S&T FORESIGHT MALAYSIA 2050

Science & Technology Foresight Malaysia 2050

Emerging Science, Engineering & Technology (ESET) Study

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AKADEMI SAINS MALAYSIA

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FOREWORD

"In order to prosper in a diverse world, stamp our mark of harmony, and be sustainable, we need to understand the forces of change and respond proactively. Let's come together and build a Progressive Malaysia 2050 through STI."

YB Datuk Seri Panglima Wilfred Madius Tangau

Science and technology foresight is a critical component in setting the science, technology and innovation (STI) agenda, policies and strategies of nations and regions to yield greatest economic and social benefits. Particularly so in an age where mega trends such as rapid urbanisation, demographic shifts and technological breakthroughs serve as game changers with far-reaching impacts on individuals, society, industries and nations.

Today, emerging technologies are rapidly converging to not only transform the economy but more importantly solve societal issues. For example, the internet of things (IoT), artificial intelligence, robots and life sciences are creating new values and redefining mobility, healthcare as well as safety and security of people. In terms of economic activities, emerging technologies are unveiling new paradigms through smart manufacturing, precision agriculture, machine learning, virtual reality and augmented reality.

We are also living in a hyper-connected world. Gartner has predicted that over 20 billion connected "things" will be in use worldwide by 2020. The new globalisation is driven by information technology, which has radically reduced the cost of moving ideas across borders. Such connectivity enables the coming together of knowledge, talent and technology in a robust manner to leverage new economic opportunities in emerging markets. As a result, new business models that integrate technology and services to provide greater efficiency and flexibility are often exceeding customer expectations.

As the ministry mandated to lead the nation's STI agenda, a major responsibility of the Ministry of Science, Technology and Innovation (MOSTI) is to develop and implement an effective STI Policy. We also need to ensure an enabling ecosystem for STI to thrive not only now but in the future. This requires everyone to come together and play their part. Only then can we ensure the enhancement of Malaysia's existing strengths to the next level as well as boost the preparedness for future demands by fully harnessing emerging technologies.

No matter how advanced the technology or solution, if it is not well understood and received by society, it will not catalyse harmony, prosperity and sustainability. We must move society from awareness to being STI literate and ultimately to become a scientifically engaged society. As such, communication and collaboration must become the order of the day.

I wish to congratulate the Academy of Sciences Malaysia (ASM) as the nation's STI thought leader for this inaugural effort in producing this Science and Technology Foresight Report towards Malaysia 2050. I hope this report would serve as a useful reference to facilitate informed decision making related to national STI planning as well as monitoring and evaluation. By virtue of the rapid advancement of technology, a report of this nature should be updated at regular intervals to ensure we remain ahead of the curve.

In order to prosper in a diverse world, stamp our mark of harmony, and be sustainable, we need to understand the forces of change and respond proactively. Let's come together and build a "Progressive Malaysia 2050" through STI.

YB Datuk Seri Panglima Wilfred Madius Tangau
Minister of Science, Technology and Innovation.

FOREWORD

Change is inevitable in the face of 21st century challenges like globalization, digital era, global economic crisis and the disruptive technologies. Emerging Science, Sngineering and Technologies (ESET) are rapidly redefining institutional set-ups, research, development and innovation approaches, industry business models, lifestyles, community obligations and solutions for societal needs. As such, it is vital to harness the power and promise of emerging technologies for socio-economic transformation of the nation.

In fulfilling its mandate as a 'Thought Leader' for the nation on Science, Technology and Innovation (STI), ASM strives to drive and deliver value in the form of independent, credible, relevant and timely scientific input for nation building. The Academy embarked on the Malaysia 2050 flagship study in 2009 through the Mega Science Studies followed by the Emerging Science, Engineering and Technology Study (S&T Foresight), Envisioning Malaysia in 2050 Study as well as the New Economic Opportunities Study.

The aim of the Academy's Malaysia 2050 flagship study is to look at the big picture of the future we desire and share insights as well as expert knowledge towards addressing national imperatives, reengineering key economic sectors and reimagining solutions for societal challenges by leveraging STI. This is well aligned to providing strategic STI input to realise the aspirations of the National Transformation 2050 initiative (TN50) and Malaysia's strategic development goals of becoming a high-income, inclusive and sustainable nation.

This S&T Foresight study by ASM has produced two key outputs. The first 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. These 95 emerging technologies have been mapped on a time horizon of three phases i.e. present (2015-2020), probable future (2021-2035) and possible future (2036-2050). The second key output is 21 Impactful Emerging Technologies to realise six envisioned outcomes for a Progressive Malaysia 2050 that is harmonious, prosperous and sustainable. Based on the two key outputs of the report, two value propositions and six strategic interventions are recommended for the consideration of policy makers, researchers, industry players, STI professional bodies as well as civil society.

The development of this S&T Foresight report involved a participatory and inclusive ideation and validation process that enabled ASM to explore creative avenues and diverse perspectives. Extensive stakeholder engagements across sectors and expert consultations both at the national and international levels through workshops, surveys and interviews reflect this robust process. This S&T Foresight report is supported by individual reports for the five respective technology areas of biotechnology, digital technology, nanotechnology, green technology and neurotechnology. The individual reports can be accessed online via the ASM website.

Producing this S&T Foresight was a daunting undertaking for ASM but I am gratified that everyone involved responded with such enthusiasm, commitment and diligence in the spirit of collaboration and national service to deliver this report. I would like to take this opportunity to congratulate and thank all members of the ESET Working Group that was responsible for this report under the leadership of Datuk Ir (Dr) Abdul Rahim Hashim FASc. Sincere appreciation to all the five Technology Area Working Group members led by ASM Fellows and strategic partners from Malaysia Digital Economy Corporation (MDEC) and GreenTech Malaysia. A big thank you also goes to all ASM Fellows, Associates, stakeholders and experts from the quadruple helix for your participation and input towards this study. Last but not least, I wish to thank the ASM Analysts, ASM science communication team and each one who was involved in one way or another to make this report possible.

This report would serve as a useful reference to guide the national STI agenda in relation to the setting of national STI priority areas, channelling of strategic investments and reinventing requisite interventions. We must embrace change and use the advancement of technologies to empower the people. Ultimately, the Malaysian people are the drivers of a Progressive Malaysia 2050 and custodians of our nation's harmony, prosperity and sustainability. Together let us proactively navigate Malaysia's future by design and not by chance.

"Together let us proactively navigate Malaysia's future by design and not by chance."

Professor Datuk Dr Asma Ismail FASc

Professor Datuk Dr Asma Ismail FASc
President, Academy of Sciences Malaysia

PREFACE

> *"This calls for a multiplicity of technology developments and applications as well as cross-sector collaboration catalysed by a dynamic and integrative ecosystem."*
>
> *Datuk Ir (Dr) Abdul Rahim Hashim FASc*

This Science and Technology (S&T) Foresight Report is a key deliverable of the Envisioning Malaysia 2050 Foresight initiative by ASM that was embarked in 2015. This study focuses on identifying emerging science, engineering and technology areas that should be harnessed and developed to shape a Progressive Malaysia 2050 that is harmonious, prosperous and sustainable.

Futurists observe that the world is currently witnessing four great convergences i.e. between humans and machines, software and biology, the physical and virtual worlds as well as artificial intelligence and human intelligence. Several studies and global initiatives allude to the NBIC revolution referring to the convergence of Nanotechnology, Biotechnology, Information Technology and Cognitive Science. In addition, horizon scanning of S&T foresight exercises undertaken by other nations showed that focus areas were identified predominantly within the five broad technology areas namely Biotechnology, Digital Technology, Green Technology, Nanotechnology and Neurotechnology. The focus on nuclear technology in the context of alternative energy and space technology to explore interplanetary frontiers were some outliers identified in the global horizon scanning.

In keeping with the global momentum on emerging science, engineering and technologies, this study also looks into emerging technologies within the above mentioned five broad technology areas to power Malaysia's STI advancement towards 2050. Based on projections by stakeholders, the five technology areas are collectively expected to contribute to about 30% of Malaysia's GDP by 2020. As technology accelerates and gains computational power, technology convergence and complexity also increases with many possible applications in various fields. This reinforces the importance of ensuring that emerging technologies are leveraged for the nation's competitiveness and sustainability in the long term. On that premise, his Science and Technology (S&T) Foresight Report is a key deliverable of the Envisioning Malaysia 2050 Foresight initiative by ASM that was embarked in 2015. This study focuses on identifying emerging science, engineering and technology areas that should be harnessed and developed to shape a Progressive Malaysia 2050 that is harmonious, prosperous and sustainable.

Futurists observe that the world is currently witnessing four great convergences i.e. between humans and machines, software and biology, the physical and virtual worlds as well as artificial intelligence and human intelligence. Several studies and global initiatives allude to the NBIC revolution referring to the convergence of Nanotechnology, Biotechnology, Information Technology and Cognitive Science. In addition, horizon scanning of S&T foresight exercises undertaken by other nations showed that focus areas were identified predominantly within the five broad technology areas namely Biotechnology, Digital Technology, Green Technology, Nanotechnology and Neurotechnology. The focus on nuclear technology in the context of alternative energy and space technology to explore interplanetary frontiers were some outliers identified in the global horizon scanning.

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TABLES & FIGURES

ACRONYMS

€	Euro currency
£	Pound currency
km/h	Kilometres per hour
nm	Nanometer
CO2	Carbon dioxide
CO2E/kWh	Carbon dioxide emissions per kilowatt
GtCO2	Gigatonnes Carbon Dioxide
4IR	Fourth Industrial Revolution
AI	Artificial Intelligence
ASEAN	Association of Southeast Asian Nations
ASM	Academy of Sciences Malaysia
BCI	Brain Computer Interface
BIOTEK	National Biotechnology Division
BNM	Central Bank of Malaysia
B.R.A.I.N	Brain Research Through Advancing Innovating Neurotechnologies
CCTV	Closed-circuit television
CLBG	Company Limited by Guarantee
COP21	2015 Paris Climate Conference
CoE	Centre of Excellence
DNA	Deoxyribonucleic Acid
DOSM	Department Of Statistics Malaysia
DTFZ	Digital Free Trade Zone
E&E	Electrical and Electronics
ESET	Emerging Science, Engineering and Technology
EU	European Union
FDA	Food and Drug Administration
FIEP	Fund for Infrastructure and Educational Programs
FTEG	Financial Technology Enabler Group
GDP	Gross Domestic Product
GERD	Gross Expenditure on Research and Development
GHG	Greenhouse Gas
GIS	Geographical Information System
GLCs	Government-Linked Companies
GMTI	Global Muslim Travel Index
GNI	Gross National Income
HDC	Halal Industry Development Corporation
IBM	International Business Machines corporation
ICT	Information and Communication Technology
IoT	Internet of Things
IF	Islamic Finance
IIS	Institut Ibnu Sina
IHLs	Institutes of Higher Learning
INEE	Institute of Nano Electronic Engineering
INIC	Iran Nanotechnology Initiative Council
IP	Intellectual Property
IPCC	Intergovernmental Panel on Climate Change
IPharm	Malaysian Institute of Pharmaceuticals and Nutraceuticals
IPv6	Internet Protocol version 6
IRPA	Intensification of Research in Priority Areas
ITMA	Institute of Advanced Technology
KeTTHA	Ministry of Energy, Green Technology and Water
KISTEP	Korea Institute of S&T Evaluation and Planning
LLCs	Large Local Companies
LNNA	National Nanotechnology Laboratory for Agriculture
LNNano	Brazilian Nanotechnology National Laboratory

MARDI	Malaysian Agricultural Research and Development Institute
MATRADE	Malaysia External Trade Development Corporation
MCMC	Malaysian Communications and Multimedia Commission
MDGs	Millennium Development Goals
MDEC	Malaysia Digital Economy Corporation
MIDA	Malaysian Investment Development Authority
MFT	Muslim Friendly Tourism
MOEJ	Ministry of Environment Japan
MOHE	Ministry of Higher Education
MOHR	Ministry of Human Resources
MOSTE	Ministry of Science, Technology and Environment
MP	Malaysia Plan
MSC	Multimedia Super Corridor
NANOTEC	National Nanotechnology Center
NBD	National Biotechnology Directorate
NBIC	Nanotechnology, Biotechnology, ICT and Cognitive Sciences
NCD	Non-Communicable Diseases
NEM	New Economic Model
NGOs	Non-Governmental Organisations
NIH	National Institutes of Health
NKEA	National Key Economic Areas
NND	National Nanotechnology Directorate
NRI	Network Readiness Index
NSC	National Council of Science
NSCNN	National Steering Committee for Nanoscience and Nanotechnology
NSRC	National Science Research Council
NSTB	National Science and Technology Board
OECD	Organisation for Economic Co-operation and Development
OIC	Organisation of Islamic Cooperation
OTEC	Ocean Thermal Energy Conversion
PwC	PriceWaterhouse Coopers
PRAs	Public Research Assets
R&D	Research and Development
R,D & C	Research and Development and Commercialisation
R,D,C&I	Research and Development, Commercialisation and Innovation
R,D & I	Research, Development and Innovation
RFID	Radio Frequency Identification
RIE	Research, innovation and enterprise
RM	Ringgit Malaysia (Malaysia currency)
RUSNANO	Russian Corporation of Nanotechnologies
S&T	Science and Technology
SDGs	Sustainable Development Goals
SME	Small and Medium-sized Enterprises
STEM	Science, Technology, Engineering and Mathematics
STI	Science, Technology and Innovation
UKM	Universiti Kebangsaan Malaysia
UN	United Nations
UNEP	United Nations Environment Programme
UNESCO	United Nations Educational, Scientific and Cultural Organization
UNFCCC	UN Framework Convention on Climate Change
UPM	Universiti Putra Malaysia
US	United States
USD	US Dollar
UTM	Universiti Teknologi Malaysia
UTP	Universiti Teknologi PETRONAS
WEF	World Economic Forum

EXECUTIVE SUMMARY

New and emerging technologies are poised to take the new economy that is innovation-led, knowledge-intensive and collaborative to the next level of unprecedented breakthrough, opportunities and impact. These technologies are redefining the global socio-economic landscape, challenging convention as well as blurring lines between man and machine. They provide immense opportunities for realising value creation towards enhancing people's well-being, productivity gains, operational efficiency and environmental friendliness.

Mega trends such as rapid urbanisation, demographic shifts and technological breakthroughs are triggering far-reaching impacts on individuals, society, industries and nations. At the same time, the world is facing unparalleled risks that need to be mitigated and complex challenges that need to be tackled effectively.

Recognising this, ASM in 2015, embarked on an ESET study that aimed to provide S&T Foresight input to ASM's flagship initiative on Envisioning Malaysia 2050. This ESET study focuses on how emerging science, engineering and technology will shape Malaysia towards 2050.

This Integrated ESET Report aims to describe Malaysia's Science and Technology towards 2050 and emphasises the development of emerging technologies in five main technology areas, namely Biotechnology, Digital Technology, Green Technology, Nanotechnology as well as Neurotechnology. These ESET areas were identified based on their importance and prospect to Malaysia's advancement as well as convergence of the ESET areas is projected to create a set of powerful tools that have the potential to transform societies, industries and potentially providing solutions to societal grand challenges such as food security and ageing population (OECD, 2014).

This report outlines key emerging technologies within the ambit of the five technology areas, in terms of global outlook, Malaysia's positioning that underscores their prospects based on the nation's strengths and needs as well as Malaysia's R&D needs assessment. The study has identified 95 emerging technologies relevant to Malaysia's STI advancement towards 2050. In addition, this study presents 21 impactful emerging technologies that should be prioritised towards realising a Progressive Malaysia 2050 that is harmonious, prosperous and sustainable.

According to the UN, the world's population is expected to grow up to 9.7 billion in 2050. Emerging technologies would have to be successfully harnessed to meet the needs of a growing population in a sustainable manner. A growing world population and increasing economic development will cause a sharp rise in global demand for water, food and energy, placing further pressure on the natural environment. By 2050, it is estimated that 60% more food will be required to feed the world population. Severe water stress is expected due to a projected 55% increase in water demand. As for energy consumption, a sharp rise of up to almost 40% by 2040 is projected (OECD, 2016).

The Intergovernmental Panel on Climate Change (IPCC) has advocated that climate change mitigation efforts to ensure not more than 2 degree Celsius rise in global temperature, would require 40-70% reductions in global Greenhouse Gasses (GHG) emissions by 2050 (IPCC, 2010). Continuous degradation and erosion of the natural environment is expected to result in resource scarcity and climate change, irreversibly threatening two centuries of rising living standards. This calls for deployment of green technologies to realise a low carbon economy.

By 2050, almost 70% of the global population is expected to be living in urban areas with nearly 90% of the increase concentrated in Asia and Africa (UN, 2014). Given the rapid urbanisation rate, sustainable development challenges will be increasingly intense in cities, particularly in the lower-middle-income countries where the pace of urbanisation is fastest. As such, STI based interventions and solutions would need to be accelerated to improve the lives of both urban and rural dwellers.

According to the UN, the global ageing population i.e. those above 60 years old by 2050 would be around 21% that is around one in five persons. Almost every country in the world is experiencing growth in the number and proportion of older persons in their population. By 2050, it is projected that the number of older persons (above 60 years of age) in the world will exceed the number of young (below 15 years of age) for the first time in history.

The ageing population phenomenon is triggering one of the most significant social transformations of the twenty-first century. The impact would be felt across sectors and aspects of society such as labour and financial markets, demand for goods and services including housing, transportation and social protection, as well as family structures and intergenerational ties. There is a need to leverage STI to prepare for the economic and social shifts associated with an ageing population.

This is not only the age of extraordinary technological breakthrough but also technological convergence. Emerging technologies are converging to realise scope, speed and scale beyond imagination. For example the combined force of developments in nanotechnology, biotechnology, robotics, cognitive science, artificial intelligence and information technology are forging breakthroughs in machine learning and augmented reality replacing current value chains and redefining societal norms. The combination of next-generation genomics with advances in nanotechnology has unveiled new forms of targeted cancer drugs (McKinsey Global Institute, 2013).

The key concepts, findings and recommendations of this study are summarised as follows based on each chapter of this report:

Chapter 1 provides a snapshot of how STI is impacting socio-economic transformation. Each wave of the industrial revolution has been generated by the emergence of new technologies that have a transformative effect on individuals, communities, businesses and nations. This has brought about a value shift in the way people think, live, work and play. The chapter also deliberates the importance of S&T foresight to identify prospective emerging technologies relevant to Malaysia towards 2050.

Chapter 2 delineates the study approach undertaken by the ESET team according to each stage, process and output to identify emerging technologies for Malaysia based on the nation's strengths and needs towards 2050 and further prioritise based on attractiveness and feasibility criteria

Chapter 3 discusses several phenomena shaping the world today such as global trends, global risks, Fourth Industrial Revolution and Industry 4.0. The role of STI as an enabler advancing a nation's economic growth such as South Korea, Japan, Taiwan and Singapore as well as in achieving global initiatives e.g. 2030 Agenda for Sustainable Development and COP 21 are also described in this chapter in addition to position of selected developed countries and developing countries in the five technology areas as well as S&T Foresight exercises undertaken by other nations.

Chapter 4 elaborates on the five technology areas Biotechnology, Digital Technology, Green Technology, Nanotechnology and Neurotechnology in Malaysia and related initiatives in developing these technology areas.

Chapter 5 is a highlight of this report as it elucidates the outputs of this study and offers insights on the possible interplay of emerging technologies in the five technology areas towards a harmonious, prosperous and sustainable Malaysia.

This study provides three landmark outputs as follows:

i. A list of *284 products, services*, *technologies*, *possible applications and outcomes* relevant to Malaysia towards 2050 (refer Appendix 2).

ii. *Malaysia's Emerging Technology Timeline towards 2050 that showcases 95 emerging technologies* and their interlinkages based on Malaysia's strengths and needs. This timeline depicts the 95 emerging technologies for Malaysia in three phases: present (2015-2020), probable future (2021-2035) and possible future (2036-2050). Please refer to Figure 5.2 for Malaysia's Emerging Technology Timeline.

iii. *21 Impactful Emerging Technologies towards realising Progressive Malaysia 2050* prioritised based on feasibility and attractiveness in Malaysia's context guided by global trends and global risks. Please refer to Figure 5.6 for the 21 impactful emerging technologies.

Chapter 6 discusses the current challenges or constraints faced by the five technology areas in Malaysia. Similar challenges were identified in the five technology areas, which are funding for R&D, setting of research priorities, talent, awareness and partnership of academia - industries.

Chapter 7 outlines the way forward to build on Malaysia's strengths and prepare for future needs by harnessing the power and promise of emerging technologies. This chapter puts forward two key value propositions. The first is related to taking Malaysia's strengths to the next level through mastery of emerging technologies. The second is to ensure Malaysia is harmonious, prosperous and sustainable through localisation of emerging technologies. In addition, six strategic interventions are proposed to respond to the need for dynamic strategy and synergy in charting Malaysia's competitiveness and sustainability towards 2050. Cross-cutting challenges are addressed towards realising a Progressive Malaysia 2050 through STI.

