ii. MaGIC
iii. MAVCAP
iv. MITI
v. Other relevant ministries, organisations & industry players</td></tr>
</table>

ISSUES & CHALLENGES			
6. Lack of total S&T talent planning and development to move STI agenda that also affecting nanotechnology's talent pool and the demand. **7.** Lack of effective approach in developing and attracting nanotechnology talent.			
STRATEGY			
3.4 Intensifying demand and attracting more and better talent to participate in the nanotechnology workforce.			
INITIATIVES	**SHORT-TERM (2021-2022)**	**MEDIUM-TERM (2023-2025)**	**LONG-TERM (2026-2030)**
3.4.1 Providing competitive salary and remuneration packages for nanotechnology talents which includes RSET.	A strategic planning and strategy for the revised salary and remuneration packages for nanotechnology talents.	1% increase in nanotechnology talents.	2% increase in nanotechnology talents.
3.4.2 Strengthening public-private partnerships in nanotechnology talent's skills development, entrepreneurship & academic training programmes.	Implementation of at least 2 strategic collaborative nanotechnology talent's skills development, entrepreneurship & academic training programmes with industries.	Implementation of at least 3 strategic collaborative nanotechnology talent's skills development, entrepreneurship & academic training programmes with industries.	Implementation of at least 4 strategic collaborative nanotechnology talent's skills development, entrepreneurship & academic training programmes with industries.
3.4.3 Implementing upskilling programme for the existing STI talents in nanotechnology.	At least 100 STI talents participated in nanotechnology upskilling programme annually.	At least 150 STI talents participated in nanotechnology upskilling programme annually.	At least 200 STI talents participated in nanotechnology upskilling programme annually. Increasing of 30,000 talents in nanotechnology by 2030.
34.4 Certifying nanotechnology professionals and technologists.	At least 50 nanotechnology professionals and technologists are certified.	At least 60 nanotechnology professionals and technologists are certified.	At least 70 nanotechnology professionals and technologists are certified.
PLAYERS			
Lead by: i. MOSTI ii. NNC		**Supported by:** i. NMB ii. MBOT iii. MOE iv. MOHE v. MOHR vi. Other relevant ministries, organisations & industry players	

<table>
<tr><th colspan="4">ISSUES & CHALLENGES</th></tr>
<tr><td colspan="4">8. Lack of appreciation and awareness on nanotechnology in all levels of community in commercialisation.</td></tr>
<tr><th colspan="4">STRATEGY</th></tr>
<tr><td colspan="4">3.5 Mainstreaming science communication for promoting nanotechnology.</td></tr>
<tr><th>INITIATIVES</th><th>SHORT-TERM (2021-2022)</th><th>MEDIUM-TERM (2023-2025)</th><th>LONG-TERM (2026-2030)</th></tr>
<tr><td>3.5.1 Executing strategic science communication initiatives/ programmes for nanotechnology commercialisation to increase awareness among the public.</td><td>At least 5 strategic nanotechnology science communication initiatives/ programmes for development, implementation and monitoring of nanotechnology commercialisation.</td><td>At least 5 strategic nanotechnology science communication initiatives/ programmes for development, implementation and monitoring of nanotechnology commercialisation.</td><td>At least 5 strategic nanotechnology science communication initiatives/ programmes for development, implementation and monitoring of nanotechnology commercialisation.</td></tr>
<tr><th colspan="4">PLAYERS</th></tr>
<tr><td colspan="2">Lead by:
i. MOSTI
ii. NNC</td><td colspan="2">Supported by:
i. NMB
ii. Science Media Centre
iii. Pusat Sains Negara
iv. Planetarium Negara
v. Petrosains
vi. Other relevant ministries and science communication bodies</td></tr>
</table>

STRATEGIC THRUST 4: STRENGTHENING STANDARD, SAFETY AND REGULATION

ISSUES & CHALLENGES			
1. Lack of awareness on standards, safety, and regulation specific for nano.			
STRATEGY			
4.1 Promoting the importance of standard and safety among industries towards increasing the value of nanotechnology products.			
INITIATIVES	**SHORT-TERM (2021-2022)**	**MEDIUM-TERM (2023-2025)**	**LONG-TERM (2026-2030)**
4.1.1 Developing a comprehensive nano database as an inventory of local nano-based products as well as reference on nano safety, standard & regulation.	A comprehensive nano database with inventory of at least 100 local nano products.	Inventory of at least 200 local nano products. Database expanded to nano-products in ASEAN markets.	Inventory of at least 300 local nano products.
4.1.2 Developing indigenous standards to support local industries and to be adopted internationally, through ISO TC 229 Nanotechnologies Working Group mechanism	Development and adoption of at least 1 new national standard Development of relevant ISO Standard through ISO TC 229 Working Group	Development and adoption of at least 2 new national standards. Development of relevant ISO Standard through ISO TC 229 Working Group	Development and adoption of at least 3 vew national standards. Development of relevant ISO Standard through ISO TC 229 Working Group Local national standard to be adopted internationally.
4.1.3 Increasing awareness among industries and publics on the importance nanostandards and nanosafety through strategic awareness/ engagement programmes.	At least 5 strategic awareness/ engagement programmes on nanosafety and nonstandard are implemented by region. Participation of at least 50 companies and 50 nano products certified.	At least 5 strategic awareness/ engagement programmes on nanosafety and nonstandard are implemented by region. Participation of at least 100 companies and 100 nano products certified.	At least 5 strategic awareness/ engagement programmes on nanosafety and nonstandard are implemented by region. Participation of at least 150 companies and 150 nano products certified.

PLAYERS	
Lead by: i. MOSTI ii. NNC	**Supported by:** i. NMB ii. Standards Malaysia iii. Jabatan Kimia Malaysia iv. SIRIM Berhad v. MOH vi. National Pharmaceutical Regulatory Agency (NPRA) vii. Ministry of Environment & Water (KASA) viii. Department of Safety & Health (DOSH) ix. Ministry of Domestic Trade and Consumer Affairs (KPDNHEP) x. Other relevant ministries and regulatory bodies

<table>
<tr><th colspan="4">ISSUES & CHALLENGES</th></tr>
<tr><td colspan="4">1. Disconnected ecosystems in supporting the overall nanotechnology implementation, development, and innovation ecosystem.</td></tr>
<tr><th colspan="4">STRATEGY</th></tr>
<tr><td colspan="4">4.2 Integrating nanotechnology in regulation.</td></tr>
<tr><th>INITIATIVES</th><th>SHORT-TERM (2021-2022)</th><th>MEDIUM-TERM (2023-2025)</th><th>LONG-TERM (2026-2030)</th></tr>
<tr><td>4.2.1 Integrating nanotechnology standard and safety in the relevant legislation.</td><td>Regulatory Impact Assessment (RIA).</td><td>Developing nano related regulation.</td><td>Integration in the relevant legislation.</td></tr>
<tr><th colspan="4">PLAYERS</th></tr>
<tr><td colspan="2">Lead by:
i. MOSTI
ii. NNC</td><td colspan="2">Supported by:
i. NMB
ii. Standards Malaysia
iii. Jabatan Kimia Malaysia
iv. SIRIM Berhad
v. MOH
vi. NPR
vii. KASA
viii. DOSH
ix. KPDNHEP
x. Other relevant ministries and regulatory bodies</td></tr>
</table>

<table>
<tr><th colspan="4">ISSUES & CHALLENGES</th></tr>
<tr><td colspan="4">2. Lack of robustness for nanotechnology certification in leveraging the advantages for country’s revenue generation.</td></tr>
<tr><th colspan="4">STRATEGY</th></tr>
<tr><td colspan="4">4.3 Re-strategising nanotechnology certification in attracting more adoption towards increasing nanotechnology products’ value.</td></tr>
<tr><th>INITIATIVES</th><th>SHORT-TERM
(2021-2022)</th><th>MEDIUM-TERM
(2023-2025)</th><th>LONG-TERM
(2026-2030)</th></tr>
<tr><td>4.3.1 Enhancing nanotechnology certification package.</td><td>A revised nanotechnology certification package.

Participation of at least 50 companies and 50 nano products certified.</td><td>Participation of at least 100 companies and 100 nano products certified.

Expending certification for ASEAN region.</td><td>Participation of at least 150 companies and 150 nano products certified.</td></tr>
<tr><th colspan="4">PLAYERS</th></tr>
<tr><td colspan="2">Lead by:
i. MOSTI
ii. NNC</td><td colspan="2">Supported by:
i. NMB
ii. Standards Malaysia
iii. Jabatan Kimia Malaysia
iv. SIRIM Berhad
v. MOH
vi. NPR
vii. KASA
viii. DOSH
ix. KPDNHEP
x. Other relevant ministries and regulatory bodies</td></tr>
</table>

Special Topic:
Major Leapfrog and High-Impact Initiatives on Nanotechnology

Major economic sectors

Based on ASM Emerging Science, Engineering & Technology (ESET) Study 2017, three major economic sectors which are fundamental to Malaysia's economic growth are electrical and electronics (E&E is embedded in the manufacturing sector), agriculture and Halal industry (reflected in services sector).

Since 1972, E&E industry has rapidly developed and became the key driver of manufacturing sector which significantly contributed to the country's economy. In 2016, Malaysia was the world's seventh largest exporter of E&E products. The E&E sector contributed 26.5% to Malaysia's GDP in 2019 as the sixth largest exporter in the world for integrated circuit in 2018 (DOSM, 2020). E&E products are also the top manufactured goods of the country with value of RM 276.7 billion in 2020 (MITI, 2020).

Whereas agriculture plays important role in Malaysia's socio-economic development by ensuring national food security and enabling people's well-being through rural employment as well as uplifting rural incomes. The agriculture sector contributed 8.8% to Malaysia's GDP in 2020 (MITI, 2020).

The Halal industry is rapidly expanding business and there is immense opportunity for Malaysia to position itself as a global Halal supplier. The global halal market is expected to reach 2.2 billion people by 2030 due to the increasing of awareness among the Muslim and non-Muslim population on the quality of Halal products. The Halal industry is a significant contributor to Malaysia's economy in 2016 with 7.5% contribution to Malaysia's GDP. Malaysia has the potential to raise its Halal global market share from 2.2% in 2018 (as cited in Halal Industry Master Plan, 2020) to 5% in 2030, estimated at RM1 trillion.

To date, services, manufacturing and agriculture sectors remained among the key economic sectors for the country with contribution of RM 820.1 billion, 316.3 billion and RM 101.5 billion respectively to the 2019 country's GDP (Source: The Malaysian Economy in Figures 2020, EPU June 2020).

The three major economic sectors are potential to be further developed to make leap to the next level advancement by harnessing cutting-edge technologies to realise outcomes that would lead to high-tech, progressive and prosperous nation. Therefore, it is imperative for the 10 technology drivers listed in the 10-10 *My*STIE Framework to be leveraged towards a vibrant socio-economic development of the country through these economic sectors.

Top 5 impactful emerging technologies in nanotechnology

New technologies are redefining industries and creating new opportunities on a scale that were never seen before. Therefore, 95 emerging technologies from 5 emerging areas (biotechnology, digital technology, green technology, nanotechnology & neurotechnology) and its timeline were identified through ASM ESET Study 2017 based on Malaysia's strength and needs. From the 95 emerging technologies, 21 impactful emerging technologies were prioritised based on the feasibility and attractiveness in Malaysia's context guided by the global trends and global risks to elevate Malaysia's well-being, wealth creation and governance towards realising a prosperous, harmonious and sustainable nation by 2050.

From the 21 technologies, 5 impactful emerging technologies in nanotechnology were identified due to its high potential towards socio-economic development in Malaysia:

- nanomaterials (2021-2035),
- photovoltaic cells (2021-2035),
- nanosensors IoT (2015-2020),
- nano based drug delivery system (2021-2035) and
- fuel cell (2021-2035).

These impactful emerging technologies are predicted to contribute to socio-economic areas such as healthcare for a healthy nation, reducing carbon footprint and democratisation of knowledge.