Value Proposition 1

In order to build on Malaysia's strengths and position Malaysia globally in niche areas, it is recommended that strategic science, technology and innovation intervention and investment in relevant emerging technologies be considered to realise the following:

i. Make Malaysia a powerhouse for high value chain activities in E&E sector to bring about disruptive innovations through endogenous development of technologies by 2030

ii. Make Malaysia a regional leader in Agrotechnology and Agribusiness to increase food security through enhancement of self-sufficiency levels by 2030

iii. Make Malaysia a premier global Halal hub to expand global market revenue and reach by 2030

Value Proposition 2

The 21 impactful emerging technologies identified for Malaysia to be adopted as a guide for research area priority setting at the national level to realise following outcomes among others:

i. Ensure well-being and health of the people of Malaysia by:
- Turning the tide from reactive to preventive healthcare to reduce burden of disease
- Ensuring a high quality of life by maximising safety and security in terms of how people live, work and play
- Investing in the brain science research and development to advance knowledge and application to positively impact mental health, learning and social interaction

ii. Accelerate socio-economic transformation leveraging the digital tsunami towards:
- Reducing the inequality divide between the rural and urban population by increasing accessibility, affordability and availability of technological interventions
- Enhancing livelihood through creation of new business models utilising disruptive technologies
- Democratisation of knowledge to empower people to make informed decisions

iii. Move to a low waste, resource efficient society by deploying emerging technologies to better balance production and consumption. This is in line with the global shift to a circular economy that expects to improve GDP per material input ("doing more with less"), reduce municipal waste and increase recycling rates among others (OECD, 2015).
- Balance people, planet, profit elements through a water-food-energy nexus approach
- Reduce carbon footprint and fulfil Malaysia's commitment to reduce GHG emission intensity (per unit of GDP) to 45% by 2030, relative to emissions intensity in 2005.
- Value add resources and their management efficiency to mitigate resource scarcity and climate change impact
- Enhance generation and utilisation of renewable energy and materials

Strategic Intervention 1:
Good Governance
- There is a need to revisit of the practice of companies being designated to drive the technology agenda for areas that have been identified as the nation's engine of growth.
- A government anchored directorate should be in place to lead the way in partnership with relevant corporations
- This age of unprecedented technology convergence, necessitates trans-disciplinary institutional set-ups aimed at providing integrated solutions for societal challenges besides technology advancement and economic growth.

Strategic Intervention 2:
Institutionalising Science and Technology (S&T) Foresight to future proof the nation
- Malaysia would benefit immensely from institutionalising science and technology foresight to enhance future technological readiness and innovation capacity of the nation.
- Unpredictability of changes brought about by emerging technologies calls for the adoption of a long term outlook and open perspective that supports a multiplicity of technology developments and applications
- Setting of national level R&D priority areas is crucial to effectively harness the promise of emerging technologies and get all stakeholders on board with a unified focus in terms of resources, talent, strategic investment, collaboration among others.

Strategic Intervention 3:
Talent the Winning Factor

- It has to be talent by design and not by chance
- The core competency of the 21st century is the ability to learn and this must be embedded, nurtured, reinforced and incentivized throughout the talent development value chain
- Need to invest in building the workforce of the future, in particular by strengthening and expanding the science, technology, engineering and mathematics (STEM) talent pool.
- Prioritise high level STEM specialisation in cutting edge, disruptive technology ahead of time taking the cue from foresight intelligence
- Sharpen talent pool competencies in the 4Cs: critical thinking, creativity, collaboration and communication
- Create opportunities and resources for talent in cutting edge technology areas to collaborate with the brightest and best globally

Strategic Intervention 4:
Collaborative Networks for Disruptive Innovation

- The need to establish collaborative networks in Malaysia's priority sectors. The 21 impactful technologies identified in this study to bring about 6 impactful outcomes could serve as a guide for the areas to establish collaborative networks.
- Carry out industry led strategic planning to enable demand driven R&D and mobilise emerging technology applications

Strategic Intervention 5:
Collaborative Networks for Disruptive Innovation

- There is a need to facilitate, diversify and increase private sector and social financing platforms for the development and application of emerging technologies. This will not only reduce dependence on public sector funds but maximize social impact by generating a measurable, beneficial social or environmental deliverable alongside financial returns.
- Encourage and incentivise technology based start-ups with private sector and community partnership to harness emerging technologies

Strategic Intervention 6:
Data is Power

- National Technology Data Centre to be established by empowering existing entity with expanded mandate
- The Data Centre not only collects data but carries out homogenisation, integration and analytics of the data
- Should be carried out by Data Scientists who work in concert with experts to churn out relevant data.
- Analysed data should be made available through a public domain

In order to capitalise on Malaysia's strengths and future needs in emerging technologies in the five technology areas of Biotechnology, Digital Technology, Green Technology, Nanotechnology and Neurotechnology, a conducive, catalytic, integrative and transformative STI ecosystem would be paramount.

This calls for a robust and agile governance of STI, in particular the R&D ecosystem. Strategic investment in R&D, talent development, infrastructure enhancement with a long term perspective must be prioritised. Such an ecosystem would be crucial in facilitating stakeholders at all levels of the quadruple helix to carry out their roles effectively underpinned by responsive policy direction, catalytic leadership, science, technology and innovation knowledge and collaborative strategies. Everyone has a part to play to realise the dream of a 'Progressive Malaysia 2050 through STI.

INTRODUCTION 1.0

1.1 Background

New and emerging technologies are poised to take the new economy that is innovation-led, knowledge-intensive and collaborative to the next level of unprecedented breakthrough, scale, opportunities and impact. These technologies are redefining the global socio-economic landscape, challenging convention as well as blurring lines between man and machine. They provide immense opportunities for realising value creation, productivity gains, operational efficiency and environmental friendliness.

Emerging technologies are creating waves at the heart of smart factories, smart products and services to lead the way to enhancing innovation capacity, spur economic growth and achieve sustainability. Disruptive technologies such as mobile internet, big data, internet of things, automation of knowledge work and cloud are driving change like never before. Mega trends such as rapid urbanisation, demographic shifts and technological breakthroughs serve as game changers that would have far-reaching impacts on individuals, society, industries and nations. At the same time, the world is facing unparalleled risks that need to be mitigated and complex challenges that need to be tackled effectively.

STI is fundamental to realising the 2030 Sustainable Development Goals (SDGs), as it improves efficiency in economic, societal and environmental terms, enables the development of new and sustainable ways to satisfy human needs and empowering people to drive their own future as well as towards tackling global challenges such as ensuring water, food, energy and health security, discovery of alternative energy sources, preparing for an ageing society and changing lifestyles, fighting diseases, creation of a 'green economy' towards a 'post-carbon' society (Sokolov and Chulok, 2013). New and emerging technologies offer great promise towards improving lives, transforming industries and safeguarding our planet (World Economic Forum, 2017)

In 2015, ASM embarked on an ESET study that aimed at providing Science and Technology Foresight input to the flagship study on Envisioning Malaysia 2050. This ESET study focused on how emerging science, engineering and technology will shape Malaysia by year 2050. Five technology areas were identified namely, Biotechnology, Digital Technology, Green Technology, Nanotechnology and Neurotechnology as key technology areas to power Malaysia's STI advancement towards 2050. The definition of the five technology areas are outlined.

Definition of the 5 Technology Areas

Green Technology

Development and application of products, equipment and systems used to conserve the natural environment and resources, which minimise and reduce the negative impact of human activities. These products, equipment and systems should be able to minimise degradation of the environment, zero or low greenhouse gas (GHG) emission and safe for use as well as promotes healthy and improved environment for all forms of life (Ministry of Energy, Green Technology & Water Malaysia, 2015). Green technology is creating high-efficiency and low-emission transportation options, building and industries of tomorrow with more energy efficient and environmentally friendly than those of the past and possible better management of energy, water and waste in the future.

Neurotechnology

Convergence of emerging science, engineering and technology over the past decade has resulted in the emergence of neurotechnology, which can be defined as the manipulations of technical and computational tools to measure, analyse and re-wire the working of the nervous system in order to identify the properties of nerve cell activities, diagnose illnesses, restore and/or rescue neurological functions and even controlled by external devices. Application of neurotechnology is not limited to medical industry; it can be applied in financial market, law enforcement, marketing, education and warfare (ESET Neurotechnology Report, ASM, 2017)

Nanotechnology

Application of scientific knowledge to manipulate and control matter in the nanoscale (ranges between approximately 1 and 100 nm) in order to make use of size and structure dependent properties and phenomena. Nanoscale materials have unique electromagnetic, thermal and optical characteristics which are distinct from those associated with individual atoms or molecules or with bulk materials are essential in solving many of the problems facing humanity. These materials could have new possibilities of applications by making lighter, stronger, smarter, cheaper, cleaner and more durable consumer and engineered products.

Biotechnology

OECD defined Biotechnology as application of science and technology to living organisms as well as parts, products and models thereof, to alter living and non-living materials for the production of knowledge, goods and services (Van Beuzekom and Arundel, 2006).The crosscutting nature of biotechnology offers a distinct opportunity for economic growth while offering solutions to the myriad challenges globally encountered in food security, energy security and healthcare.

Digital Technology

The branch of scientific or engineering knowledge that deals with creation and practical use of digital or computerised devices, methods, systems is named digital technology (Dictionary.com, 2015). The adoption of digital technology has had an enormous impact on economy, politics, personal life and society in terms of connectivity and interacting in real-time. Digitalisation of industries or sectors is providing new opportunities and enabling new business models such as sharing economy for environment and welfares (OECD STI Outlook 2016).

The scope of the ESET study are as follows:

i) Global Outlook for the five identified technology areas

ii) Malaysia's positioning for the five identified technology areas

iii) R&D needs assessment in Malaysia

iv) Development of Malaysia's Emerging Technologies Timeline from present until year 2050

v) Identify strategic emerging technologies that would drive a Progressive Malaysia 2050

Through the ESET study, ASM aimed to identify the most promising emerging technologies for a progressive Malaysia 2050 through science and technology foresight. It is hoped that this report would serve as a guide for strategic intervention and investment as well as research priority setting towards developing the identified key emerging technologies to offer value propositions and competitive advantages for Malaysia.

This report would be a useful reference for policy makers, government ministries and agencies, institutions of higher learning, research institutes, industry practitioners, innovative regional clusters, economic corridors and other organisations that play a role in facilitating the discovery of new knowledge, advancing technology platforms and realising innovation in the form of new products and services as well as technologies at the forefront of forging a harmonious, prosperous and sustainable Malaysia.

1.2
Emerging Technologies and Its Impact

Emerging technologies are generally referred to as technologies that are being developed or projected to be developed over the next 5-10 years that would have significant impact on the economy and society.

In 2010 the World Economic Forum elaborated emerging technologies as follows:

- Technologies that arise from new knowledge, or the innovative application of existing knowledge
- Technologies that lead to the rapid development of new capabilities
- Technologies that are projected to have significant systemic and long-lasting economic, social and political impacts
- Technologies that create new opportunities for and challenges to addressing global issues
- Technologies that have the potential to disrupt or create entire industries

Since the first Industrial Revolution more than 250 years ago, a series of advances in technology has propelled a steep growth trajectory. Each new wave of technology brought about surges in productivity and economic growth, enabling efficient new methods for performing existing tasks and giving rise to entirely new types of businesses (McKinsey Global Institute, 2013).

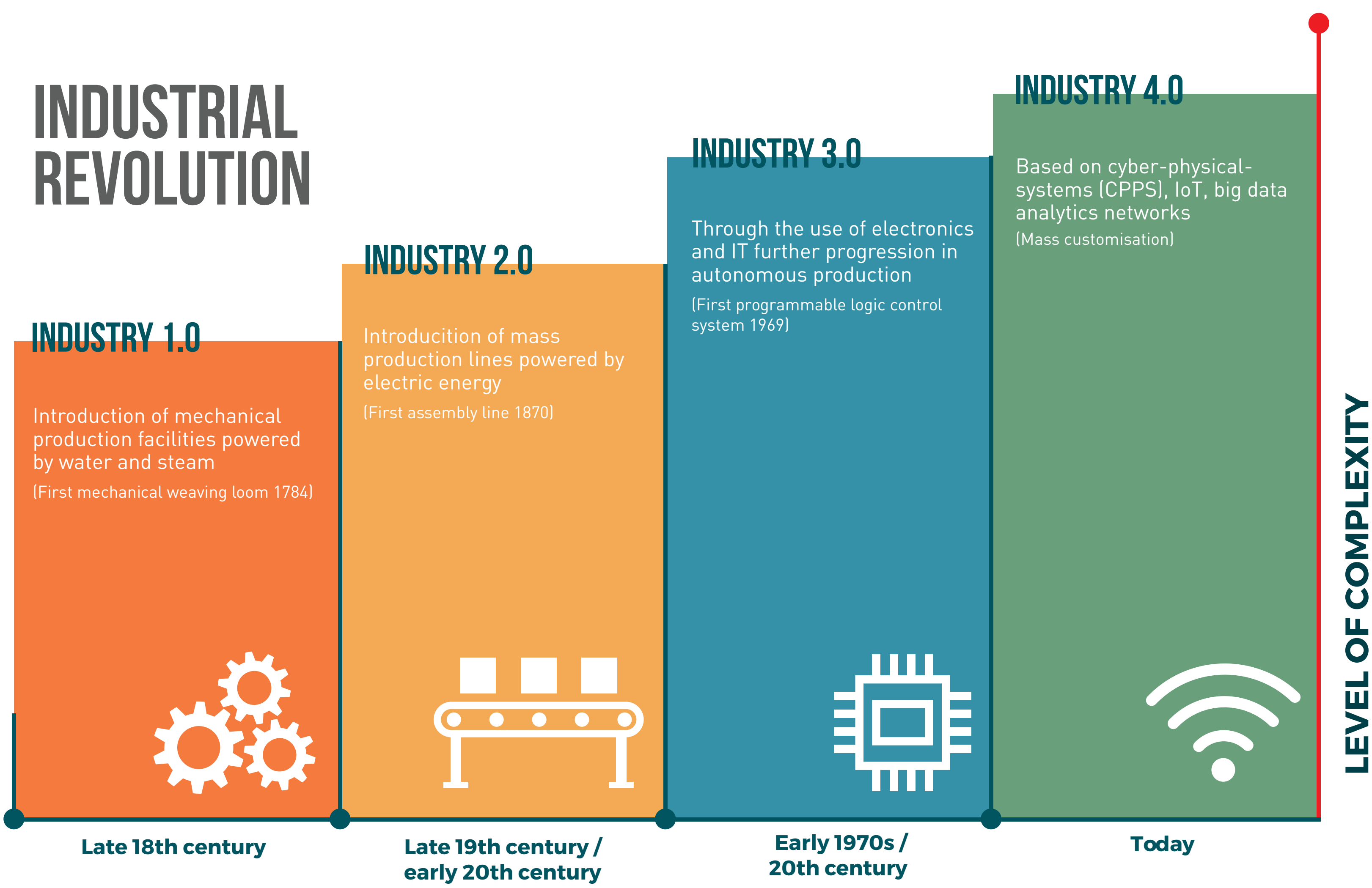


Figure 1.1:
Each new wave of technology brought about surges in productivity and economic growth.

Emerging technologies cover a wide range of technologies that will in time have transformative effects ranging from emergence of new industries, disruption of current value chains to major societal changes (World Economic Forum, 2010). Many of these technologies are still at the research and development stage and therefore off the radar of stakeholders. Although policy makers and decision makers who are involved in strategic planning of socio-economic development may not be privy to detailed information on such emerging technologies, global trends, market demand and industry momentum often provide valuable insights on the next big wave of technologies. Such science and technology foresight is important to enable a requisite level of preparedness, investment and optimisation of the STI ecosystem to ride the next big wave of emerging technologies.

In many parts of the world, emerging technologies have revolutionised farming and the way food is produced today, while traditional manufacturing has evolved towards precision manufacturing requiring less labour. New business models that integrate technology and services to provide greater efficiency and flexibility are often exceeding customer expectations and fast becoming a mainstay.

This is not only the age of extraordinary technological breakthrough but also technological convergence. Emerging technologies are converging to realise scope, speed and scale beyond imagination. For example the combined force of developments in nanotechnology, biotechnology, robotics, cognitive science, artificial intelligence and information technology are forging breakthroughs in machine learning and augmented reality replacing current value chains and redefining societal norms. The combination of next-generation genomics with advances in nanotechnology has unveiled new forms of targeted cancer drugs (McKinsey Global Institute, 2013).

It would augur well for Malaysia to identify and invest in the development and application of emerging technologies based on the country's strengths and future needs. This will undoubtedly open the path to enhanced value proposition and competitive advantage in terms of accelerating productivity, supporting economic sectors and improving national income.

1.3

Importance of S&T Foresight for Malaysia

Foresight or future studies endeavours to identify possible futures, reimagine desirable outcomes and develop strategies towards realising the desired future through the application of a systemic, participatory, future intelligence gathering and medium-to-long term vision building process towards informing and influencing present day decisions and mobilising joint actions (Miles and Keenan, 2002).

The foresight process adopted for this study as in most cases was participative, involving multi-stakeholder feedback and open discussion. In the case of Europe, foresight exercises form an essential part of thinking, debating and shaping the future. This need is further augmented due to today's increased complexity of science, technology and innovation and its interrelationship, influence ad impact on society (CORDIS EU,2010).

S&T Foresight exercises are very relevant for Malaysia to determine research, development and innovation priorities based on scenarios of future developments in STI, society and culture, economics and finance as well as geopolitics. Future studies provide valuable insights for informed decision making for example which research priorities require public funding at the national, regional and international levels. In the face of limited financial resources and the rapid rate of scientific and technological change, governments and actors in the research and innovation system have to make informed, purposive decisions in support of STI advancement in the long term. According to Sokolov and Chulok, 2013, foundation for future economic growth depends on the long-term priorities established for STI. This determines the opportunities for entering prospective markets while creating new ones. It also provides a basis for technological modernisation of various sectors of the economy while ensuring a high skilled, competent and sustainable talent pool.

2.1 Study Approach

The ESET study approach encompasses scoping, intelligence gathering, convergence of findings, selection of emerging technologies and prescriptions stages as illustrated in Figure 2.1.

STAGE	Scoping	Intelligence gathering	Converging of findings	Meet in the middle	Prescriptions
PROCESS	• Setting of study scope • Potential stakeholders • Development of study's framework	• Horizon scaning • Surveys • Strategic consultations	Collation of findings from five technology area reports • Biotechnology • Digital Technology • Green Technology • Nanotechnology • Neurotechnology	• Identification of Malaysia's current strengths in STI • Foresight of Malaysia's future STI needs • Development of Malaysia's Emerging Technology timeline • Technology prioritisation	• Gap analysis • Identification of priority R&D areas for Malaysia
OUTPUT	• Scope of study • Strategic partners • Framework of study	• Five technology area reports	• 284 possible scenarios, products and services, platforms and technologies	• 95 emerging technologies for Malaysia • 21 prioritised technologies	• Recommendation

Figure 2.1: ESET Study approach

Scoping
ESET Working Group developed the scope of study based on horizon scanning on global emerging science, engineering and technology, where five technology areas (biotechnology, digital technology, green technology, nanotechnology and neurotechnology) were chosen to be studied. The framework of study was developed and potential strategic partners to lead each technology area were identified.

Intelligence Gathering
Each technology area trends and outlook globally and Malaysia was carried out through literature review of reading materials including global and Malaysia foresight reports, case studies and journal articles. In addition, experts surveys on each technology area's global outlook, Malaysia's position and R&D Needs Assessment in Malaysia was concurrently undertaken. For emerging technologies in Malaysia's context towards 2050, a technology timeline on the five technologies areas developed by Richard Watson and team in Imperial College, United Kingdom was referred (Appendix 1). Data collated through these approaches were analysed and summarised. Strategic consultations for each technology area participated by researchers, scientists, policy makers, consultants, captains of industries and representatives from NGOs were organised to share findings on each technology area and gather stakeholders constructive views on the findings.

Convergence of Findings
284 possible scenarios, products & services, platforms and technologies were gathered as findings from all five technology areas reports.

Selection of Emerging Technologies

An exercise on identification of Malaysia's current strengths in S&T and foresight of Malaysia's future needs were undertaken through strategic consultations where the findings from this exercise were analysed by analysts and reviewed by technology experts. 95 emerging technologies were identified from these five technology areas based on Malaysia's strengths and future needs in realising the envisioned future of Malaysia towards 2050. Based on this, a Malaysia's emerging technologies timeline was developed and was categorised into three phases: present future (2015-2020), probable future (2021-2035) and possible future (2036-2050).

As a developing country, we need to prioritise our investment in selected emerging technologies based on our feasibility and attractiveness criteria in order to capitalise on potential of these emerging technologies to our country's development. A technology prioritisation survey was conducted among field experts, policy makers and captains of industries in each technology area to determine which future emerging technologies should be prioritised according to Malaysia's feasibility and attractiveness criteria. Respondents assessed selected technology/technologies against the identified set of attractiveness (governance, wealth creation and well-being) and feasibility (capacity, market, funding, policy, society) criteria for each criterion of selected technology. Prior to this, a discussion with field experts was held to develop list of technology's attractiveness and feasibility criteria to be assessed by respondents.

Prescription

Based on the data gathered through survey and strategic consultations on emerging technologies for Malaysia towards 2050 and cross cutting challenges linked to the five technology areas that underpin the emerging technologies, a gap analysis was carried out. This was followed by formulation of recommendations for strategic interventions and investments to develop the five technology areas to ensure a Progressive Malaysia 2050 that is harmonious, prosperous and sustainable.

2.2 Conduct of ESET Study

Emerging Science, Engineering and Technology - Inclusive input from policy makers, scientific community, academia, industry leaders and NGOs

Figure 2.2: Conduct of ESET Study

3.1 Global Trends and Global Risks

Global trends significantly impact the social, economic, political, environmental or technological landscape. Mega trends such as shift in global economic power, emergence of disruptive technology, rapid urbanisation, demographic and social change as well as climate change are triggering far-reaching impacts on individuals, society, industries and nations. At the same time, the world is facing unparalleled risks that need to be mitigated and complex challenges that need to be tackled effectively.

According to the UN, the world's population is expected to grow up to 9.7 billion in 2050. Emerging technologies would have to be successfully harnessed and deployed to meet the needs of a growing global population in terms of water, food, energy and health security in a sustainable manner.

A growing world population and increasing economic development will cause a sharp rise in global demand for water, food and energy, placing further pressure on the natural environment. By 2050, it is estimated that 60% more food will be required to feed the world population. Severe water stress is expected due to a projected 55% increase in water demand. As for energy consumption, a sharp rise of up to almost 40% by 2040 is projected (OECD, 2016).

Shift in Global Economic Power

The falling prices of crude oil, depreciation of strong currencies and rise of emerging economies poised challenges to the dominant powerhouses are some of the signs of global economic shift occurring presently. PriceWaterhouse Coopers (PwC) in a 2015 report projected the world economic growth to average just over 3% per annum between 2014 and 2050, in light of recent trends. The global economy is expected to double in size in 2037 and nearly triple by the year 2050. A significant slowdown is anticipated in the years beyond 2020 as China's expansion and emerging economies moderate to a more sustainable long term rate, and growth in a working age population slows down in large economies. The trend also points to a global economic power shift away from North America, Western Europe, and Japan over the next 35 years. China and India are instead projected to lead the global market, and countries like Colombia, Poland, Malaysia and Indonesia hold great potential for sustainable long term growth, as long as the fundamentals are strong.

Emergence of Disruptive Technology

Since the Industrial Revolution of the late 18th and early 19th centuries, technology has had a unique role in powering growth and transforming economies. In many cases, when a technology first emerges, its disruptive potential is not readily apparent. In other cases, however, a disruptive technology can be the result of scientific or technological breakthrough. Some of these technologies are specific and target a niche market, while others possess the potential for widespread use and may create new markets (National Academy of Sciences, 2010). On the contrary, technology often disrupts, displacing older ways of doing things and rendering old skills and organisational approaches irrelevant (McKinsey & Company, 2013). Disruptive technologies would continue to evolve in the coming decades. Hence, it is in the hands of policy makers, entrepreneurs, business leaders and citizens to maximise application of these technologies while dealing with the challenges.

Rapid Urbanisation

By 2050, 66% of the global population is expected to be living in urban areas with nearly 90% of the increase concentrated in Asia and Africa (World Urbanisation Prospects, the 2014 Revision). Population shifts in India, China and Nigeria are expected to account for 37% of the global population migration to urban areas. Increase of population density and activities in urban areas across the globe would significantly transform the structure of societies, distribution of resources and governance systems. Given the rapid urbanisation rate, sustainable development challenges will be increasingly intense in cities, particularly in the lower-middle-income countries where the pace of urbanisation is fastest. As such, STI based interventions and solutions would need to be accelerated through the application of emerging technologies to improve the lives of both urban and rural dwellers.

Demographic and Social Change

The world population is expected to increase in the coming years with a demographic shift seen with number of seniors increasing as they have longer life expectancy and declining birth rates. According to the UN, the global ageing population i.e. those above 60 years old by 2050 would be around 21% that is around one in five persons. Almost every country in the world is experiencing growth in the number and proportion of older persons in their population. The visibility of an ageing society is predicted to be more pronounced in Asia, Europe and Latin America towards 2050. It is projected that by 2050, the number of older persons (above 60 years of age) in the world will exceed the number of young (below 15 years of age) for the first time in history.

The ageing population phenomenon is triggering one of the most significant social transformations of the twenty-first century. The impact would be felt across sectors and aspects of society such as labour and financial markets, demand for goods and services including housing, transportation and social protection, as well as family structures and intergenerational ties (OECD, 2016). There is an urgent need to leverage STI to prepare for the economic and social shifts associated with an ageing population.

A more diversified labour force that includes women and senior citizens will be crucial to address escalating pressures faced by working age members with more dependents. The age disparity is also expected to place additional strain on the social fabric as limited opportunities exist presently for senior citizens to meaningfully contribute to society.

According to the World Bank Group, two thirds of all jobs could be susceptible to automation in developing countries in the coming decade. Another estimate by Forbes stated that 47% of US jobs are at risk from automation. The requirements of jobs are shifting into expert knowledge versus catering for physically demanding roles. Machines are expected to fully take over the cumbersome, dangerous and routine tasks as they would be able to deliver greater productivity and efficiency. The role and responsibilities of people in this new operating landscape will increasingly shift to knowledge work, process control and decision making. As such, the ability to learn, unlearn, relearn and co-learn reinforced through reskilling and upskilling would be increasingly important as emerging technologies lead the way to greater automation.

The democratisation of knowledge also gives rise to a society where ideas and knowledge can be easily accessed by many and no longer limited to an elite group. The digital revolution enables knowledge to be freely acquired, shared and developed thereby empowering people to make informed decisions.

Climate Change

Global warming, rise of sea levels and extreme weather events are becoming more frequent and more severe recently. Impacts related to climate change are evident across regions and in many sectors important to society such as human health, agriculture and food security, water supply, transportation, energy, ecosystems, and others and are expected to become increasingly disruptive throughout this century and beyond.

According to the Intergovernmental Panel on Climate Change (IPCC), climate change mitigation efforts to ensure not more than 2 degree Celsius rise in global temperature, would require 40-70% reductions in global Greenhouse Gasses (GHG) emissions by 2050 (IPCC, 2010). Continuous degradation and erosion of the natural environment is expected to result in resource scarcity and climate change, irreversibly threatening two centuries of rising living standards. This calls for deployment of green technologies to realise a low carbon economy.

Global Risks

As we race to keep up with technological changes of unprecedented depth and speed, leveraging on new economic businesses models and conserving our environment by going towards a lower-carbon future, managing these transitions and the interconnected risks that entail will require long-term thinking, investment and international cooperation (The Global Risk 2017 Report, WEF).

On the global landscape, extreme weather events, large scale involuntary migration, natural disaster, terrorist attacks, data fraud or theft are the top five global risks in term of likelihood identified by The World Economic Forum's Global Risks Perception Survey 2016.

For emerging technologies, the risk or uncertainties that may rise is a wider gap between the have and have not in a society, hence, the challenge to be addressed is making technologies affordable, accessible and available for everyone in a society.

3.2
Industry 4.0 and Fourth Industrial Revolution

McKinsey Global Institute (2012) described Industry 4.0 as the digitalisation of the manufacturing sector due to advancement in ICT giving rise to four disruptions:

i) Astonishing rise in data volumes, computational power and connectivity;
ii) The emergence of analytics and business-intelligence capabilities;
iii) New forms of human-machine interaction such as augmented reality
iv) Improvement in digital instructions to the physical world such as advanced robotics and 3-D printing.

Nine technological pillars that are poised to function as key enabling technologies to transform industrial production in line with Industry 4.0 have been identified by the Boston Consulting Group as shown in Figure 3.1.

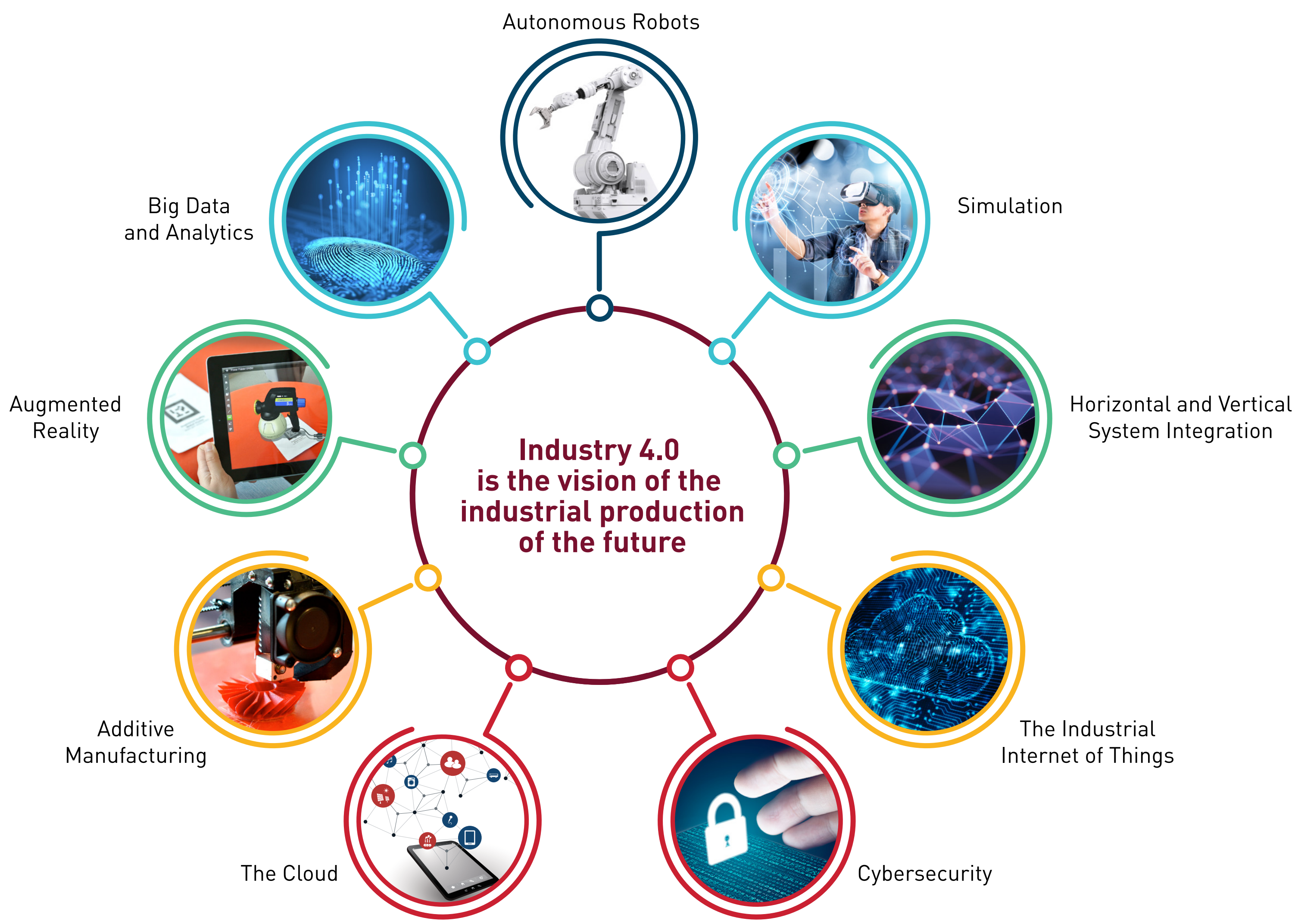


Figure 3.1: Nine technologies transforming the industrial production landscape.
(**Source:** Boston Consulting Group, 2015)

Industry 4.0 focuses on transformation of the production or manufacturing base, also known as 'Smart manufacturing/ Factory of the Future'. It originated from the German government's strategic initiative to transform the secondary industry into modernised cybernetic based manufacturing and production systems that are efficient and more cost effective. This initiative aims to establish Germany as a market leader and provider of advanced manufacturing solutions.

Many nations are aggressively planning and pursuing adoption of the fourth industrial revolution elements as shown in Figure 3.2:

a. Firstly on a macro level, focusing on the overall transformation to drive innovation and economic growth or
b. Secondly, on a niche level, zooming into 'smart manufacturing'/ Industry 4.0

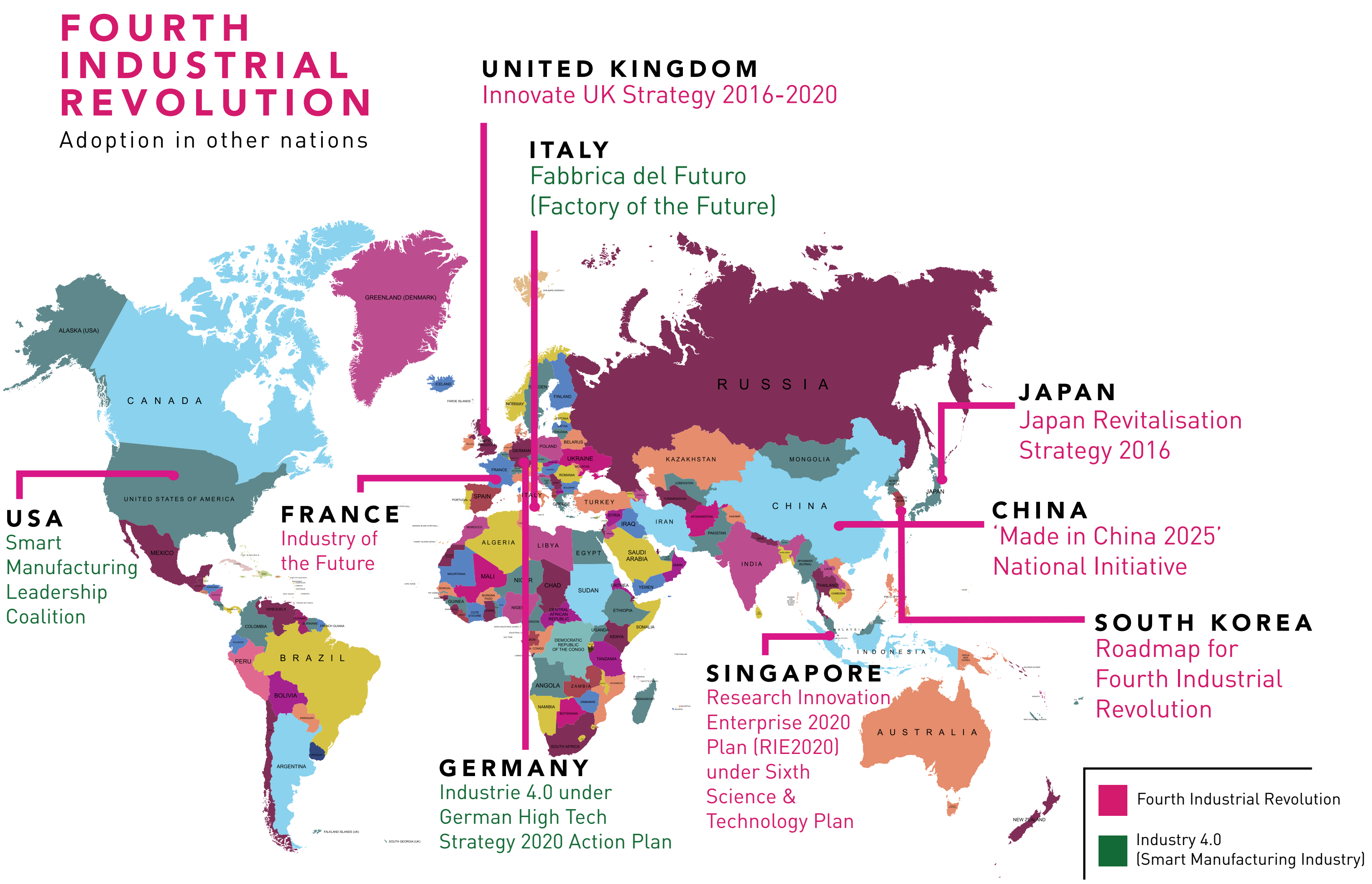


Figure 3.2: Adoption of Fourth Industrial Revolution in other nations (Compiled by ASM, 2017).

The Fourth Industrial Revolution or 4th IR is today's buzz word. It is expected to phenomenally change the way we live, work, and relate to one another. It is predicted to be unlike anything humankind has experienced before in terms of its scale, scope and complexity. The 4th IR is a tipping point in science, technology and innovation that is unveiling unprecedented advances. The 4th IR is an overarching, total transformation into new system and / or way of life that will change the way we do business. This covers almost every aspect of living, all economic sectors and activities.

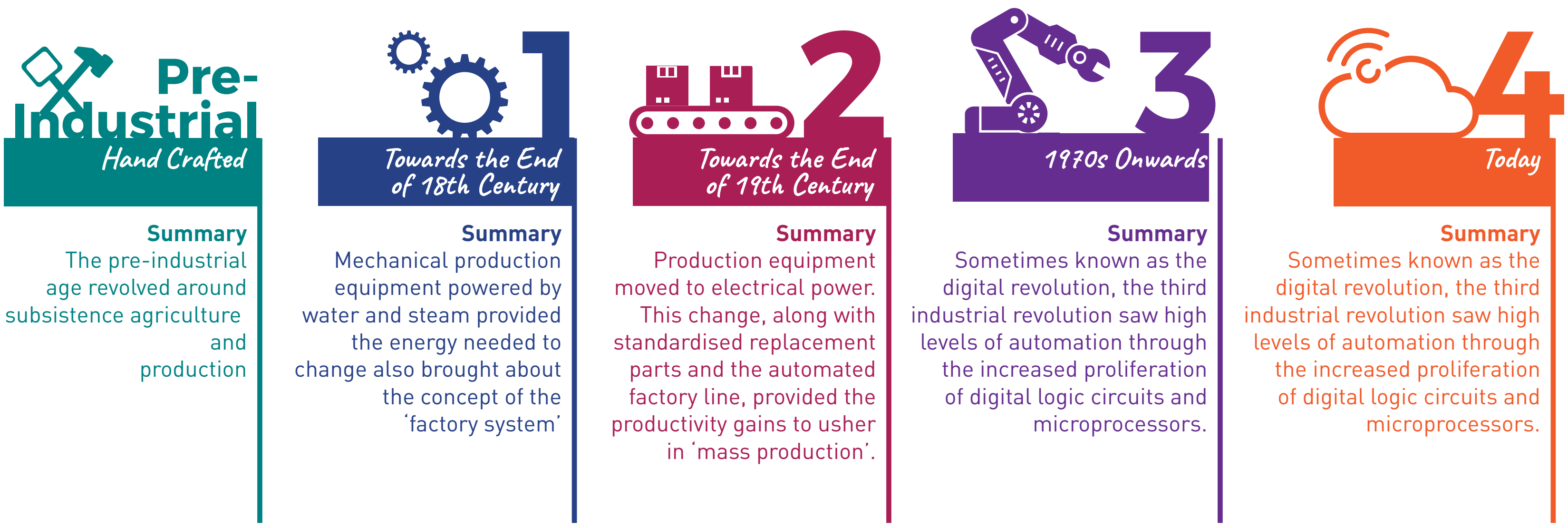


Figure 3.3: Industrial revolutions timeline (Adapted from source: EEF)

Governments around the world including Malaysia will need to become agile and improve current regulatory and STI ecosystem in their countries in order to guide innovation towards the betterment of society.

It is indispensable for all stakeholders to make sure that 4IR is a sustainable revolution as technological advances could cause unintended consequences to the environment and society.

Taking into account the mega trends and global risks the world is facing, would identifying ways to leverage or mitigate these issues ensure harmony, prosperity and sustainability?