As we move towards the future, more and more technology convergence would occur. In nanotechnology, nanomaterials-based sensors that enhance sensitivity and specificity are already being combined with digital technology to give rise to nanoscale environmental surveillance in the form of dust sized particles, known as smart dust networks. Further into the future (around 2036-2050), advancement in nanomaterials and its interfacing with digital technology would give rise to nanorobots that are versatile and safe for applications such as drug delivery system. Furthermore, the next generation of super smartphones would be affordable, flexible due to single layered nanomaterials which do not require battery to be charged and easy to use.

In today's global world, we see advances in renewable energy, electric vehicles and hybrid technology have led significant reductions in emissions and waste with further improvements currently being made in the areas of biofuels, organic photovoltaics, and hydrogen-powered vehicles. Over the last decade, investment in renewable energy technologies such as fuel cell and photovoltaic cell are increasing in Malaysia.

Therefore, it is timely for these 5 impactful emerging technologies in nanotechnology to be further embarked towards socio-economic development and technology advancement in Malaysia.

The major Leapfrog & High-Impact initiatives

Based on the above major economic sectors and 5 impactful emerging technologies in nanotechnology, it is proposed for 3 leapfrog and high-impact initiatives in the economic sectors which prioritising the development of the above mentioned impactful emerging technologies:

1. Nano leapfrog and high impact initiative in halal
2. Nano leapfrog and high impact initiative in E&E
3. Nano leapfrog and high impact initiative in agriculture

These leapfrog and high-impact initiatives are aligned with the 30 national niche areas and the proposed high-impact initiative indicated in 10-10 *My*STIE Framework. The application 10 technology drivers towards 10 socio-economic drivers will also be adopted in this leapfrog and high-impact initiatives to ensure inclusive socio-economic development and sustainable management of natural resources towards the high-tech, progressive, and prosperous nation.

(*Additional texts for the special topic*).

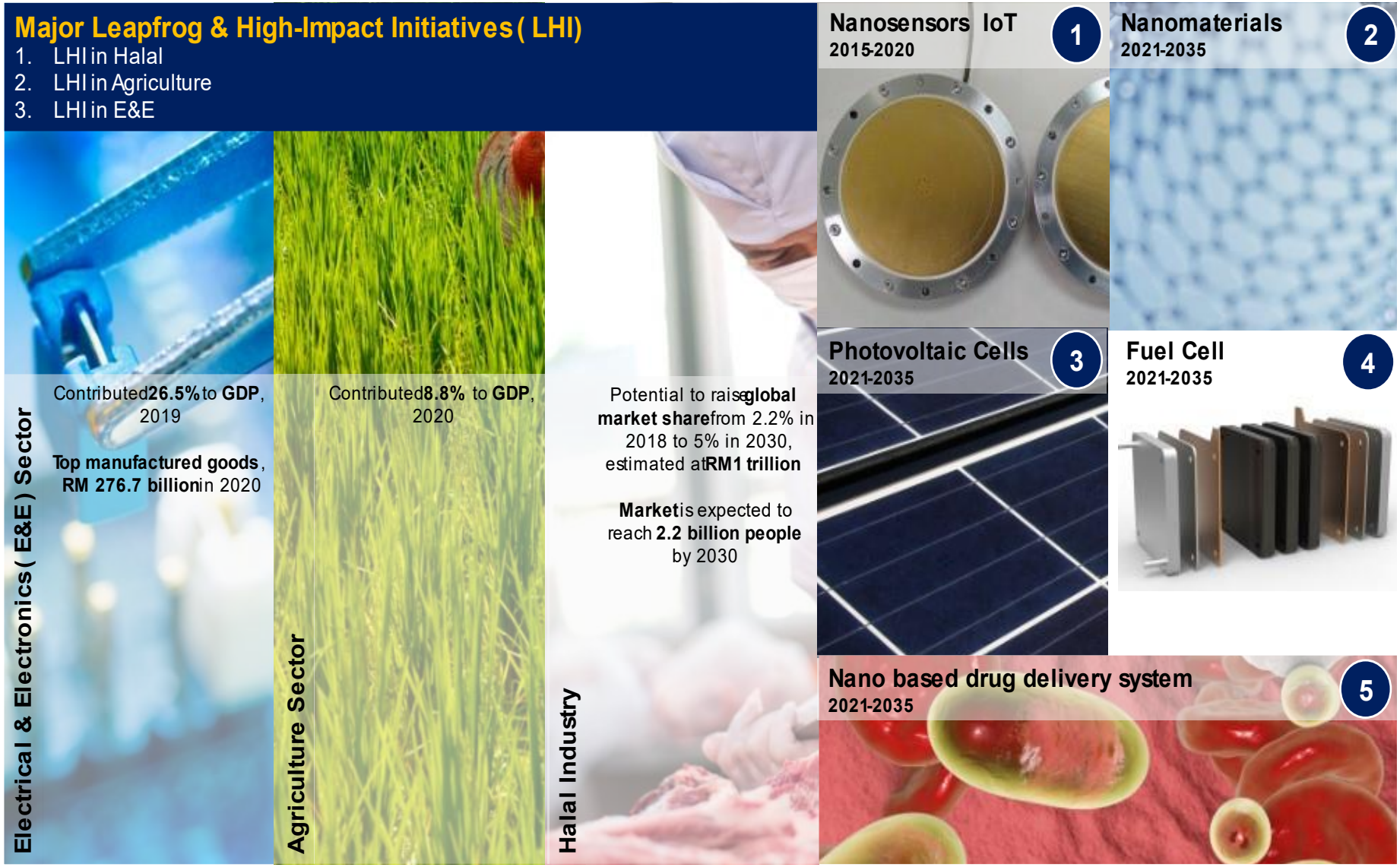


Figure 39: Major leapfrog & High-Impact Initiatives

Further Reading

Definition of Nanotechnology

Nanotechnology refers to the application of scientific knowledge to manipulate and control matter in the nanoscale (ranges approximately between 1 to 100 nanometers) in order to utilize size and structure dependent properties and phenomena. Nanoscale materials have unique electromagnetic, thermal and optical characteristics distinct from those associated with individual atoms or molecules or with bulk materials thus making them crucial in solving the myriad challenges faced by humanity. Nanomaterials could have novel possibilities of applications through them allowing for lighter, stronger, smarter, cheaper, cleaner and more durable consumer and engineered products.

Table 11. Overview of USA, South Korea and Germany Nanotechnology Ecosystem.

Country	USA	South Korea	Germany
Policy/ Plan	NNI (2001)	NNI-K (2001)	Action Plan Nanotechnology (2010, 2015, 2020)
Act	21st Century Nanotechnology Research and Development Act (2003)	Nanotechnology Development and Promotion Act (2002)	-
Coordination	National Nanotechnology Coordination Office (NNCO)	Ministry of Science and ICT (MSIT)	Federal Government
Involvement	20 Federal Departments, Independent Agencies and Commissions	5 Ministries: 1. MSIT 2. MOTIE 3. MOHW 4. MOEL 5. ME	7 Ministries: 1. BMBF 2. BMAS 3. BMEL 4. BMG 5. BMUB 6. BMVe 7. BMWi
Funding	Funding from participating agencies	Specified Government Nanotechnology Funding	Anchored in specialist programmes of the Federal Government

Country	USA	South Korea	Germany
Key Areas	All aspects of nanotechnology	Industrialisation of 7 Key Technologies: 1. 3D nano-electronics device 2. Environmental IoT nano-sensor 3. Food safety nano-sensor 4. Functional nano-fibres 5. Precious metal free catalysts 6. Rare-earth free nanomaterials for industrial use 7. Low energy water treatment systems	Future Tasks outlined in HST: 1. Digital Economy and Society 2. Sustainable Economy and Energy 3. Innovative Working Environment 4. Healthy Living 5. Intelligent Mobility 6. Civil Security
Commercialisation	Special programmes designed to seed nanotechnology commercialisation (more than 40)	Linking R&D and commercialisation aspects through the Nano-Convergence programme	Promotes the innovative power of SMEs through targeted measures and reduces existing barriers to innovation: • Online portal nano-map.de, interactive map of the participants from science and industry to aid in the search for cooperation partners. • Technology discussions and dialogue events to address sector-specific problems at an early stage and support the diffusion of new application options into commercial practice.

Safety (EHS), Rules and Regulations	Nanotechnology Environmental and Health Implications (NEHI) Working Group (cumulative nanoEHS investment of USD 1.26 billion since 2005) collaborates on nanoEHS research and related policy issues with other countries and international organisations	Participate in the OECD Working Party on Manufactured Nanomaterials (WPMN) Korean Agency for Technology and Standards (KATS) is involved with ISO/TC229 1st and 2nd nano-safety management plan (2012-2016; 2017-2021)	German institutes and industry are engaged in the standardisation of nanotechnology at: • International level (ISO, IEC) • European Level (CEN, CENELEC) • National Level (DIN, DKE, VDI)
Impact	Recognition as the global leader of nanotechnology.	High-ranking in nanotechnology R&D. Increased in nanotechnology convergence industrial core index year-on-year. Increase in royalty and commercialisation performance of national R&D projects.	Collaboration has succeeded in creating synergies, pooled various ministerial activities and prevented double funding.

National Nanotechnology Initiatives of Malaysia (NNIM)

NNIM mission is "nanotechnology for sustainable national development of science, technology, industry, and economy".

NNIM was formulated to advance nanotechnology and related science by clustering local resources and knowledge between researchers, industry and government.

NNIM dealt with promoting:

- World-class nanotechnology research institutions;
- Strong expenditure on nanotechnology R&D;
- Competitive business environment;
- Robust education and training systems;
- Highly skilled, educated and diverse workforce; and
- Efficient infrastructure and integrated nanotechnology activity.

NNIM strategies included:

- Improving Malaysian economic competitiveness to face global challenges;
- Accelerating scientific breakthrough on selective beneficial nanotechnologies; and
- Enhancing societal and environmental contributions from nanotechnology.

National Nanotechnology Centre (NNC)

The roles of NNC are:

- Develop and strengthen national capacity and capability through the development and implementation of policy as well as supporting infrastructure and physical facilities in tandem with early education in nanosciences for the development of human capital;
- Plan, coordinate and monitor research, development and commercialisation (R,D&C) activities in Malaysia to support the government strategic aspirations;
- Plan, coordinate and monitor activities that contributing to the development of nanotechnology-based industry as sources of economic growth; and
- Facilitate the positioning of Malaysia's nanotechnology related industry players and products in the global supply chain.

NND was rebranded to the National Nanotechnology Centre (NNC) in 2016.

National Nanotechnology Statement (NNS)

Five themes of NNS are:
Theme 1: Inculcation of a nanotechnology culture
Theme 2: Strengthening of research and innovation as a national niche focus area
Theme 3: Enhancement of collaboration and networking
Theme 4: Upholding of regulation and acts
Theme 5: Promotion of commercialisation and industrialisation

NanoMalaysia Berhad (NMB)

NMB is a Company Limited by Guarantee under MOSTI's purview. Its main objectives of establishment are to "re-energising industries and catalysing economic growth deployment and adoption of nanotechnology in industries business growth and sustainable development cutting edge technological leadership and creating true values".

NMB is entasked to deliver the following activities:

- Act as a business entity entrusted to focus on the commercialisation and development of nanotechnology;
- Plan and coordinate the commercialisation of nanotechnology R&D in high impact areas such as electrical and electronics, food and agriculture, energy and environment, and health and medicine;
- Plan and manage activities that contribute to the development of nanotechnology-based industries;
- Strategise the positioning of nanotechnology industry of Malaysia in the global supply and value chain;
- Facilitate investment in nanotechnology commercialisation; and
- Facilitate the development of human capital (scientists and engineers, researchers, and professionals) in the nanotechnology industry.