3.3
Position of Other Developed and Developing Countries

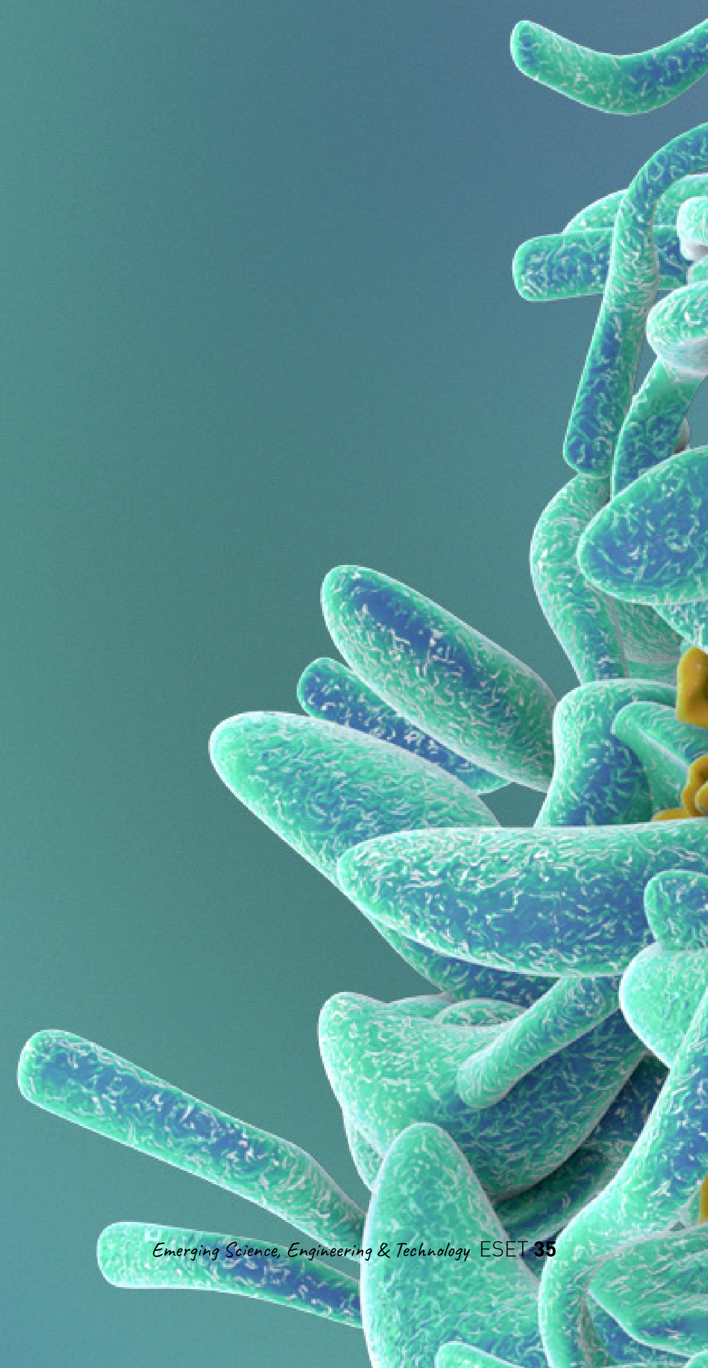
Biotechnology
Historically, R&D in biotechnology has largely been focused on healthcare, with approximately 90% of the global biotechnology investment concentrated on therapeutic products (Frazer and Marsh, 2006). Recently however, market growth has been changing due to general concerns regarding food scarcity and energy security. As discussed in the Canadian foresight report, vertical agriculture could become the remedy for food scarcity. Thus, the long-term development of other sectors is likely to catch up with the Healthcare sector over the next 20 years.

Additionally, industrial biotechnology is viewed as the 'next big thing' due to current investment driven by energy security and climate change concerns (OECD, 2009). It is estimated that the global market for industrial biotechnology could reach roughly 300 billion euros by 2030 (OECD, 2011).

United States: Biomedical innovation is a major strength of the US research enterprise. The National Institutes of Health (NIH) invests over 30 billion USD annually in biomedical research, of which 10% supports research conducted by 6,000 scientists in its own laboratories. In 2010, revenues from genetically modified plants and microbes were estimated to be approximately 300 billion USD, equivalent to more than 2% of U.S. Gross Domestic Product (White House, 2012).

China: Currently, the Chinese government invests in quasi-venture capital companies, and attracts capital from the private sector to support start-up companies. One of the major areas of focus has been stem-cell treatment for Alzheimer's disease. Additionally, the State Council tries to boost the biotechnology industry by offering heavy funding support, and a 50% tax deduction (Xuan, 2009). China has also identified biotech as one of the emerging industries to bolster the economy in it's 13th Five-Year Plan for Economic and Social Development of the People's Republic of China (2016–2020).

Britain: It is estimated that British industrial biotechnology and bioenergy activities involved around 225 companies and generated 2.9 billion pound in sales revenue annually during the financial year 2013/14. Around 8,800 people are employed in activities involving industrial biotechnology and bioenergy activities, with occupations ranging from highly skilled biological scientists to technicians and analytical staff (Capital Economics, 2015).



Digital technology

The Networked Readiness Index (NRI) by the World Economic Forum (WEF) is one way to determine the position of developed and developing countries in digital technology as a form of measurement for countries to take advantage of the opportunities in Information and Communication Technology (ICT) field. According to the WEF, the NRI seeks to better understand the impact of ICT on the competitiveness of nations and is a composite of three components:

a) The environment for ICT offered by a given country or community (market, political, regulatory, and infrastructure environment);
b) The readiness of the country's key stakeholders (individuals, businesses, and governments) to use ICT; and
c) The usage of ICT among these stakeholders.

Based on the NRI Index, we are able to view the best and worst performing countries, and concurrently the regional performances (Figure 3.4). Out of the 10 NRI pillars, Singapore is the best performing country for four pillars, namely Business and Innovation Environment, Skills, Government usage and Social Impacts. Pakistan tops the Affordability pillar. In terms of regional performances, European countries perform better than countries from other regions in most pillars.

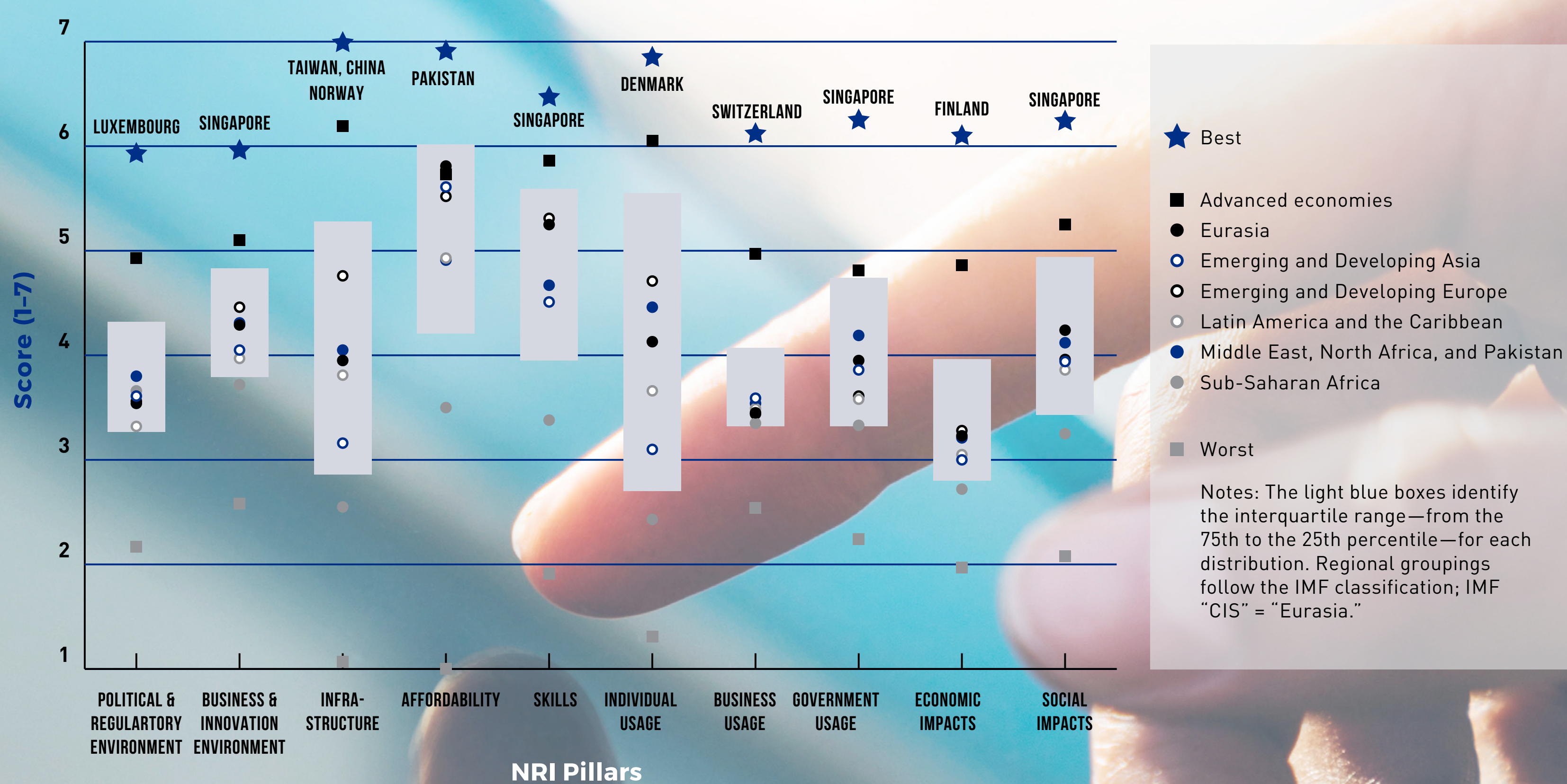
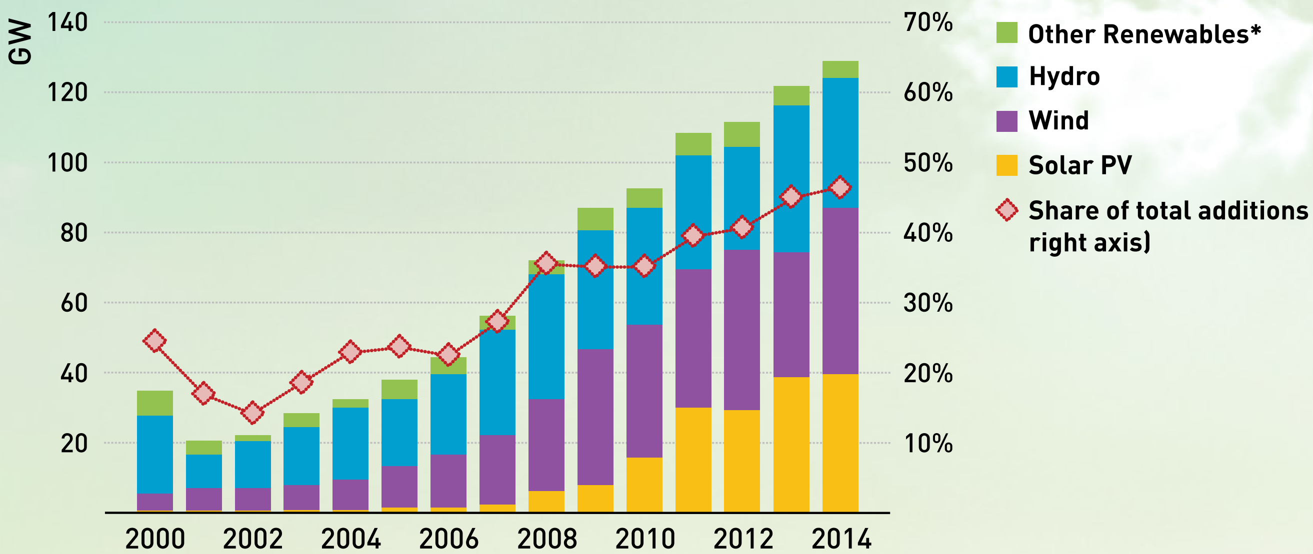


Figure 3.4: Best and Worst Performers and Regional Performance by NRI Pillar (**Source:** The Global Information Technology Report 2016, World Economic Forum)

Green Technology

On the global scene, green technology can be categorised into three categories which are Electricity, Transportation, and Industrial/Residential/Commercial. These categories derived from the Energy Information Administration's documents on flows of primary energy in OECD countries. Conveniently, each category consumes about one-third of annual primary energy consumption. This report also considers Water and Waste as a fourth category, and a relevant flow when considering green technology.



* Include geothermal, marine, bioenergy and concentrating solar power.

Figure 3.5: Global renewables-based power capacity additions by type and share of total capacity additions, 2000 - 2014 (Source: IEA, 2015)

The global position of green technology can be gauged by referring to addition of renewables-based power capacity and share of total capacity additions illustrated in Figure 3.5. From the year 2002 to 2014, the global renewables-based power capacity has been increasing steadily. This coincides with the views of the international experts and international technology foresights that emerging renewable energy technologies have "cemented the position of renewables as an indispensable part of the global energy mix" (Pontin, 2013).

Renewables excluding large hydro have gone from being labelled as 'alternative energy' and a niche choice for wealthy countries only 10 years ago, to the majority (55.3% in 2016) of new generating capacity installed worldwide. Renewable energy excluding large hydro produced an estimated 11.3% of the world's electricity in 2016, up from 10.3% in 2015 and 6.9% five years earlier, in 2011. Renewables generation in 2016 prevented the emission of some 1.7 gigatonnes of carbon dioxide (Frankfurt School-UNEP Centre, 2017)

Nanotechnology

Innovation surrounding nanotechnologies has mainly been driven by large Nanotechnology firms and institutions such as IBM, Samsung, Micron, Canon, MIT, UC Regents, and L'Oreal (Roco et al., 2011) that have access to capital, equipment, and the ability to attract technical manpower. Additionally, the lack of clear frameworks or standards for governance of Nanotechnology (Auplat, 2012) makes it difficult to both define regulatory policies and mass produce nanotechnologies.

Nanotechnology is one of the key elements for advanced manufacturing, which is currently being pursued by 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 China's 16 mega-engineering programmes to 2020, by which time the country plans to be 'innovation-driven'. In 2014, advanced manufacturing was also incorporated into Canada's revised research strategy, Seizing Canada's Moment: Moving Forward in Science, Technology and Innovation.

In 2008, ***Brazil*** established the National Nanotechnology Laboratory for Agriculture (LNNA) and, three years later, the Brazilian Nanotechnology National Laboratory (LNNano). This investment, together with funding of specific research projects in related fields by federal and state governments, 'have led to considerable growth in the number of researchers working in materials science', as indicated in the UNESCO Science Report (2015).

Over 500 companies in the ***Russian Federation*** were involved in manufacturing nanotech products in 2013, according to the state corporation RUSNANO. State Corporation Russian Corporation of Nanotechnologies (RUSNANO) on the other hand was created for the formation of the structure and infrastructure of the national nanoindustry in terms of national nanotechnological network with the initial capital of 130 million rubles. By the end of 2013, Rusnano was supporting 98 projects and had established 11 nanocentres for technological development and transfer and four engineering companies in different regions.

India planned to become a 'global knowledge hub' in nanotechnology with the launch of its Nano Mission Project, included within the Eleventh Five-Year Plan (2007–2012) as part of the government's strategy to maintain India's capacity for high-tech inventions by investing in new areas. This project has since funded about 240 research projects. The 12th Five-Year Plan (2012–2017) has since continued the initiative, with plans for the establishment of an institute dedicated to nanoscience and technology and the introduction of postgraduate programmes in 16 universities and institutions across the country. In 2014, the government set up a nanomanufacturing technology centre within the existing Central Manufacturing Technology Institute, in order to strengthen the centre's activities through a public–private partnership.

Globally, owing to the trans-disciplinary nature of Nanotechnology, there are growing collaboration efforts to address the limited technical and financial capacity that hinders the industry's growth.

Neurotechnology

As a nearly $150-billion-a-year industry, neurotechnology includes over 800 public and private organisations researching, developing and marketing pharmaceuticals, biological, medical devices as well as diagnostic and surgical equipment for the treatment of neurological, psychiatric illness and nervous system injuries (Lynch et al., 2009). Over 850 companies were involved in the neurotechnology industry in 2008 within three sectors: neuropharmaceuticals, neurodevices and neurdiagnostics (Lynch et al. 2009). This sector represents one of the largest untapped medical market and is a truly global industry as it addresses the largest unmet medical market, 2 billion people worldwide.

One of the most important characteristics of neurotechnology is that its applications are not just limited to cures for diseases and disorders. On the contrary, advances in neurotechnology will impact many different fields, including medicine, defence and intelligence agency operations, the justice system, advertising, business, communications, and even politics. Neurotechnology can help to cure mental disorders, understand human thought processes, improve imaging and BCI, and reduce cognitive load. Such technologies can enhance human intelligence, make people more efficient, alert, and effective thus revolutionise the way in which society functions through the enhancement of human intelligence and physical abilities (Potomac Institute for Policy Studies, 2015).

Although currently there is an absence of significant global policies in the field of neurotechnology as reported in ASM ESET Neurotechnology Report (2017), there are several initiatives and research projects by the US and European Union (EU) that provides direction for this area as follows:

- B.R.A.I.N Initiative - Brain Research through Advancing Innovating Neurotechnologies
- Neurodegenerative Disease Incentive Initiative
- National Neurotechnology Initiative
- FDA Neurological Devices Advisory Committee
- California Blueprint for Research to Advance Innovation Neuroscience
- Center for Neuroscience Innovation
- NeuroNEXT
- NeuroLaunch
- Neurotechnology: New Frontiers for European Policy, published by European Journal of Government

3.4

Emerging Technologies and Its Impact

2030 Agenda for Sustainable Development

When we consider sustainability, we are guided by the UN's 17 SDGs with 169 targets that are to be achieved by year 2030. The common vision and end game of the 17 SDGs are illustrated in Figure 3.6.

Figure 3.6: 17 United Nations Sustainable Development Goals

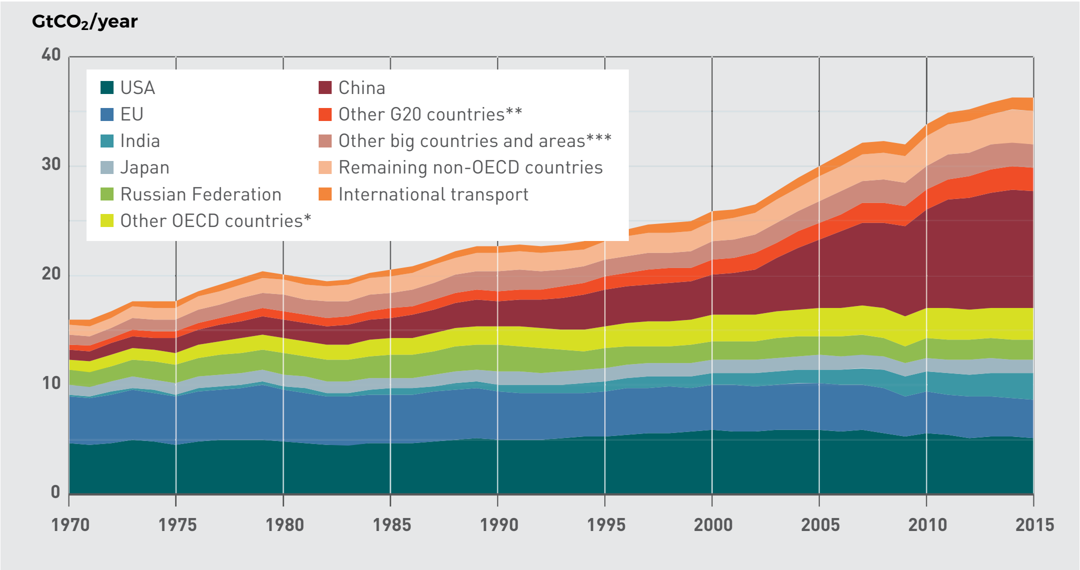
Although the SDGs are not legally binding, countries are expected to take ownership and establish a national framework for achieving the 17 Goals. Successful implementation will be dependent on the sustainable development policies, plans and initiatives of respective countries.

A survey on crucial emerging technologies for the realisation of SDGs towards 2030 from the perspective of scientists identified biotechnology, digital technology, green technology, nanotechnology, and neurotechnology areas as playing a vital role to achieve the 2030 Agenda. According to Global Sustainable Development Report 2016, energy technologies as well as information, communication and computer technologies maybe the two most crucial technology clusters for the SDGs. Application of energy technologies will lower the cost of clean, non-carbon based energy technologies and carbon sequestration. Information, communication and computer technologies play a crucial role providing information and analytics. This can lead to smarter decisions and provide more effective services as well as new innovation in each of the SDG areas. The report also mentions that rapid advancement in biotechnology, nanotechnology and neurotechnology holds great potential to affect many sectors, such as manufacturing, construction and transportation sectors (Global Sustainable Development Report 2016).

2015 Paris Climate Conference (COP 21)

In December 2015, 196 Parties to the UN Framework Convention on Climate Change (UNFCCC) adopted the Paris Agreement, which aims to strengthen the global response to the threat of climate change by keeping the global temperature rise in this century well below 2 degrees Celsius above pre-industrial levels and to pursue efforts to limit it to 1.5 degrees Celsius.

Global carbon dioxide emissions from fossil fuel combustion, cement production and other industrial processes are the major source of total global greenhouse gas emissions. Currently, they account for about 68 per cent of total global greenhouse gas emissions, and were estimated to be 36.2 gigatonnes carbon dioxide (GtCO2) in 2015 (UNEP, 2016). Figure 3.7 compares the carbon dioxide emissions from fossil-fuel use and industry of different nations. China (shown in dark red) and US (shown in dark blue), are responsible for a large proportion of global emissions.



*Other OECD countries include Australia; Canada; Mexico; Republic of Korea and Turkey.
**Other G20 countries include Argentina; Brazil; Indonesia; Saudi Arabia; South Africa and Turkey.
***Other big countries and areas include Egypt; Iran; Kazakhstan; Malaysia; Nigeria; Taiwan, Province of China; Thailand and Ukraine.v

Figure 3.7: Carbon dioxide emissions from fossil-fuel use and industry (Source: UNEP, 2016)

Improving energy efficiency is essential to meeting the objectives of the Paris Agreement and is a greenhouse gas mitigation option offering many economy-wide benefits. Countries that already have strong energy efficiency policies can testify to the multiple benefits, including improved air quality, increased social welfare, competitiveness and the creation of jobs (UNEP, 2016).

Global Sustainable Electricity Partnership, an alliance of 11 electricity companies worldwide serving more than 1.2 billion customers through its report for the COP21 summit published in 2015 urges for the following four key principles to be embraced:

(i) Establish secure, stable, clear, consistent and long-term policies that address critically important energy, legal/regulatory, economic development, financial and environmental matters aimed at reducing emissions with the goal of ensuring an adequate supply of cleaner, secure, reliable, accessible and affordable electricity.