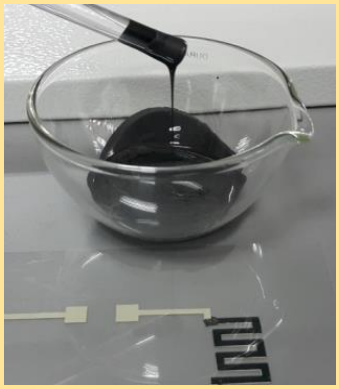
Malaysia Nano Centre of Excellences (Nano COEs) -2011-2014

Five centres have been identified as Nano COEs in Malaysia, for the period of **2011-2014**

1. Institute of Micro Engineering and Nanoelectronics (IMEN), UKM – *Nanoelectromechanical Systems (NEMS) and Lab-on-Chips for the biomedical industry*
2. Institute of Nanoelectronics and Engineering (INEE), UNIMAP – *Nano DNA Chips for medical diagnostics*
3. Centre for Innovative Nanostructures and Nanodevices (COINN), UTP – *Solar energy*
4. NEMS/MEMS Research Laboratory, MIMOS - *Self-Powered Breath Sensors for Intelligent Wearable & Healthcare Monitoring Systems.*
5. Enabling Science and Nanotechnology Research, Ibnu Sina Institute for Fundamental Science Studies (IIFS), UTM – *Novel Functional Nanomaterials: Synthesis and Computational Design*

Some of successfully commercialised products under the NANOVerify programme

Electronic Devices and Systems



Name of Company	SERDANG PASTE TECH SDN BHD
Name of product	CONDUCTIVE INK
Certificate No	PENDING CERTIFICATION
Product Description	Composition of materials and preparation method in producing thick film paste for screen printing, composed of organic binder using linseed oil mixed with certain active powder
Company website	https://sciencepark.upm.edu.my/upload/dokumen/20190513153547Serdang_Paste_Tech_ Sdn._Bhd.pdf
Contact Person in Charge	Mohd Asnawi
Expiry date	PENDING

Energy and Environment

Name of Company	PT JAVA INDAH
Nama of product	Zeolyte Catalyst
Certificate No	NVCCC00043
Product Description	Zeolite Catalyst which is suitable to reduce COD level of effluent discharge from factory waste.
Company website	-
Contact Person in Charge	Lina Nasaputra
Expiry date	19 April 2021

Food and Agriculture

Name of Company	ORILIN RESOURCES SDN BHD
Nama of product	CANDY TABLET
Certificate No	NVC000057
Product Description	Handy chewable tablet to relief mild cough, throat irritation and helps eliminate bad breath
Company website	https://orilinresources.wixsite.com/orilinresources
Contact Person in Charge	Mohd Azlan bin Abdullah
Expired date	7 August 2022

Name of Company	BONDING TECHNOLOGY RESOURCES SDN BHD
Nama of product	Chemi-Bond Nano Fertilizer
Certificate No	NVC000087
Product Description	Organic fertilizer
Company website	www.chemibond.com.my
Contact Person in Charge	Ms. L. Y. Sin
Expiry date	7 August 2022

Wellness, Medical and Healthcare

Name of Company	TRUMER MEDICARE SDN BHD
Nama of product	Trucare Nano Silver Spray
Certificate No	NVC000048
Product Description	Antibacterial and treatment of wound
Company website	www.trucare.com.my
Contact Person in Charge	Yee Chin Siong
Expiry date	31 January 2022

Name of Company	FARMASIA SDN BHD
Nama of product	Silvergrade Hand Sanitizer
Certificate No	NVC000075
Product Description	Utilizes nano colloidal silver for anti-virus, anti-fungal and anti-bacterial properties
Company website	www.farmasia.com.my
Contact Person in Charge	Wan Rizzal bin Wan Zaki
Expiry date	31 January 2022

Table 12. List of Ministries/Agencies/Organisations related to nanotechnology.

Category	Ministry / Agency	Roles
Nanotechnology Coordinating Body	National Nanotechnology Centre (NNC)	• A division under MOSTI to oversee and implementing Nanotechnology Agenda for the nation; • National focal point and central coordinating body for research activities, technology, and product development as well as safety, standards and regulatory matters pertaining to the nanotechnology in Malaysia.
Nanotechnology (NT) research institutions & institutes	Institute of Higher Learnings (IHLs)	• The Institute of Higher Learning offers postgraduate degrees that has nanotechnology application in the research studies under the Masters and Doctoral programme. These contribute to the development of intellectual capital and research activities in the field of nanotechnology. Research from fundamental to pre-commercialisation stage are mostly covered by the IHLs.
	KIMIA Malaysia	• KIMIA Malaysia is ready to conduct research especially related to the development of methods to ensure that the chemicals used in this nanotechnology product are not harmful to health and the environment; • In terms of R&D, KIMIA Malaysia will work with well-known research institutions (Examples: Nanotechnology Research Center (NIOSH); Institute of Occupational Medicine, Singapore; The Dutch National Institute for Public Health and the Environment; National Institute of Materials Science, Japan) to formulate a comprehensive framework in developing SOPs for nanomaterial testing.
	Malaysian Space Agency (MYSA)	• Develop the nation's capability in a comprehensive and coordinated manner in the field of technology, application, and space science.

Category	Ministry / Agency	Roles
	Nuklear Malaysia	• Malaysian Nuclear Agency (Nuklear Malaysia) has been promoting the use of nuclear technology in nano material research for various applications. The earlier works, up to 2015, revolves mainly on carbon nano tube (CNT), nanocomposite and nano-hybrid bio composite; • This resulted in the International Atomic Energy Agency (IAEA) awarding Nuklear Malaysia as one of its International Collaborating Centre (ICC) for Radiation Processing of Natural Polymer and Nano Materials for the period 2016 – 2020; • Recently IAEA had widened the scope for the ICC to "Research, Training and Development in Nuclear Sciences and applications (2019 – 2023)" which included two other ICCs in Advance Non Destructive Testing and Gamma Green House awarded to Nuclear Malaysia; • Currently there are 25 research (lead by Nuklear Malaysia or as collaborator) in nanotechnology involving radiation.
	Astronautic Technology Sdn Bhd (ATSB)	• Wholly owned company by the Malaysian government under the Minister of Finance Inc. supervised by Ministry of Energy, Science, Technology, Environment and Climate Change with the mandate primarily to develop space and satellites technology focusing in research and development employing advanced and innovative technologies for the space industry; • ATSB has extensive experience in satellite design and development with specific technologies for Structures, Thermal, Communications, Orbital Dynamics, Optical, Attitude Determination and Control Systems, Embedded Onboard Computer Systems, Electro Optics and Flight Software.
	InnoBio	• Leading manufacturer of functional ingredients with an independent R&D