(ii) Develop a systemic approach to electricity systems which takes into account the interrelations and synergies between various elements of the electricity value chain, in order to enable electricity providers as they plan, design, construct and operate the most advanced electricity systems with the goal of providing cleaner, reliable, sustainable, secure, flexible, and resilient electricity generating and delivery infrastructures.

(iii) Promote and engage in public-private partnerships that facilitate decision making among electricity providers, government representatives, and private stakeholders and that foster the development and deployment of new commercially available technologies.

(iv) Make urgent progress with innovative research, development and demonstrations of advanced economically viable technologies that will stabilize and reduce emissions and accelerate the efficient generation, delivery and end-use of electricity.

Principle (iv) clearly highlighted the importance of innovation to achieve the target of keeping the global temperature rise this century below 2 degrees Celsius. The advancement of 5 key technologies areas described in this report will further help Malaysia to achieve the aforementioned target.

3.5

Remarkable Socio-economic Transformation – Country Examples

In the present age, undoubtedly S&T development is critical for a nation's advancement and many nations are mainstreaming S&T in their development policies and plans. South Korea, Singapore, Taiwan and Japan are examples of nations that began emphasising S&T in their national agenda in the 1960s and 70s. Today, these nations are among the top thirty economies among 138 economies ranked in the Global Competitiveness Index 2016-2017 Rankings (WEF, 2016).

A remarkable socio-economic transformation was noted in these countries over the past decades. Some rose from a nation experiencing aftermath of World War II or newly gained independence with limited resources to become high-income economies.

IMD Ranking				WEF Ranking	
Technological Infrastructure		Scientific Infrastructure		Innovation and Sophistication Factors	
1st	Singapore	1st	USA	1st	Switzerland
2nd	Netherlands	2nd	Japan	2nd	USA
3rd	Finland	3rd	China	3rd	Germany
4th	China	4th	Israel	4th	Japan
5th	Switzerland	5th	Switzerland	5th	Sweden
6th	USA	6th	Germany	12th	Singapore
15th	Taiwan	8th	South Korea	17th	Taiwan
17th	South Korea	10th	Taiwan	22nd	South Korea
18th	Hong Kong	12th	Singapore	23rd	Hong Kong
19th	Japan	24th	Hong Kong	29th	China

Source: IMD World Competitiveness Yearbook (2017), World Economic Forum Global Competitiveness Report (2016).

Figure 3.8: Korea, Japan, Singapore and Taiwan are among the top thirty countries in the World Economic Forum Global Competitiveness Index 2016-2017 Rankings for innovation and sophistication factors

South Korea

The Republic of Korea is a nation that transited from a technologically backwater state into an increasingly knowledge-based economy within a single generation (25 years). According to literature, the implementation of science and technology policies in the 1960s and 1970s were crucial for supporting industrialisation and rapid economic growth for South Korea. In 1962, the First Five-Year Economic Development Plan was launched along with the subsequent plans which demanded for new technologies. Lacking the technological capability, South Korea relied almost completely on foreign sources for technologies. Korea's policy strategy was geared to promoting transfer of foreign technologies to the nation. On the other hand, domestic absorptive capacity developed by digesting, assimilating and improving upon the transferred technologies (Sungchul Chung, 2011). The 1980s saw the industrial policy transformed from technology learning to technology development, as well as the shift in the government's role from planning and financing to promoting and facilitating private industrial R&D (Ocon et al., 2013). Between the 70s and 80s, the Korean government developed state-funded research institutes in strategic areas of S&T. In addition, the country focus shifted from an export industry of labour intensive products such as clothing, footwear and materials, to heavy industries such as car manufacturing, shipbuilding and consumer electronics. The shift enabled the development of the country's major enterprise conglomerates such as Samsung, LG and Hyundai. In the following decade, South Korea's government shifted its attention to high technology industries and later to knowledge-intensive industries (CeBIT Australia, 2017).

In 1993, the first technology foresight was implemented and since then, South Korea's technology foresight has continuously advanced in response to society's increasing demands (Choi, 2016). The Framework Act on Science and Technology that was enacted in 2001 required the South Korean government to formulate a basic plan for the science and technology sector every five years. The National S&T Foresight carried out every five years reflects S&T development trends within current S&T areas and identifies future technologies that may have high potential.

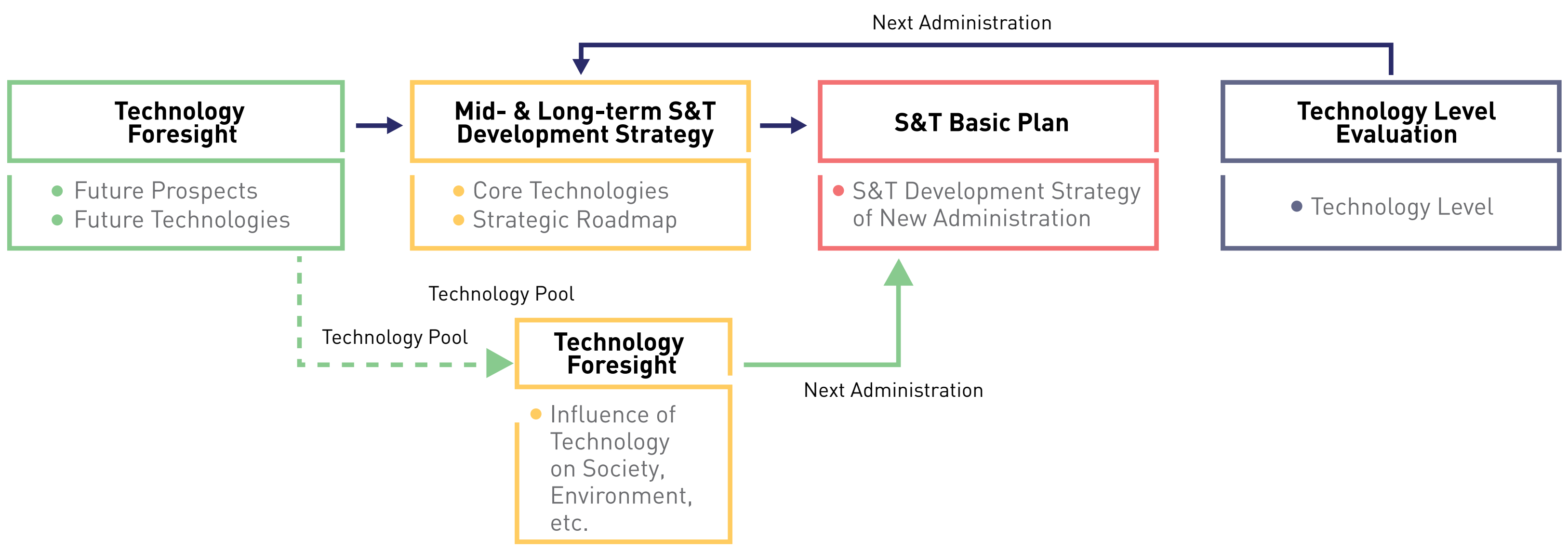


Figure 3.9: S&T planning activities in South Korea, **Source:** Choi, 2016)

Presently, according to the 2017 Bloomberg Innovation Index, South Korea is one of the world's most innovative economies. In 2016, South Korea's GDP per capita was USD 27, 538.8 compared to USD 158.2 in 1960 (World Bank, 2017).

Singapore

This nation's 50-year journey of economic transformation can be categorised into five distinct phases: labour-intensive in the 60s to skills-intensive in the 70s to capital-intensive on the 80s to technology intensive in the 90s and 2000s to today, knowledge and innovation intensive (Chye Kiang Heng, 2017). The economic development of Singapore has seen significant intensification, starting about the same time as South Korea in the 1960s. The nation's GDP per capita was around USD 427.9 in 1960. The late 1960s, saw Singapore's government emphasising on improving and restructuring the country's economy through the support of R&D capability.

The establishment of the Ministry of Science and Technology in 1968 spurred the role of S&T in Singapore's education system and economy. In the 70s, the nation initiated an industrialisation programme where electronics and energy sectors flourished and indirectly created job opportunities as well as upskilling of the local workforce. The National Science and Technology Board (NSTB) was established in 1991 replacing the Science Council formed in 1967. NSTB launched a SGD2 billion 5-year National Technology Plan to shape the nation's development on S&T and boost R&D activities as well as investments. During the first and second S&T plans, various science and engineering research institutes were set up to support specific industry verticals.

These institutes have since developed many productive collaborations with businesses, that have in turn catalysed companies to set up dedicated R&D facilities in Singapore (Nature, 2011). In addition, the formation of science institutes and universities spearheaded the development of quality human resources, high and advanced technologies as well as knowledge-intensive products and services. With a long-term focus on developing the R&D ecosystem, the next step was building up to become a leading global city of talent, enterprise and innovation by trying to attract, develop and nurture research talents (Ocon et al., 2013). The many initiatives undertaken throughout the past five decades to develop the nation's S&T have led to Singapore being consistently ranked in the top 10 in the Global Innovation Index. According to the World Bank, Singapore's GDP per capita was USD 53,960.7 in 2016.

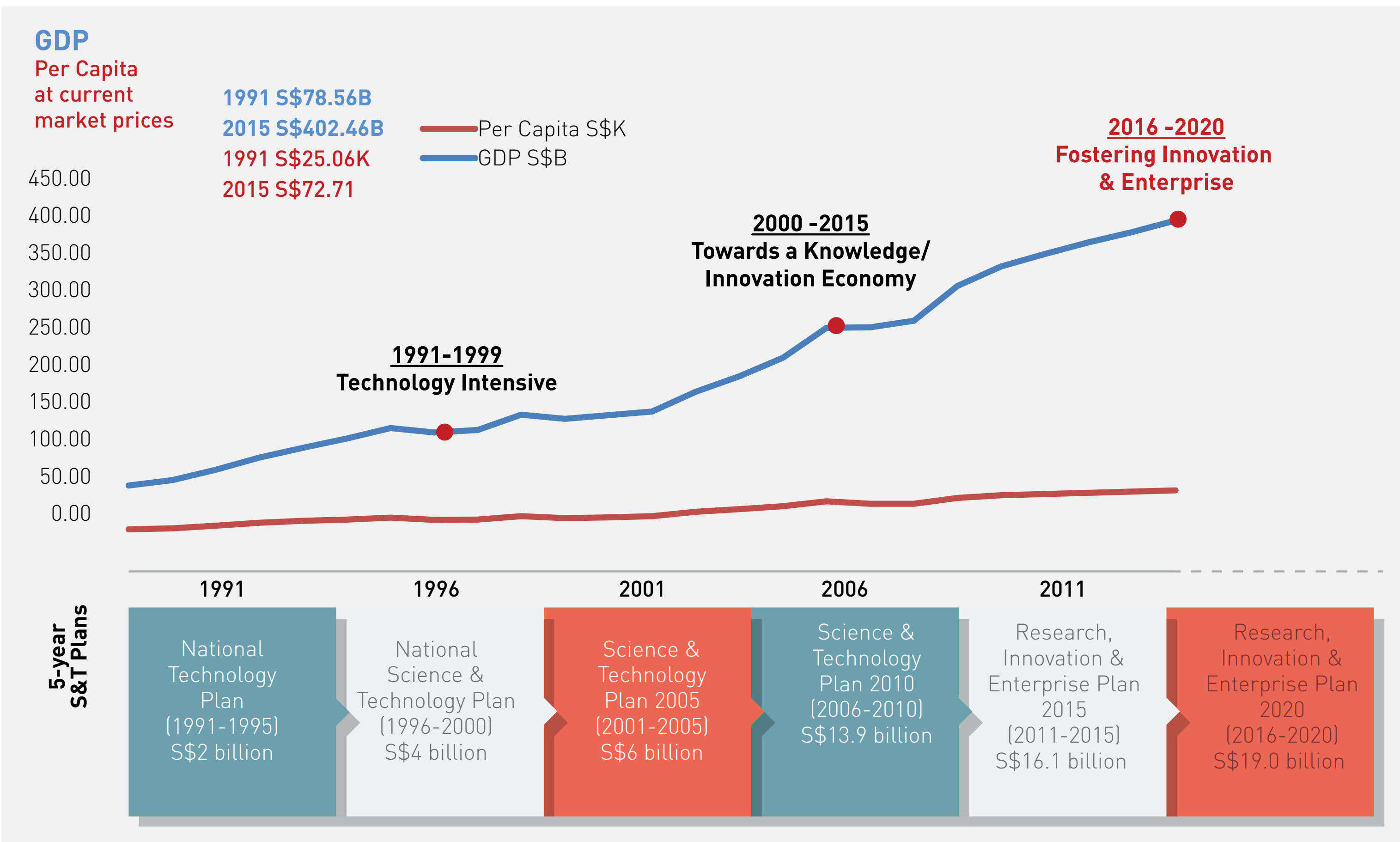


Figure 3.10: Singapore'seconomy from 1991 to present.
(Source): National Research Foundation Prime Minister's Office Singapore, 2016)

Japan

Japan was the first country in the non-European cultural sphere to attempt to absorb the western scientific and technological tradition, and this led to the nation's modern socio-economic development. The process started in the mid-nineteenth century, and as witnessed in the 1970s and 80s, after the devastation of the country during the Second World War, the nation achieved industrial success based on superior technological advances. Public policies toward science and technology were formulated when the Council of Science and Technology was set up in 1959. These policies played a key role in its industrial development through the process of catching up to advanced industrial countries of the world.

By building up a research and innovation system particularly suited to the goal of catching up, stressing learning processes such as reverse engineering and improvement engineering (Science and Technology Policy - Volume II, 2009), Japan forged its socio-economic advancement. In the 90s, science and technology took a dip in terms of investment in R&D at the national level both in the public and private sector. To improve this situation, the Science and Technology Basic Plan based on the Science and Technology Basic Law was enacted in November 1995 with the aim to comprehensively and systematically advance science and technology. The government formulated the basic plan based on anticipating the next decade, putting into effect science and technology policies over a 5-year period.

At present, the 5th Science and Technology Basic Plan covers the 5-year period between 2016-2021 with the aim to chart how STI can contribute to sustainable and inclusive development in Japan and globally, leading to a more prosperous future (Report on the 5th Science and Technology Basic Plan, 2015). Japan's long-term outlook for the nation's development and corresponding initiatives have proven to be successful in increasing the nation's GDP per capita to USD 38,894.5 in 2016 compared to USD 479 in 1960 (World Bank, 2017).

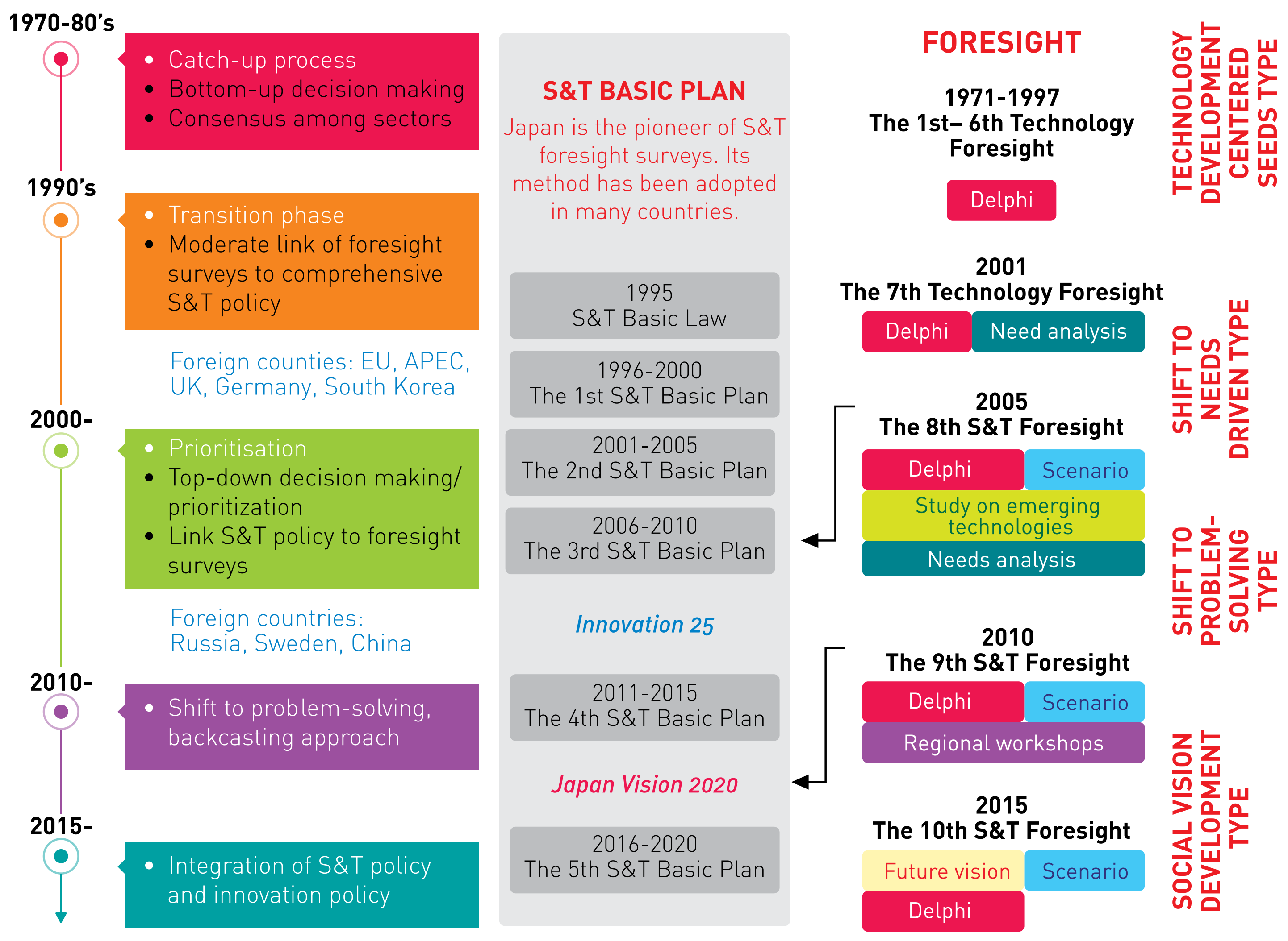


Figure 3.11: History of Japans' Foresight Surveys (Source: National Institute of Science and Technology Policy).

Taiwan

Taiwan's economic development saw transformation from an import-substitution phase during the 1950s into an export orientation phase into the early 1960s and to a science and technology-oriented phase that began in the 1980s (Robert Ash and Megan Greene, 2007). In 1959, the National Science Development Council was formed to promote scientific development in Taiwan and focused on research primarily meeting Taiwanese basic needs such as increasing the production of agricultural products. Taiwan's GDP per capita was USD 160 in 1960. This focus moved to the establishment of export processing zones in the early 1960s which increased employment opportunities, attracted investment and acquired foreign technology.

This decade also saw the earlier council formed in 1959 being replaced by National Council of Science (NSC) responsible for promotion and funding of S&T research in Taiwan and execution of national S&T development policies (Encyclopaedia of Technology and Innovation Management, 2010). In addition, a series of 4-year National Scientific Plans were implemented in three phases over a period of 12 years to strengthen the basic and industrial research ecosystem. The National S&T Conference held every four years since 1978, provides recommendations concerning Taiwan's S&T development, challenges and vision which serves as a basis for drafting S&T policies and promoting Taiwan's scientific and technological research and development for the National S&T Development Plan. Today, Taiwan is classified as one of the high income economies by World Bank (GDP per capita USD 22,540 in 2016) and a high-technology powerhouse for electronic products.

Development of Taiwan's S&T Framework and Evolution of Policies

1959-1979

Major S&T Agencies Executive Yuan	Major S&T Conferences	S&T Policies
National Council on Science Development (1959) National Science Council (1969) Applied Technology Research Development Group (1976) S&T Advisory Group Executive Yuan (1979) Office of S&T Advisors in Ministries (1979)	➡ 1st National S&T Conference (1978)	➡ S&T Development Plan (1979)

1982-2012

Major S&T Agencies Executive Yuan	Major S&T Conferences	S&T Policies
National Science Council (1982)	1982-2012 organise yearly 2nd-9th National S&T Conferences	S&T Development Plan revised every 5 years White Paper on S&T revised every 5 years

Figure 3.12: Timeline of Taiwan's National S&T system (Adapted from Encyclopaedia of Technology and Innovation Management, 2010 and Ministry of Science Taiwan, 2017)

Korea, Singapore, Japan and Taiwan are not the only countries that have emphasised mainstreaming of S&T in their national development plans. There are many nations across the globe that have undertaken S&T foresight exercises regularly and input from these exercises are included the countries future development plans and related policies.