Category	Ministry / Agency	Roles
		centre, professional cGMP large-scale production with international quality standards, and worldwide marketing and distribution; • InnoBio has a national joint engineering research centre, a national post-doctoral research station, and a provincial enterprise technology centre with commercialisation capability. Its R&D team is composed of more than 90 well-known experts and scholars from abroad in the fields of biochemistry and medicine.
	National Institutes of Biotechnology Malaysia (NIBM)	• National Institutes of Biotechnology Malaysia (NIBM) is a consortium of three national biotechnology institutes – Malaysian Institute of Pharmaceuticals & Nutraceuticals (IPHARM), Agro-Biotechnology Institute Malaysia (ABI), and Malaysia Genome Institute (MGI); • NIBM collaborates with University of Malaya under the NanoMITe grant. One of the targeted outputs of NIBM involvement in the project is the development of human capital in the field of nanotechnology.
	Institute for Medical Research (IMR)	• The IMR is the biomedical research arm of the Ministry of Health, Malaysia; • IMR undertakes research to advance scientific knowledge and understanding as well as to provide evidence for informed decision making and formulation of effective preventive and control programs and activities. Research is also carried out with the purpose of developing enabling technologies or products and identifying new biomarkers for use in the early detection and diagnosis of disease, monitoring of disease progression and targeted therapy.
	Malaysian Agricultural Research and	• The Malaysian Agricultural Research and Development Institute (MARDI) has been

Category	Ministry / Agency	Roles
	Development Institute (MARDI)	established since 1969 and it is a statutory body under the Ministry of Agriculture and Agro-based Industry Malaysia which has been mandated to conduct research in agriculture, food and agro-based industries; • MARDI research is focused on the development and production of agricultural-related products (such as nano fertilisers, nano-pesticides, nano-fungicides).
	Malaysian Palm Oil Board (MPOB)	• MPOB is the government agency entrusted to serve the country's oil palm industry. Its main role is to promote and develop national objectives, policies, and priorities for the wellbeing of the Malaysian oil palm industry; • The thrust of MPOB's activities is on Research and Development (R&D). A whole spectrum of R&D work ranging from upstream production to downstream processing is carried out by the various research divisions as follows and is also being supported by non-research divisions: a) Biological Research Division b) Integration Research & Extension Division c) Engineering and Processing Division d) Advanced Oleochemical Technology Research Division e) Product Development & Advisory Service
	Malaysian Rubber Board (MRB)	• The Malaysian Rubber Board (MRB) is the custodian of the rubber industry in Malaysia. • The primary objective of MRB is to assist in the development and modernisation of the Malaysian rubber industry in all aspects from cultivation of the rubber tree, the extraction and processing of its raw rubber, the manufacture of rubber

Category	Ministry / Agency	Roles
		products and the marketing of rubber and rubber products; • The research and innovation sector in MRB cover the upstream, midstream and downstream operations.
Nanotechnology commercialisation bodies	NanoMalaysia Berhad	• NanoMalaysia Berhad (NanoMalaysia) is Malaysia's lead agency responsible for the commercialisation of nanotechnology in the country; • NanoMalaysia's role is to provide support for commercial entities within the nanotechnology industry, to achieve targeted outcomes in moving towards an innovation-driven economy.
	Technology Park Malaysia (TPM)	• Technology Park Malaysia Corporation Sdn Bhd (TPM) is the innovation facilitator and technology enabler of Malaysia; • TPM Innovation Incubation Centre aspires to accelerate the growth of technopreneurs in the renewable energy, ICT, biotech and engineering industries to grow from ideation to commercialisation via provision of intervention programmes in critical areas; • TPM Centre for Technology Commercialisation (CTC) is dedicated to stimulate the needs of the country's key stakeholders in harnessing technology for wealth creation. Universities, research institutes, venture financiers, technopreneurs, intellectual property specialists, governmental regulators, researchers, business entities and industry players will come together at CTC to make technology commercialisation a reality; • CTC is working with the Innovation and Commercialization Division of MOSTI towards the commercialisation of products developed through R&D activities sponsored by the Ministry. CTC's Project Monitoring Team (PMT) has also

Category	Ministry / Agency	Roles
		been appointed by MOSTI to manage and monitor grants given out under the Technofund, Sciencefund and Innofund grants.
	MIMOS Berhad	• MIMOS is focused on generating technology solutions that enable the Government to deliver better services, and the industry to achieve continued growth; • Nano Semiconductor Technology Centre, which is a comprehensive shared service facility located at the MIMOS premises for small, medium, and large enterprises in the E&E sector; • As the national applied research centre for ICT, micro- and nanoelectronics, we have been a key player in the development of the E&E sector. MIMOS have established a strong ecosystem through our shared facilities, and we are moving into nanotechnology as a key enabler. The Nano-Semiconductor Technology Centre will serve as a catalyst to thrust nanotechnology as a new growth engine; • Collaboration between NMB and MIMOS focuses on commercial of market-driven nanoelectronics, particularly graphene-based, is poised to elevate Malaysia's E&E industry in terms of high-complexity products and high-value job creation through the National Graphene Action Plan 2020
	Malaysian Global Innovation and Creativity Centre (MaGIC)	• Malaysian Global Innovation and Creativity Center (MaGIC) - an agency under MOSTI that helps facilitate, navigate and empower the start-up and entrepreneurship ecosystem with a mission to strengthen Malaysia's position as an innovation nation.
	Ministry of International Trade and Industry (MITI)	• The Ministry of International Trade and Industry (MITI) is a ministry of the Government of Malaysia that is responsible for international trade, industry, investment, productivity, small and medium enterprise, development