3.6
Science & Technology Foresight in Other Nations

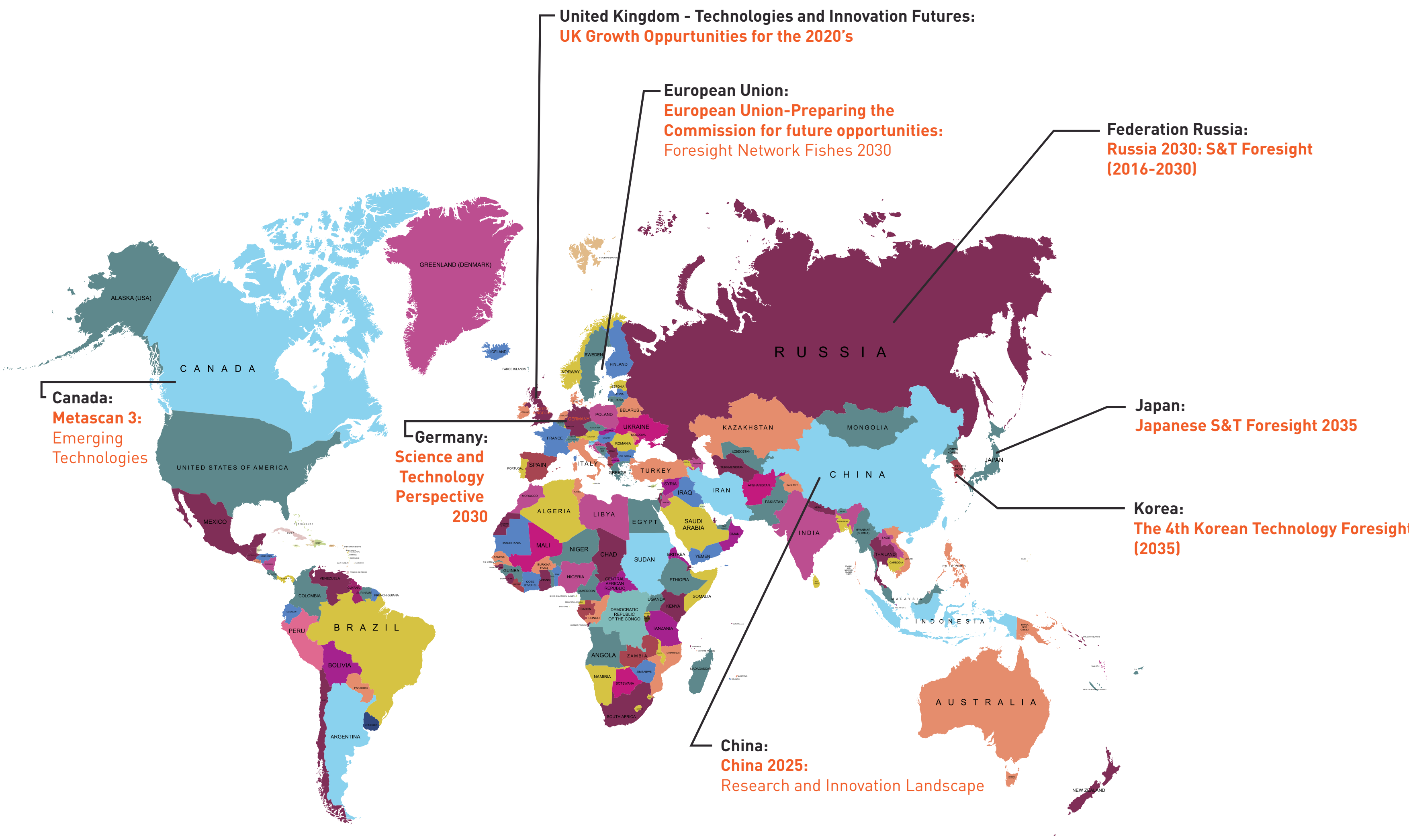


Figure 3.13: Science & Technology Foresight in Other Nations (Source: Compiled by ASM, 2017)

Japan

Japan has undertaken its Technology Foresight survey every five years since 1971. The survey canvasses a wide range of science and technology experts in Japan to get a grasp of the future path of technological development over the next 30 years. The main purpose of the survey is to contribute to government policy decision-making and decisions on resource allocation in the area of science and technology (NISTEP, 2017).

The 10th Technology Foresight exercise conducted through Delphi survey identified future technologies in seven fields, namely ICT, health, medical care and life sciences, agriculture, forestry and fisheries, space, ocean, earth and science infrastructure, environment, resources & energy, material, device & process, Social infrastructure and service-oriented society (NISTEP, 1st Preliminary Report on the 10th Science and Technology Foresight Survey, 2015). The recently undertaken 10th Foresight survey (2014-2015) looks into S&T's contribution to the world (resolve problems common to all human beings and realise global peace and prosperity), society (bolster growth in the Japanese economy and lead global rule-setting) and public (provide security and energy for people's lives and ensure employment and lives of high quality).

Germany

The Science and Technology Perspectives 2030 is a national foresight exercise undertaken by the Federal Ministry of Education and Research (BMBF) aiming to provide technology foresight and determine future societal needs in terms of research and development as well as to facilitate resilient policy development (Federal Ministry of Education and Research, 2017). The study encompassed a three-step approach: firstly, identifying societal trends and challenges to 2030, next identifying research and technology perspectives with high application potential and lastly new challenges at the interface of society and technology were identified.

United Kingdom

The Government Office for Science conducts the Technology and Innovation Futures: UK Growth Opportunities for the 2020 exercise to study the disruptive economic potential of future technological developments and new emerging trends on a time horizon of 20 years. The exercise collates views of representatives from industry, research, international institutions and social enterprises on emerging technologies through interviews, workshops and surveys. The potential emerging technologies identified were grouped as follows: biotechnological and pharmaceutical sector, materials and nanotechnology, digital and networks as well as energy and low-carbon technologies. Findings from this study will support the UK Government's prioritisation of particular emerging technologies.

China

The China-2025: Research and Innovation Landscape study provides insight into the future of research and innovation activities in China up to 2025. This foresight study was initiated by the European Commission (EU) to assess the future of science and innovation in China until 2025 aiming to contribute to the bilateral dialogue between the EU and China with the ultimate goal of developing a long-term cooperation strategy.

Through a combination of desk-study analysis, a Delphi study, media scanning, crowd-sourcing platform, and a cross impact analysis, 16 trends and related technologies in transforming China's Research and Innovation Landscape by 2025 were identified (Christofilopoulos and Mantzanakis, 2016). 16 trends that will shape Chinese Research by 2025 are economy, framework conditions, private R&D investments, energy and materials, governance, urbanisation, human rights, global economy, peace and conflict, space and defence, environment, population, intellectual property rights, global communication, language skills and education system (China 2025 Research and Innovation Landscape, 2015).

European Union

In 2013, the European Commission's network of foresight experts initiated an exercise on 'Preparing the Commission for Future Opportunities: Foresight Network Fiches 2030' to reflect on future science and technology topics that would help the European Commission's services and directorates to improve process of policy planning. The outcome of this study covered topics such as future of society, resource access, production and consumption, communication and health towards 2030 (Preparing the Commission for Future Opportunities: Foresight Network Fiches 2030 report, 2014).

Canada

METASCAN3 Emerging Technologies 2014 is a foresight study that explored how emerging technologies will shape the Canadian economy and society. It also looked into the challenges and opportunities that will be created over the next 10 to 15 years. The study by Policy Horizons Canada, a foresight organisation within the Government of Canada studied four emerging technologies (digital technologies, biotechnologies, nanotechnologies and neuroscience technologies) in relation to their prospects to drive disruptive social and economic change over the next 10 to 15 years in the manufacturing, services, natural resources, agriculture, energy, transportation, medicine, security, home and work (METASCAN3 Emerging technologies, 2014).

Singapore

Research, Innovation and Enterprise (RIE) are cornerstones of Singapore's national strategy to develop a knowledge-based innovation-driven economy and society. Public investment in research and innovation has grown over the last 25 years. Under the current five-year RIE (2016-2020 Plan), the government will be sustaining its commitment to research, innovation and enterprise, and will invest $19 billion (National Research Foundation Prime Minister's Office Singapore, 2017). Under the Research, Innovation and Enterprise 2020 Plan, Singapore is implementing four major strategic thrusts that build on the progress achieved under the Research, Innovation and Enterprise 2015 Plan to create greater value in Singapore from our investment in research, innovation and enterprise. To maximise impact, funding will be prioritised in four strategic technology domains where Singapore has competitive advantages and important national needs, namely Advanced Manufacturing and Engineering, Health and Biomedical Sciences, Urban Solutions and Sustainability and Services and Digital Economy.

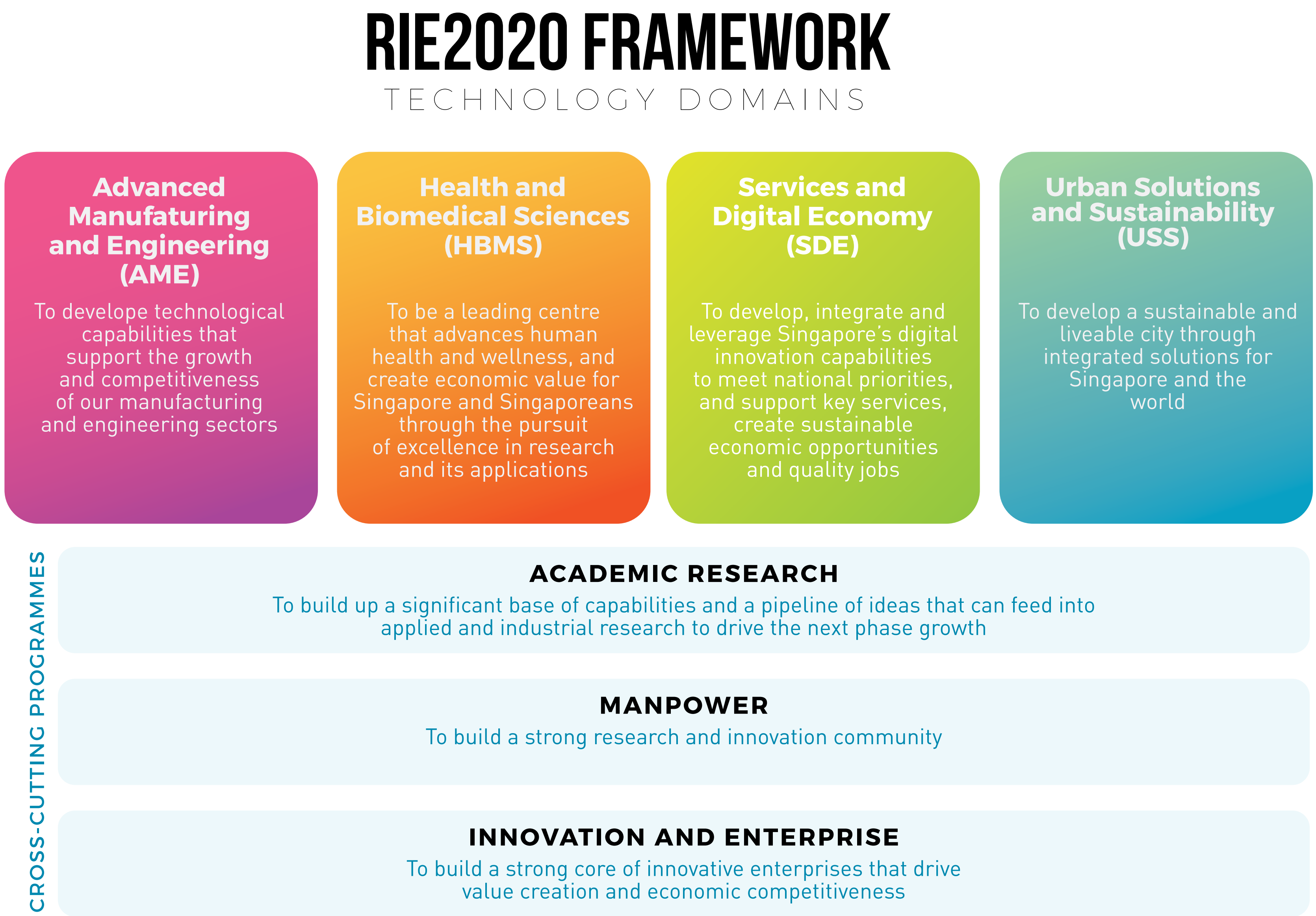


Figure 3.14: Singapore's Research Innovation and Enterprise 2020 (Source: National Research Foundation)

South Korea

South Korea has regularly conducted a national technology foresight every five years as specified in the Framework Act on Science and Technology, enacted in 2001. Korea conducted the fourth technology foresight in 2010-2012 to forecast the prospect of future Korean society up to the year 2035. This exercise had three stages: first stage - network analysis was used to discover the future issues and the new frame was developed to find the future needs, second stage - future technologies were decided in the consideration of S&T development as well as the future needs whereby a Delphi survey was performed on more than 600 future technologies to examine realization time, strategic importance, realisation measures, etc.

Two types of future technologies were identified i.e. the Demand Pull technology, where future technologies capable of addressing the needs of future society are determined through predicting the characteristics of future society while Technology Push is defined as future technologies expected to emerge from the development of S&T regardless of social needs (Choi et al., 2014). The result of the Delphi survey was analysed from various perspectives including S&T fields, social issues such as environmental pollution etc. and third stage: strategically important future technologies were selected by using portfolio analysis and scenario about future places such as home, hospital, rural areas, etc., (Choi et al., 2012).

The result of this exercise was used for establishing the 3rd S&T Basic Plan (2013-2017). The Korea Institute of S&T Evaluation and Planning (KISTEP) conducts Korea's technology foresight exercises.

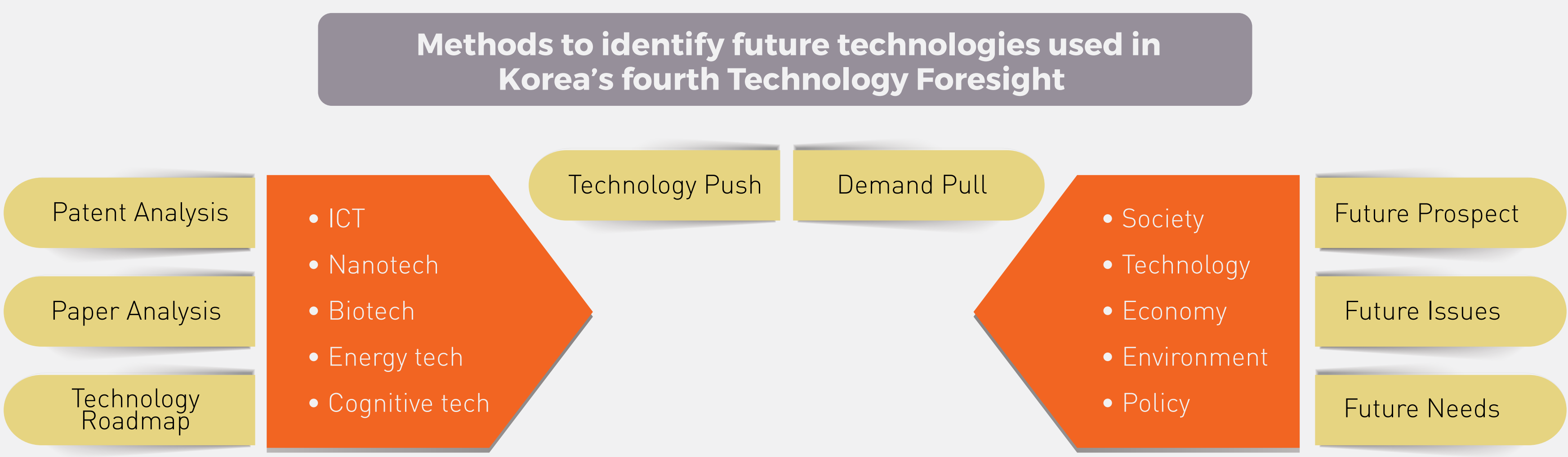


Figure 3.15: South Korea's Fourth Technology Foresight study approach.

Russia

Russia 2030: Science and Technology Foresight exercise conducted by the Ministry of Education and Science in co-operation with the National Research University Higher School of Economics aimed to identify the most promising areas of S&T development in Russia towards 2030. The study methodology involved well known traditional methods (priority setting, development of future visions, roadmapping, analysis of grand challenges) and relatively new approaches (horizon scanning, weak signals, wild cards) as well as combined technology push and market pool approaches (Russia 2030: Science and Technology Foresight, 2016). The expert community engaged were mostly Russian and Internationals scholars, businessmen and government officials. Around 3000 experts were engaged in interviews and surveys related to particular issues.

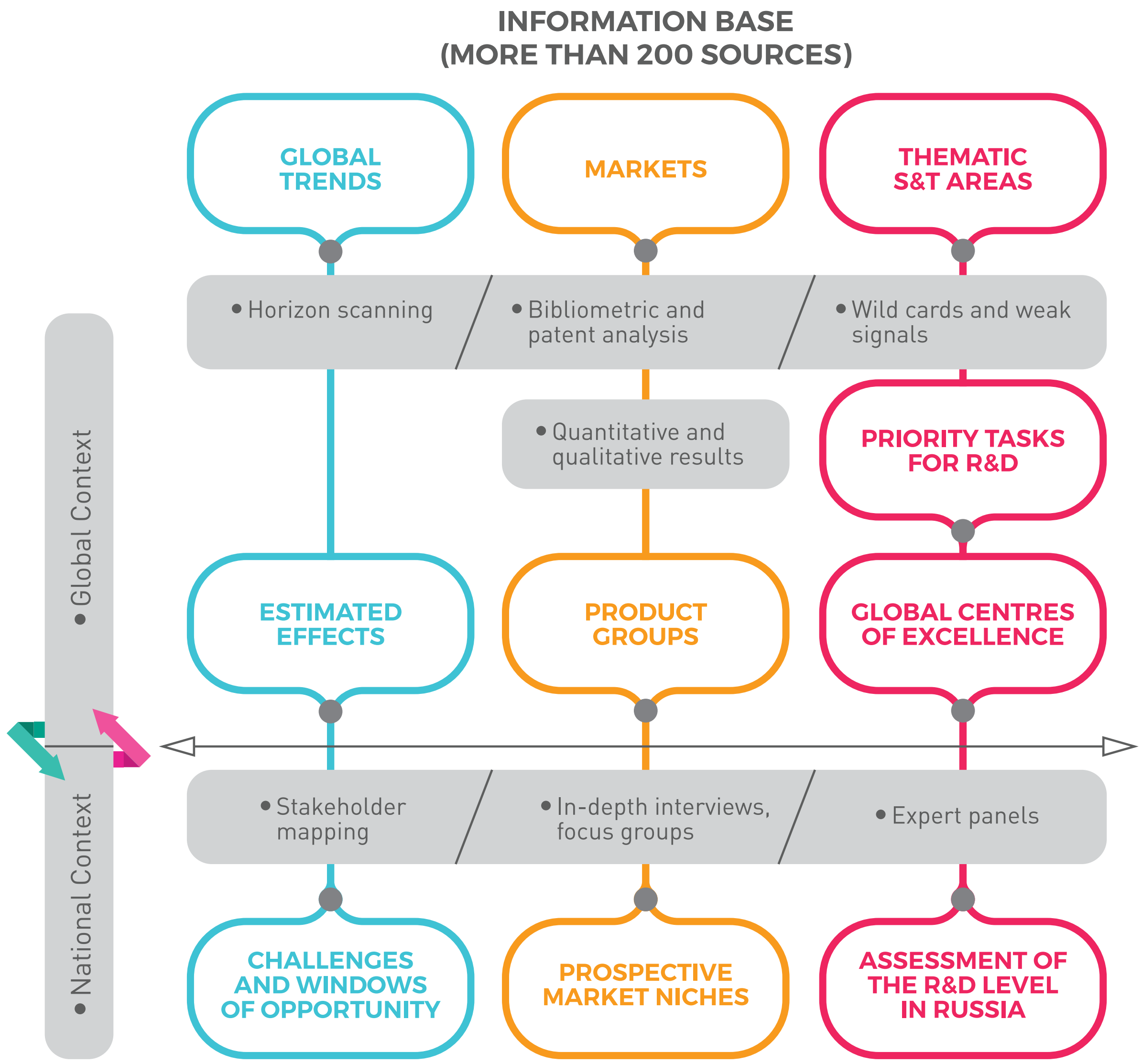
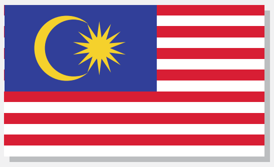


Figure 3.16: Organisational Design of Russian 2030: Science and Technology Foresight
(Source: Russian 2030: Science and Technology Foresight, 2016)

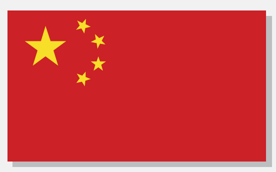
The exercise examined global challenges, opportunities and threats linked to them on a 15-year time horizon. Future innovation markets, emerging technologies, products and research areas were divided into seven priority fields: Information and communication technologies (ICT), biotechnology, medicine and healthcare, new materials and nanotechnologies, environmental management, transport and space systems as well as energy efficiency and energy saving technologies (Sokolov and Chulok, 2014). The findings of the study are implemented in accordance with the federal level state programmes on S&T and priority areas of S&T in Russia as well as list of critical technologies.