Category	Ministry / Agency	Roles
		finance institution, halal industry, automotive, steel, strategic trade.
	Malaysia Automotive Robotics and IoT Institute (MARii)	• Malaysia Automotive Robotics and IoT Institute (MARii) serves as the focal point, coordinating centre & think tank towards enhancing the competitiveness of the automotive industry and overall mobility, including intelligent transportation system & related services through adoption of robotics & IoT.
	Collaborative Research in Engineering, Science and Technology (CREST)	• Collaborative Research in Engineering, Science and Technology (CREST) was created in 2012 as an industry-lead collaborative platform for market-driven R&D focusing on Electrical & Electronics (E&E) sector. CREST brings together the industry, academia, and government to collaborate in a triple helix framework in driving industry demand driven R&D, industry relevant talent development and commercialization of the developed intellectual property (IP) into marketable products or services; • CREST is co-chair of the Technical Working Group (TWG) – Technology under Industry4WRD policy steering committee. Along with MIMOS, MAARI, SIRIM, NANO MALAYSIA, CSM, MIGHT, STANDARDS and many other agencies as well public and private universities, CREST actively promote and seek technology experimentation for Malaysia's manufacturing sectors.
	SilTerra Malaysia Sdn. Bhd.	• SilTerra Malaysia Sdn. Bhd. is a Malaysian semiconductor wafer fabrication foundry founded in November 1995. SilTerra is owned by Khazanah Nasional Berhad, the investment holding arm of the Government of Malaysia; • The technologies developed are mainly built on Complementary Metal Oxide Semiconductors (CMOS) design and fabrication processes at the 180 nm technology node down to 90 nanometer. These nodes are the

Category	Ministry / Agency	Roles
		building block of a broad range of Integrated Chips in the advanced Logic, Mixed-Signal & Radio Frequency and High Voltage applications. Most, if not all, of the devices fabricated integrated chips have sub-structures that are well below 100nm range.
	Industries	• Industries in Malaysia is divided into multinational corporation (MNC) and Small or Medium Enterprise (SME) • MNCs have operations and assets in numerous countries whereas SMEs are independent firms with limited employees.
Nanotechnology standard, safety & regulation related bodies	Department of Occupational Safety and Health Malaysia	• The Department of Occupational Safety and Health (DOSH) is a department under the Ministry of Human Resources. This department is responsible for ensuring the safety, health and welfare of people at work as well as protecting other people from the safety and health hazards arising from the activities sectors. • As a government agency, the department is responsible for the administration and enforcement of legislations related to occupational safety and health of the country, with a vision of becoming an organisation which leads the nation in creating a safe and healthy work culture that contributes towards enhancing the quality of working life.
	SIRIM Berhad	• Leading organisation for technology and quality solutions specialising in: Industrial Research, Development and Commercialisation, Certification, Testing and Inspection, Training and Design Advisory.
	Standards Malaysia	• Malaysia's Standards and Accreditation Body that develops and promotes the Malaysian Standards (MS) and provides accreditation services to conformity assessment bodies.

Category	Ministry / Agency	Roles
	Food Safety and Quality Division	• Food Safety & Quality Division was established to strengthen the activities of planning, implementing, monitoring and evaluating Food Safety and Quality Programs to protect the public against health hazards and fraud on storage, preparation, packaging processing, transportation, sale and consumption of food; as well as facilitating food trade.
	National Pharmaceutical Regulatory Agency (NPRA)	• Implement the regulatory scheme on quality of pharmaceutical products in the market through random sampling and carrying out analytical tests. • Implement the drug registration / cosmetic notification scheme through evaluation of technical data, laboratory analysis, research and information received from international agencies.
	Ministry of Environment and Water (KASA)	• The Ministry of Environment and Water (KASA) represents Malaysia in UNEP's Strategic Approach to International Chemicals Management (SAICM) meeting and update issues pertaining to nanotechnology and manufactured nanomaterials with the advice from NNC MOSTI as the national focal point.
	Ministry of Domestic Trade & Consumer Affairs (KPDNHEP)	• KPDNHEP formulates policies, strategies and reviews matters pertaining to the development of the domestic trade i.e. Distributive Trade and Consumerism Sectors. • KPDNHEP scope of work covers on the domestic trade and consumerism. • Under KPDNHEP, there is an initiative known as Malaysian Consumer Product Safety (mySAFE) businesses and consumers obtain information regarding consumer product safety in particular for goods and services under the purview of the Ministry of Domestic Trade and Consumer Affair (MDTCA).
Nanotechnology funding related bodies	Ministry of Higher Education (MOHE)	• MOHE provide fundings for research related to nanotechnology through Fundamental Research Grant Scheme

Category	Ministry / Agency	Roles
		(FRGS), Prototype Development Research Grant Scheme (PRGS), Transdisciplinary Research Grant Scheme (TRGS) and Long-Term Research Grant Scheme (LRGS). • MOHE has initiated grants worth RM 741 million for 2 years running under RMK-10 for the development of country's research and innovation. Moving up the TRL scale, an IHL that collaborating with industry can apply for funding with the Malaysia Laboratories for Academia-Business Collaboration (MyLAB) under MOHE.
	Ministry of Science, Technology, and Innovation	MOSTI funded for projects related to nanotechnology under the NanoFund, TechnoFund, ScienceFund, NanoCOE Fund, R&D Grant, and International Collaboration Fund (ICF), MOSTI-Combating COVID-19 Fund.
	Malaysian Technology Development Corporation (MTDC)	• MTDC has been the key player in technology commercialisation in Malaysia and promoting the adoption of technologies by local companies. • MTDC is in the business of Fund Management, Incubation, Advisory, and Nurturing Services. • MTDC has been entrusted by the Government to manage two types of grants since 1997 (7th Malaysia Plan):- a) The Commercialisation of R&D Fund (CRDF); and b) The Technology Acquisition Fund (TAF) • Besides these 2 funds, MTDC also offers the following funds: a) Halal Technology Development Fund b) Business StartUp Fund c) Business Growth Fund d) MTDC-microLEAP Peer-to-Peer e) MTDC-pitchIN Equity Crowdfunding

Category	Ministry / Agency	Roles
	Malaysia Venture Capital Management Berhad (MAVCAP)	• Leading venture capital company in the technology space, developing the Malaysian venture capital eco system via smart partnerships while enabling access to venture capital funding for technology companies. • Up to date MAVCAP has 11 type of Funds for technopreneurs. One of the funds that is closely related to nanotechnology is the Asia Greentech Fund I, LP (AGF). AGF is set to invest in companies operating in green energy sector such as solar, hydro, waste to energy and other green energy projects as well as green and environmental technologies in Asia.
	Cradle Fund Sdn. Bhd.	• Cradle is an agency under the Ministry of Science, Technology & Innovation (MOSTI) that creates an ecosystem that supports a strong and innovative business-building environment for technology entrepreneurs and innovators through our Cradle Investment Programme (CIP). • Cradle Fund Sdn Bhd (Cradle) aims to help promising Malaysian technology entrepreneurs pave their way to success. The type of funds offered are as follows: a) CIP IGNITE (i): Conversion of Validated Prototype to Market Ready Products/Services b) CIP IGNITE (ii): Commercialisation of Products or Services c) CIP ACCELERATE: Commercialisation of Products or Services d) Coach & Grow Programme (CGP Fund): A market driven programme providing entrepreneurs with the right tools. e) Angel Tax Incentive (ATI Fund): A new initiative to encourage more early-stage investments.
	Malaysia Debt Ventures Berhad	• Malaysia Debt Ventures Berhad (MDV) was established by the Government of

Category	Ministry / Agency	Roles
		Malaysia in 2002 with the objective of providing flexible and innovative financing and Shariah financing facilities to develop high-impact and technology-driven sectors of the economy, identified and prioritised by the Government as future engines of growth. • MDV provides project and financing facilities to high-potential technology and technology-based companies. • MDV helps fund young companies that are unable to secure funding from commercial financial institutions due to their novel business model, lack of proven operating track record and lack of collaterals. • MDV's mandate expanded to include ICT, Biotechnology and Green Technology. In 2014, MDV included Emerging Technology as part of its technology mandate.
	Kumpulan Modal Perdana Sdn. Bhd.	• Wholly owned by the Ministry of Finance. Modal Perdana is a technology VC that combs the country for that special breed of entrepreneurs who have exceptional ideas and help develop them into great companies. Modal Perdana are mandated to focus on technology development in support of Malaysia's Economic Innovation Model. • Funding options available are as follows: a) The Perdana Fund b) Perdana International Fund c) Plug & Play Technology Holdings Sdn Bhd d) Electronics & Electrical Fund
	Ministry of Health (MOH)	• MOH has fund for the Research that can support and improve the existing policy, methology and model of solutions in accordance with MOH requirements • The objective of MOH Research Grant is to:

Category	Ministry / Agency	Roles
		a) Sponsor new scientific knowledge to improve health and improve healthcare services. b) Support and fund R&D projects to generate new knowledge and discoveries that can serve as a catalyst for innovative technology and process development
	Ministry of Agriculture and Food Industries (MAFI)	• Ministry of Agriculture and Food Industry (MAFI) offer funds through the Farmers' Organisation Authority (LPP) • The Farmers Business Development Fund (TPUP) programme, which aimed to increase and strengthen entrepreneurs who have business networks with LPP. • Financing under TPUP, among others, aims to increase the number of farmers who produce products that meet local standards and can enter the international market.
	Ministry of Plantation Industries and Commodities (MPIC)	• The Ministry of Plantation Industries and Commodities (MPIC) is a ministry of the Government of Malaysia that is responsible for plantation and commodities: palm oil, rubber, timber, furniture, cocoa, pepper, kenaf, tobacco.
	Ministry of Water, Land and Natural Resources (KeTSA)	• The Ministry of Energy and Natural Resources, is a ministry of the Government of Malaysia that is responsible for energy, natural resources, lands, mines, minerals, geoscience, biodiversity, wildlife, national parks, forestry, surveying, mapping and geospatial data. • The National Conservation Trust Fund for Natural Resources (NCTF) was established to carry out activities related to conservation efforts such as communication, education and public awareness, research and development, management, protection and climate change mitigation and adaptation. The focal areas for the funding are:

Category	Ministry / Agency	Roles
		a) Natural Resource Management b) Research and Development c) Capacity building d) Sustainable Financing Mechanism
Nanotechnology Talent and Enculturation	Ministry of Human Resources (MOHR)	• Ministry of Human Resources (MOHR) is a ministry of the Government of Malaysia that is responsible for skills development, labour, occupational safety and health, trade unions, industrial relations, industrial court, labour market information and analysis, social security
	Malaysia Board of Technologists (MBOT)	• Malaysia Board of Technologists (MBOT) is a professional body that gives Professional Recognition to Technologists and Technicians in related technology and technical fields. • MBOT looks at technology-based profession that cuts across discipline based from conceptual design to a realized technology and covers from Technicians (with SKM/Diploma Level) up to Technologists (Bachelor's Degree level and above).
	Talent Corporation Malaysia Berhad	• National agency that drives Malaysia's talent strategy towards becoming a dynamic talent hub. TalentCorp initiatives are tailored for professionals, students, employers, and industry and academia partners.
	Ministry of Education	• The Ministry of Education is a ministry of the Government of Malaysia that is responsible for education system, compulsory education, pre-tertiary education, technical and vocational education and training (TVET), curriculum standard, textbook, standardised test, language policy, translation, selective school, comprehensive school.
	National STEM Centre	• The centre, an institution of informal learning, was entrusted with a mandate to promote awareness, interest and

Category	Ministry / Agency	Roles
		understanding of Science and Technology to increase the knowledge of Malaysians. • The exhibits located in National Science Centre are based on different themes which are divided into different categories. There are two main categories, Fundamental Science and Technology.
	Yayasan Hijau Malaysia	• The formation of YHM aims at promoting and educating youths on the importance of green technology and its benefits towards sustainable living through various programs and activities conducted under the organization. • YHM plays a pivotal role in promoting and encouraging the participation of Corporate Entities, Communities, and the public towards increasing green living practices in Malaysia through Corporate Social Responsibility (CSR) initiatives and sponsorships.
	National Planetarium	• The National Planetarium successfully held several educational projects for schools and the public. • The National Planetarium plays an important role in raising awareness of the importance of space science among the community and taking the first step in bringing Malaysia into the field of space science.
	National Science Centre (Pusat Sains Negara)	• Pusat Sains Negara was established to form a scientific and progressive society, a society that is innovative and forward looking, one that is not only a consumer of technology but also a contributor to the scientific and technological civilization of the future. • The National Science Center has formulated several strategies aimed at fostering public awareness, understanding and appreciation of science and technology

***Note - List is not exhaustive**

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