OTHER NATIONS' S&T FORESIGHT AREAS



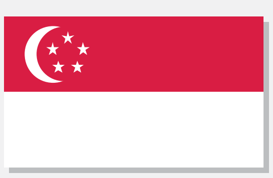
Malaysia

- **Biotechnology**
- Digital Technology
- **Green Technology**
- Nanotechnology
- **Neurotechnology**



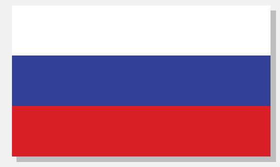
China

- **Biotechnology**
- ICT
- **Energy, environment**
- Materials



Singapore

- **Health and Biomedical Sciences**
- Services and Digital Economy
- **Urban and Digital Economy**
- Advanced Manufacturing and Engineering
- **Health and Biomedical**



Russia

- **Biotechnology, Medicine and Health care**
- ICT
- **Energy efficiency and energy saving, transport and space systems, environmental management**
- New materials and nanotechnologies
- **Medicine and Health care**

Europe Commission

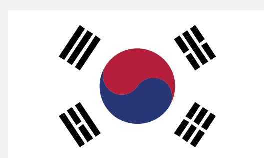
- **Health and biotech, food and nutrition**
- Digital enabling technologies
- **Environment and energy, aeronautics and space applications**
- Physical sciences and manufacturing/ enabling technologies
- **Society and well-being**

Canada

- **Biotechnologies**
- Digital Technologies
- **Nanotechnologies**
- Neuroscience Technologies

Germany

- **Biotechnology, Health**
- ICT, Optics, Production, Services Science, System research
- **Water, Energy, Environment, Mobility**
- Materials, Nanotechnology
- **Neurosciences**

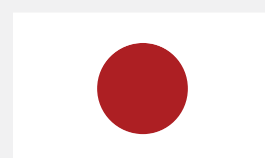


South Korea

- **Biotechnology**
- ICT
- **Energy Technology**
- Nanotechnology
- **Cognitive Technology**

United Kingdom

- **Biotechnological and Pharmaceutical Sector**
- Digital and Networks
- **Energy and Low-carbon Technologies**
- Materials and Nanotechnology



Japan

- **Health, medical care & life sciences, agriculture, forestry & fisheries,**
- ICT
- **Environment, Resources & Energy, Space, Ocean, Earth & Science Infrastructure, Social infrastructure**
- Material, device & process
- **Service-oriented society**

Most of the S&T foresight exercises undertaken by other nations looked into five technology areas namely biotechnology, digital technology, energy & environment technology, nanotechnology and neurotechnology as shown in Table 2. This is similar to this study, with the exception of energy & environment technology being referred to as green technology. Some outlier areas in other nation's S&T foresight exercises were space technology and nuclear technology depending on specific needs of certain nations in terms of alternative energy or interplanetary exploration. The similarity of focus areas of S&T Foresight studies of other countries to this study reinforces the importance of the five technology areas explored in this study to a nation's future economic growth.

4.1 Introduction

Throughout history, technological change and innovation have fuelled massive socio-economic transformations that have greatly raised living standards. Emerging technologies and innovation policies can play a pivotal role in fostering both inclusiveness and growth (OECD, 2017).

Malaysia has transformed from an agrarian-based economy with the agriculture sector as its main thrust in the early 1960s to an industrialised economy in the 2000s as shown in Figure 4.1. Once Malaysia's economy heavily depended on the export of primary crops such as rubber and oil palm, the Malaysian economy now sees the manufacturing and services sectors taking precedence as shown in Figure 4.2. The manufacturing sector contributed 23% to GDP in 2016 and the rapidly growing services sector is the major contributor to Malaysia's GDP at 54.2% in 2016 (BNM, 2017). This also resonates with the changing focus of the Malaysia Plans over the years as shown in Figure 4.3.

In the colonial period and early years after independence, Malaysia was dependent to main being resource-based. Industries such as tin mining and processing, rubber and cocoa contribute in generating economic growth. Research institutes such as the Rubber Research Institute of Malaysia and Malaysian Agricultural Research and Development Institute were established to provide R&D support for the rapidly growing resource-based industry at that time. Since then, new resource-based industries such as oil and natural gas and palm oil have emerged. Post-independence, rapid development significantly enhanced manufacturing capacity especially in the electrical and electronics sector that is now considered a major contributor to Malaysia's economic growth.

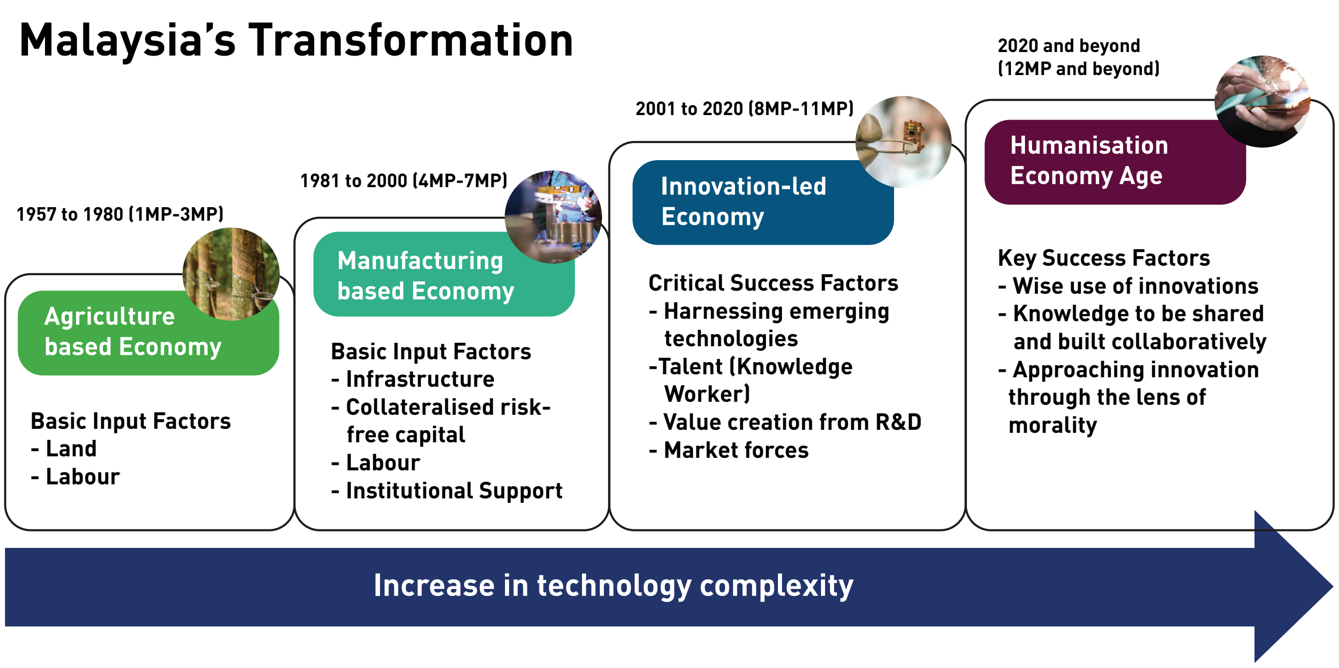
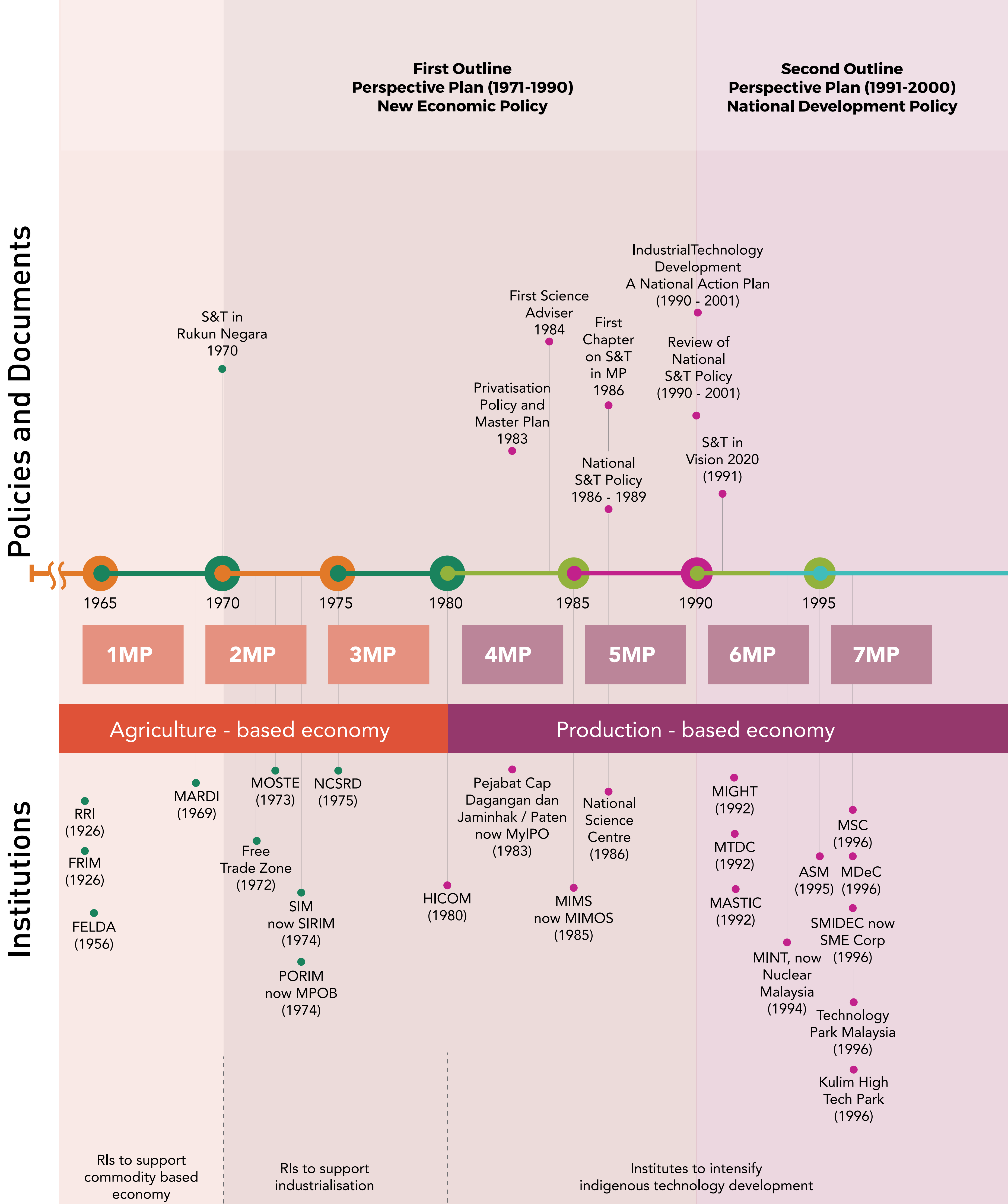


Figure 4.1: Malaysia's economic transformation from independence to today (**Source:** compiled by ASM, 2017).

On the global front, the world is transitioning from a knowledge-based or innovation-led economy to a ubiquitous humanised economy era whereby the emphasis is on outcomes for humanity's well-being rather than just impact of knowledge. The humanisation age highlights the importance of people and values based on wisdom, moral and spiritual principles. Similarly, the 11MP also focuses on being people-centric in realising outcomes that improve well-being and quality of life.

Information has now started to become a commodity as the result of the knowledge-based and innovation-driven economy. Technology enables the deciphering of abundant data and information as well as pattern recognition that translates into valuable insights and deeper knowledge. While the knowledge economy is technological and innovative, people in the humanisation-age economy will become much more reflective and see knowledge as something to be shared and built collaboratively as the impact of knowledge will be focused on humanity's well-being. Reflection does not displace innovation; it questions the purpose of innovation and how can innovation be applied for a higher purpose and humanity's benefit. It would augur well for the next Malaysia Plan to follow the same path as the 11MP with regard to being people-centric as people are the prime movers of any economy in this era.

Figure 4.2: Malaysia's Exports by Main Sectors for year 2016 to July 2017 (**Source:** Department of Statistics, Malaysia, Compiled By: MATRADE)



First Outline
Perspective Plan (1971-1990)
New Economic Policy
Second Outline
Perspective Plan (1991-2000)
National Development Policy
Policies and Documents
S&T in
Rukun Negara
1970
Privatisation
Policy and
Master Plan
1983
First Science
Adviser
1984
First
Chapter
on S&T
in MP
1986
National
S&T Policy
1986 - 1989
IndustrialTechnology
Development
A National Action Plan
(1990 - 2001)
Review of
National
S&T Policy
(1990 - 2001)
S&T in
Vision 2020
(1991)
1965
1970
1975
1980
1985
1990
1995
1MP
2MP
3MP
4MP
5MP
6MP
7MP
Agriculture - based economy
Production - based economy
Institutions
RRI
(1926)
FRIM
(1926)
FELDA
(1956)
MARDI
(1969)
MOSTE
(1973)
Free
Trade Zone
(1972)
SIM
now SIRIM
(1974)
PORIM
now MPOB
(1974)
NCSRD
(1975)
HICOM
(1980)
Pejabat Cap
Dagangan dan
Jaminhak / Paten
now MyIPO
(1983)
MIMS
now MIMOS
(1985)
National
Science
Centre
(1986)
MIGHT
(1992)
MTDC
(1992)
MASTIC
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MINT, now
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SME Corp
(1996)
Technology
Park Malaysia
(1996)
Kulim High
Tech Park
(1996)
RIs to support
commodity based
economy
RIs to support
industrialisation
Institutes to intensify
indigenous technology development

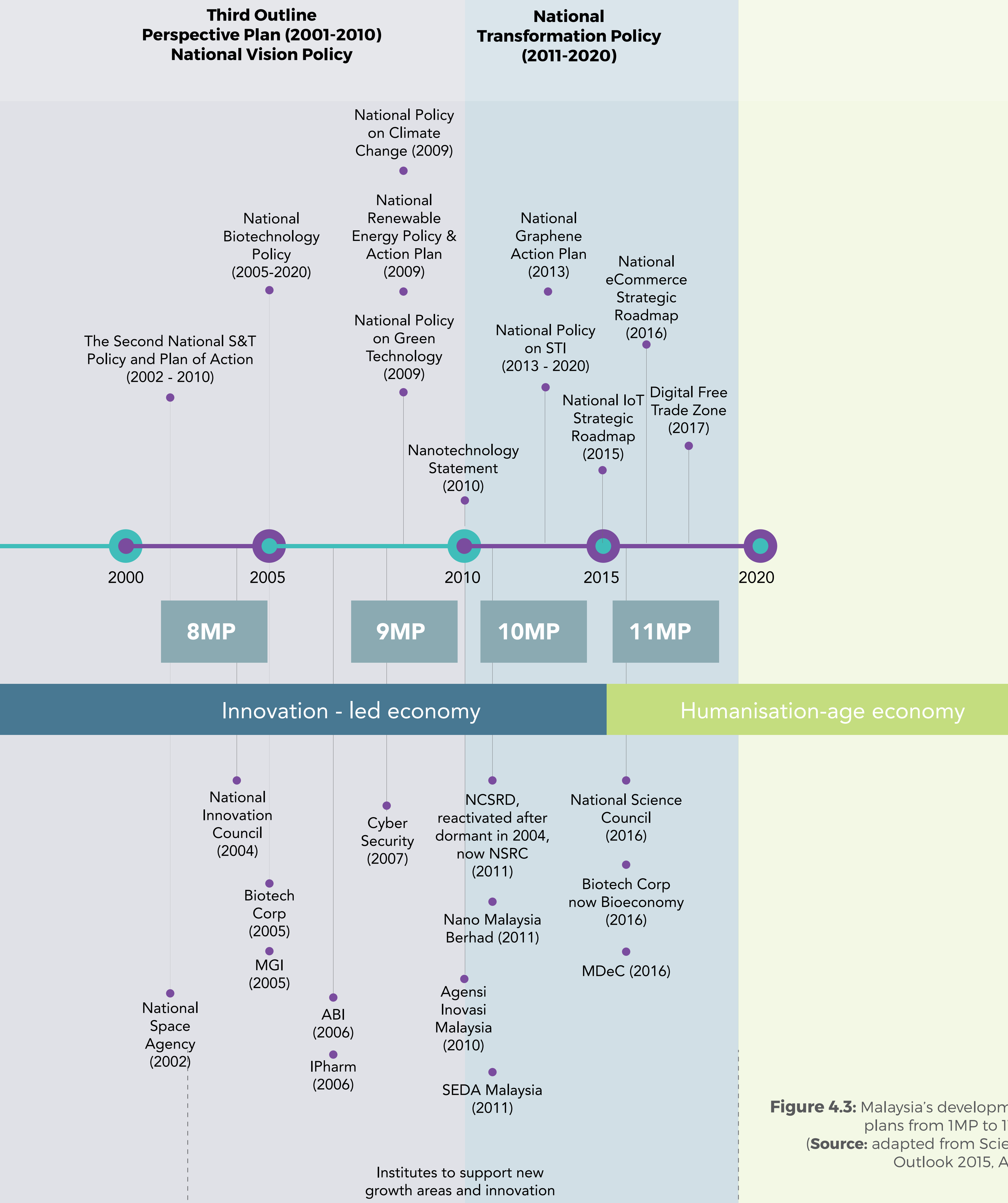


Figure 4.3: Malaysia's development plans from 1MP to 11MP (**Source:** adapted from Science Outlook 2015, ASM)

Understanding the need to develop indigenous science and technology capacity and capability for competitiveness, Malaysia charted its course towards becoming a knowledge-based economy with the launch of the long-term policy plan, Vision 2020, in 1991. As a result, scientific and technological based activities have developed rapidly.

This was followed through with the implementation of the New Economic Model (NEM, 2010-2020) with the aim to transform Malaysia into a high-income economy that is inclusive and sustainable ensuring the quality of life and quality growth for the people as shown in Figure 4.4. This has led to the diversification of the Malaysia's economic structure with growth driven by the services sector and reduced dependence on commodities as shown in Figure 4.5. Malaysia is on track towards becoming a high-income nation in terms of per capita income USD 15,000 – 20,000 by 2020 (Office of the Prime Minister of Malaysia, 2017).

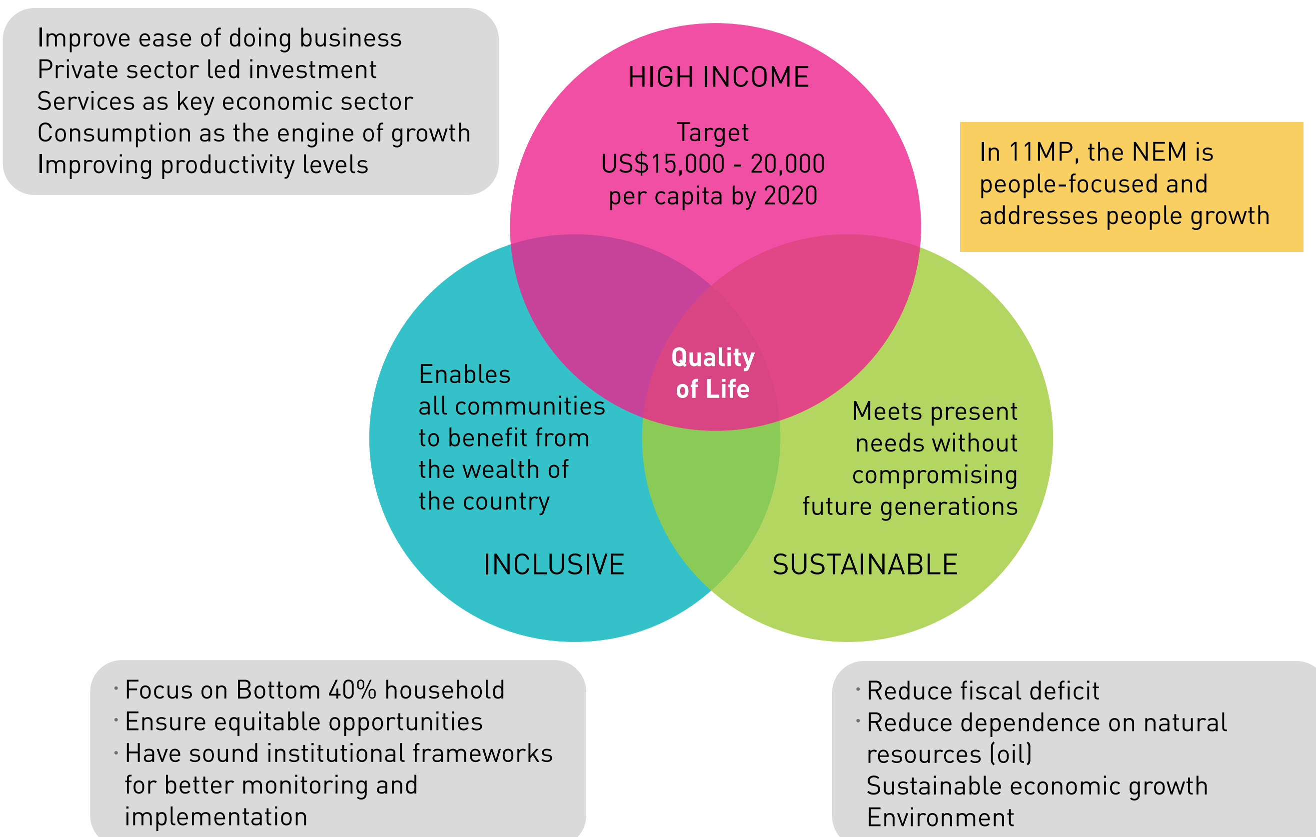


Figure 4.4: Malaysia as a high income nation, inclusive and sustainable
(**Source:** MOHE)

Malaysia's STI governance is characterised by a multiplicity of advisory committees and councils as well as ministries, agencies, etc. engaged in STI policy-making, funding and implementation, each of which is equipped with its own strategic framework and policy instruments (OECD, 2016).

Government ministries are not only involved in the formulation of STI policies but also responsible for STI funding and implementation. Entities in the STI ecosystem are often guided by their own policy instruments and strategic plans leading to a lack of synergy with other policy measures, strategic initiatives and in many cases duplication of efforts with diluted impact.

Malaysia's primary development instrument has always been the Five Year Plan scheme that details out national goals, strategic papers, policies and funding programmes. The National Science Research Council's Public Research Assets Performance Assessment (NSRC, 2013) pointed out that the release of new Malaysia Plans typically leads to the creation of new funding and commercialisation programmes while the introduction of new national strategies often gave birth to new public research assets (PRAs). The constant existence of new programmes and PRAs has resulted in competition for resources, influence and control.

In terms of R&D, although there has been a steady increase in fund allocation from the First to the 11MP, covering the period from 1966 to 2020. These funds were allocated and distributed through various funding programmes involving multiple agencies thereby reducing the net effect of increased allocation to move R&D in a strategic manner (Science Outlook, ASM, 2015).
Whilst Malaysia's development is primarily charted by the Malaysia Plan, there is a need to better plan technology development at the national level as demand for innovative technologies is gaining momentum in the nation's drive to become innovation-led.

As highlighted in the Essentials of Science, Technology and Innovation Policy, there are four critical groups of technologies that are essential for socio-economic transformation (Omar Abdul Rahman, 2013):

1. Technologies for meeting basic needs such as food, water and shelter;
2. Technologies for quality of life, e.g. education, healthcare, stabilisation of population size, environmental sustainability;
3. Technologies for wealth creation in support of economic growth and competitiveness; and
4. Technologies for good governance in both public and private sector.

On the other hand, effective planning of technology development is difficult due to the cost, complexity, and pace of technological change in the global market (Halicka, 2016). As such, technology development planning for socio-economic transformation should be embedded in instruments such as Malaysia Plans in order to develop and deploy technologies in a systematic manner with proper follow through.

4.2

Malaysia's Key Economic Sectors

Three major economic sectors which are fundamental to Malaysia's economic growth are shown in Figure 4.5. These three sectors are electrical and electronics (E&E is embedded in the manufacturing sector), agriculture and halal industry (reflected in services sector).

These sectors need to be further developed to make the leap to the next level of advancement by harnessing cutting-edge technologies to realise outcomes that would lead to a Progressive Malaysia 2050 that is harmonious, prosperous and sustainable.

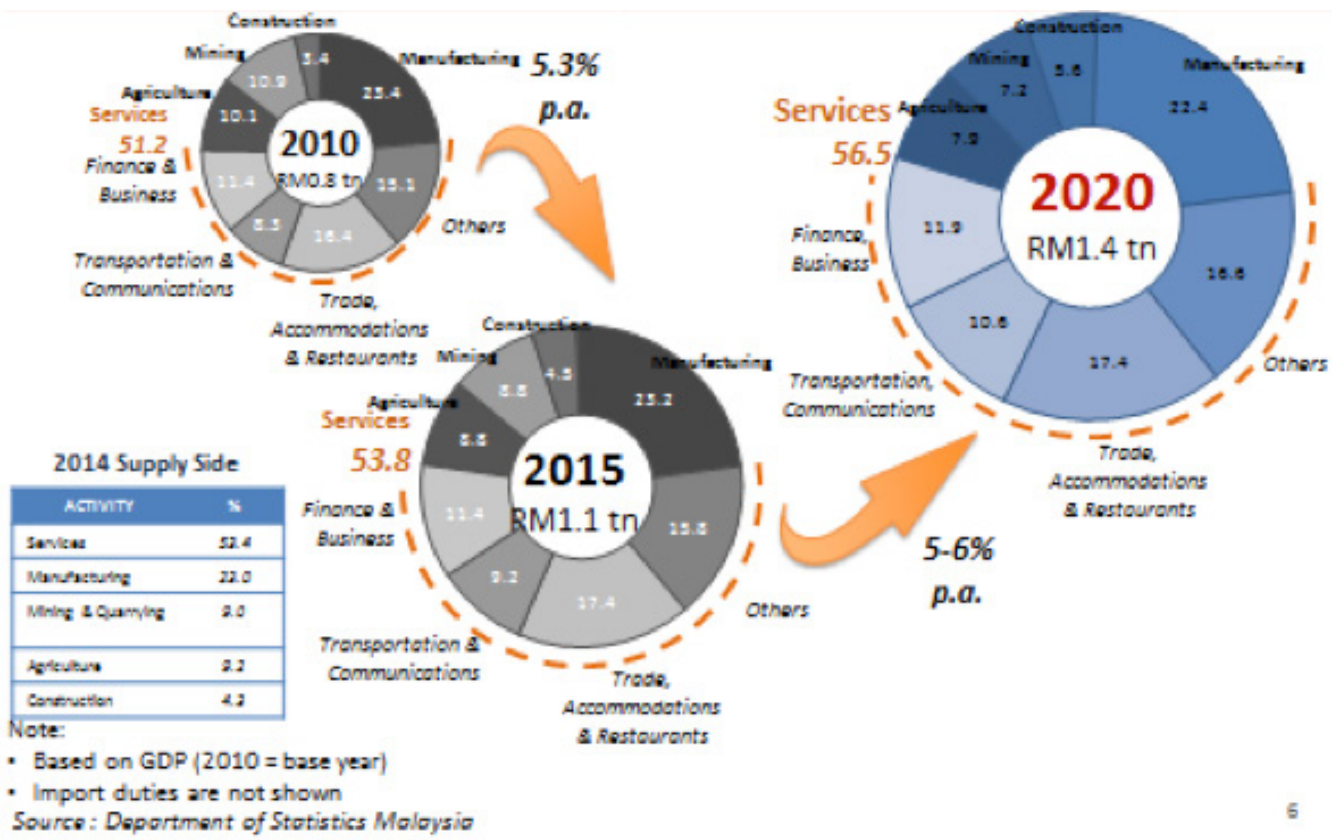


Figure 4.5: Malaysia's economic structure (**Source:** DOSM, 2016)

Electrical and Electronics

The electrical and electronics (E&E) products industry, Malaysia's largest export as of July 2017 and as shown in Figure 4.6 continues to be a bedrock of the Malaysian economy. In 2016, Malaysia was the world's seventh largest exporter of E&E products, valued at RM287.7 billion, which made up 36.6% of Malaysia's total exports as shown in Table 4.1. Exports of E&E products also accounted for 44.6% of the total value of manufacturing goods exported in 2016 (MIDA, 2017). The E&E sector also contributed 23.4% to Malaysia's GDP in 2016 and created more than 780,000 jobs for Malaysians (MATRADE, 2017).

The flipside to Malaysia's E&E industry is that it is still very much focused on manufacturing and not expanded to higher value-chain activities such as R&D. The challenge is to leverage emerging technologies to accelerate the growth of the E&E sector with emphasis on developing indigenous capacity and capability.

Table 4.1: Malaysia's external trade in 2016 (**Source:** Bank Negara Malaysia, 2017)

External Trade

	Share 2016 (%)	2014	2015	2016p
		Annual change (%)		
Gross Exports of which:	**100.0**	**6.3**	**1.6**	**1.1**
Manufactures	*82.2*	*7.1*	*6.5*	*3.2*
E&E	*36.6*	*8.1*	*8.5*	*3.5*
Non-E&E	*45.5*	*6.4*	*5.0*	*3.0*
Commodities	*17.1*	*3.9*	*-14.9*	*-8.6*
Agriculture	*9.0*	*0.5*	*-2.8*	*4.7*
Minerals	*8.2*	*6.2*	*-22.9*	*-19.8*
Gross Exports of which:	**100.0**	**5.3**	**0.4**	**1.9**
Intermediate goods	*57.1*	*7.6*	*-2.1*	*-0.1*
Capital goods	*14.3*	*-2.4*	*-0.3*	*4.9*
Consumption goods	*9.6*	*5.7*	*24.1*	*7.3*
Trade balance (RM billion)	**-**	**82.5**	**91.6**	**87.3**

p Preliminary
Source: Department of Statistics, Malaysia and Bank Negara

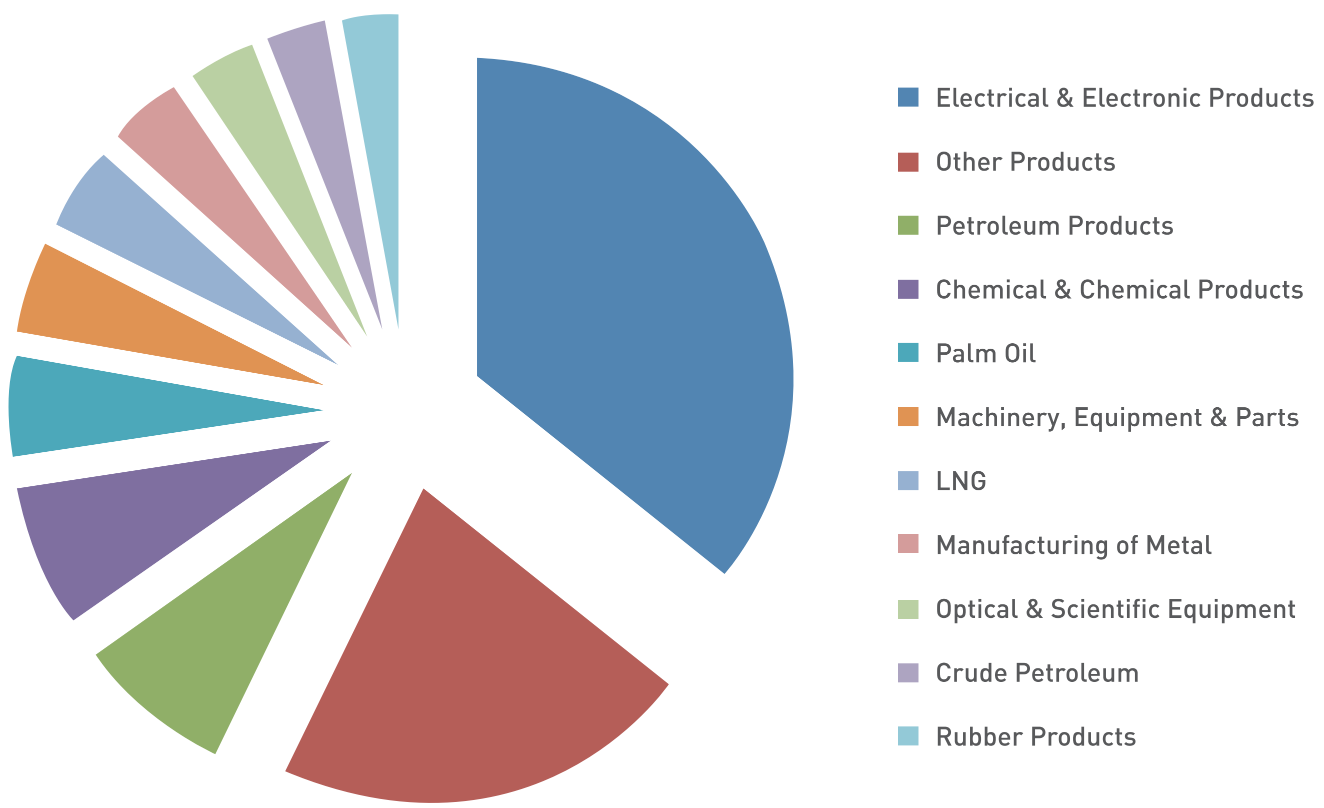


Figure 4.6: Malaysia's Major Exports between January 2017 to July 2017 (**Source:** MATRADE 2017)

Agriculture

Agriculture is a key sector for Malaysia's economic growth. The agricultural sector is one of the National Key Economic Areas (NKEA) under the Economic Transformation Programme (ETP). It plays an important role in Malaysia's socio-economic development by ensuring national food security, enabling people's well-being by providing rural employment as well as uplifting rural incomes to reduce the inequality divide.

The contribution of the agriculture sector to Malaysia's GDP was huge in the past for example around 44% in 1960. However, over the years the contribution of the agriculture sector to Malaysian GDP has dwindled from 1960 to present. The agriculture sector contributed 8.9% to Malaysia's GDP in 2015. Oil palm is a major contributor to the GDP within the agriculture sector at 46.9% followed by other agriculture (17.7%), livestock (10.7%), fishing (10.7%), rubber (7.2%) and forestry & logging (6.9%) in 2015 as shown in Figure 4.7. Under the 11MP, the targeted contribution to Malaysia's GDP by the agriculture sector is around RM110.7 billion by 2020.

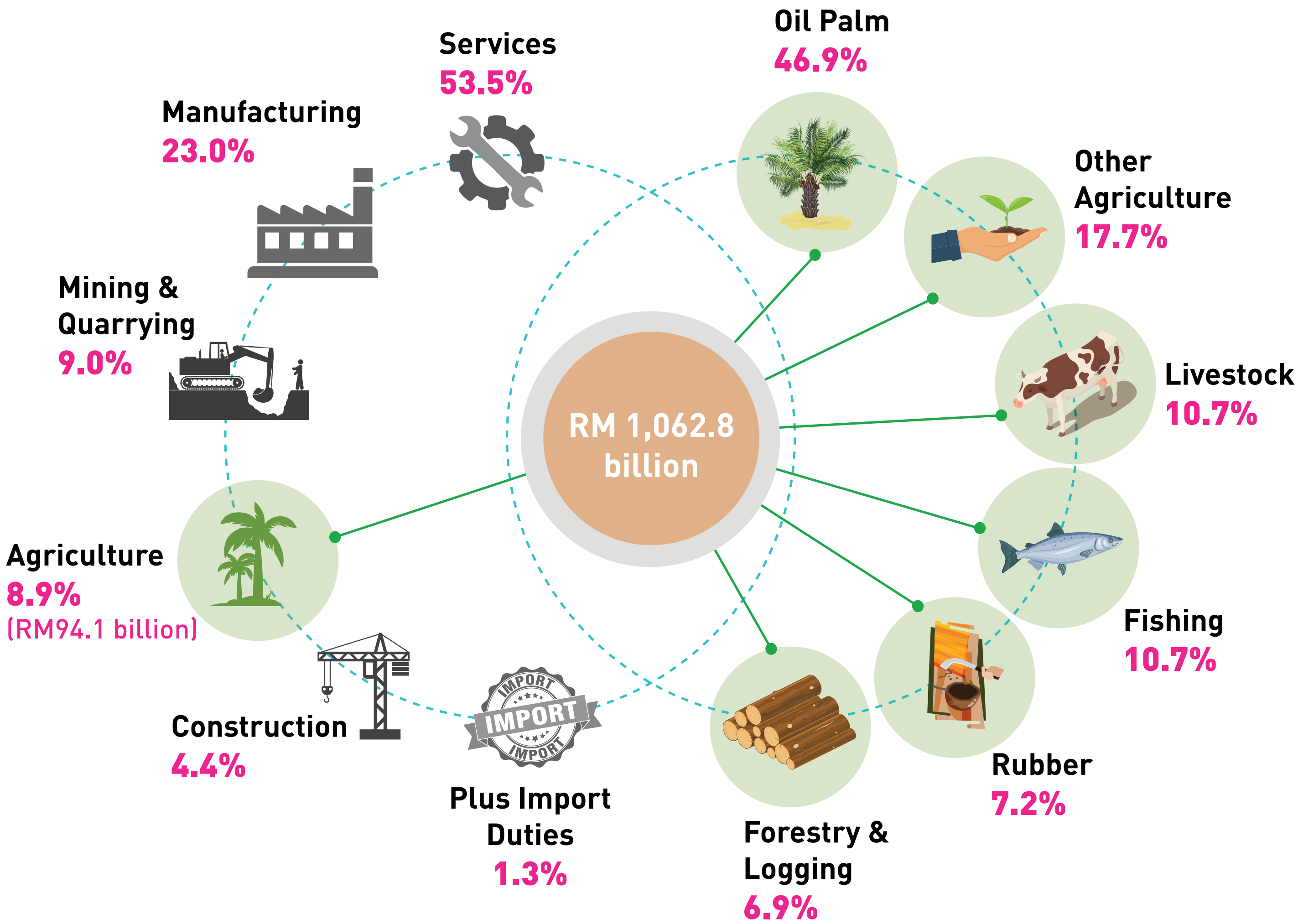


Figure 4.7: Percentage share to GDP by kind of economic activity in 2015
(**Source:** Department of Statistic Malaysia, 2016)

Malaysia has all the ingredients to thrive as an agriculture powerhouse being endowed with fertile soil, abundant rainfall and suitable climate. Malaysia has 4.06 million hectares of agricultural land across 14 states. Around 75% of the land is utilised for primary crops mainly oil palm followed by rubber, cocoa, coconut and pepper (Frost and Sullivan, 2009). The remaining land is cultivated for agro-food production. The outlook for the agriculture sector in Malaysia is both positive and promising with rising demands for local and export market, especially for the agro-food sector.

Technology would serve as a game changer to increase agriculture yields, efficiency and market reach as well as realise sustainable agriculture through precision farming. Besides that, the application of emerging technologies in the agriculture sector also enables production of more nutritious food in response to changes in dietary requirements, production of raw materials for non-food use, mitigation of natural resources depletion as well as adaptation to unexpected environmental changes due to climate change.

The evolution of the agriculture sector in Malaysia over the years as shown in Figure 4.8 reflects the emphasis to develop the technological frontier particularly through agricultural biotechnology. Malaysia needs to rise to the challenge of increasing self-sufficiency for food and reducing dependence on food imports by leveraging emerging technologies and modernising the agriculture sector to be hi-tech and hi-touch enabling economic growth and people's well-being. Recognising this, the Agriculture NKEA focuses on transforming a traditionally small-scale, production-based sector into a large-scale agriculture force. This entails capitalising on competitive advantages, tapping premium markets, aligning food security objectives with increasing GNI as well as participating in the regional agricultural value chain. The common denominator for these value propositions is technology (PEMANDU, 2015).

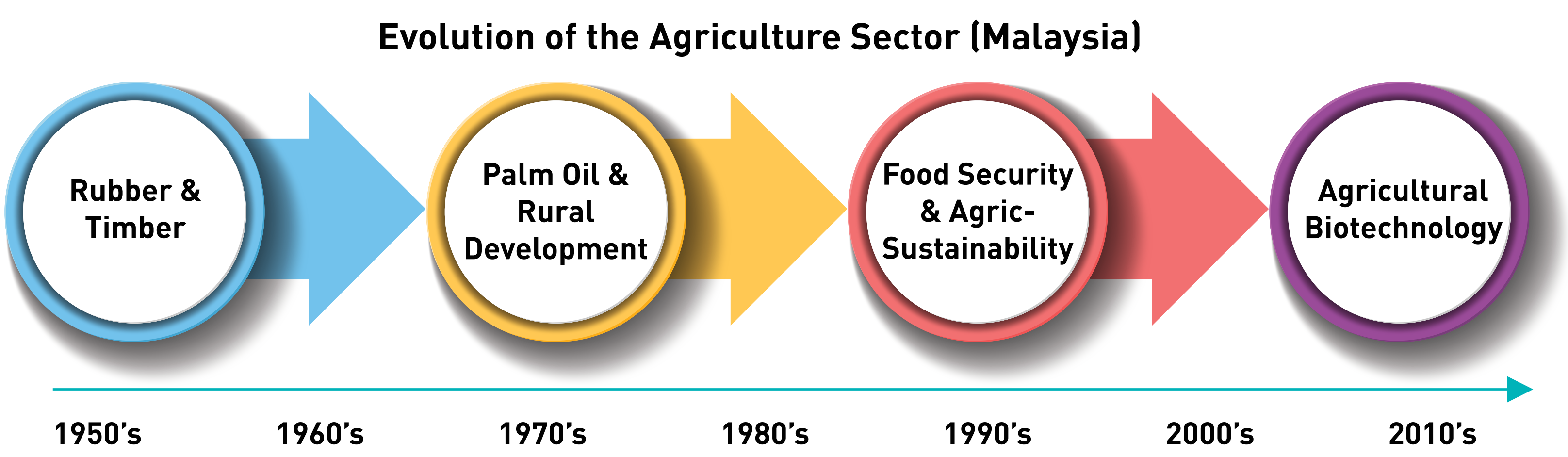


Figure 4.8: Evolution of the agriculture sector in Malaysia
(**Source:** The Malaysian Agricultural Biotechnology Sector, Frost and Sullivan, 2009)

Emerging technologies identified in this study could revolutionise the marketing and supply chain management of agricultural produce by farmers and plantation owners. Through access to digital technology they can now participate in the collaborative economy through online platforms and do away with the need for middle men. Geographical Information System (GIS) and Radio Frequency Identification (RFID) trackers can be used to precisely track agricultural products being transported from the farm to end-user. This gives rise to the Farm to Fork concept with advanced tracking and monitoring of the agriculture produce throughout the supply chain as shown in Figure 4.9.

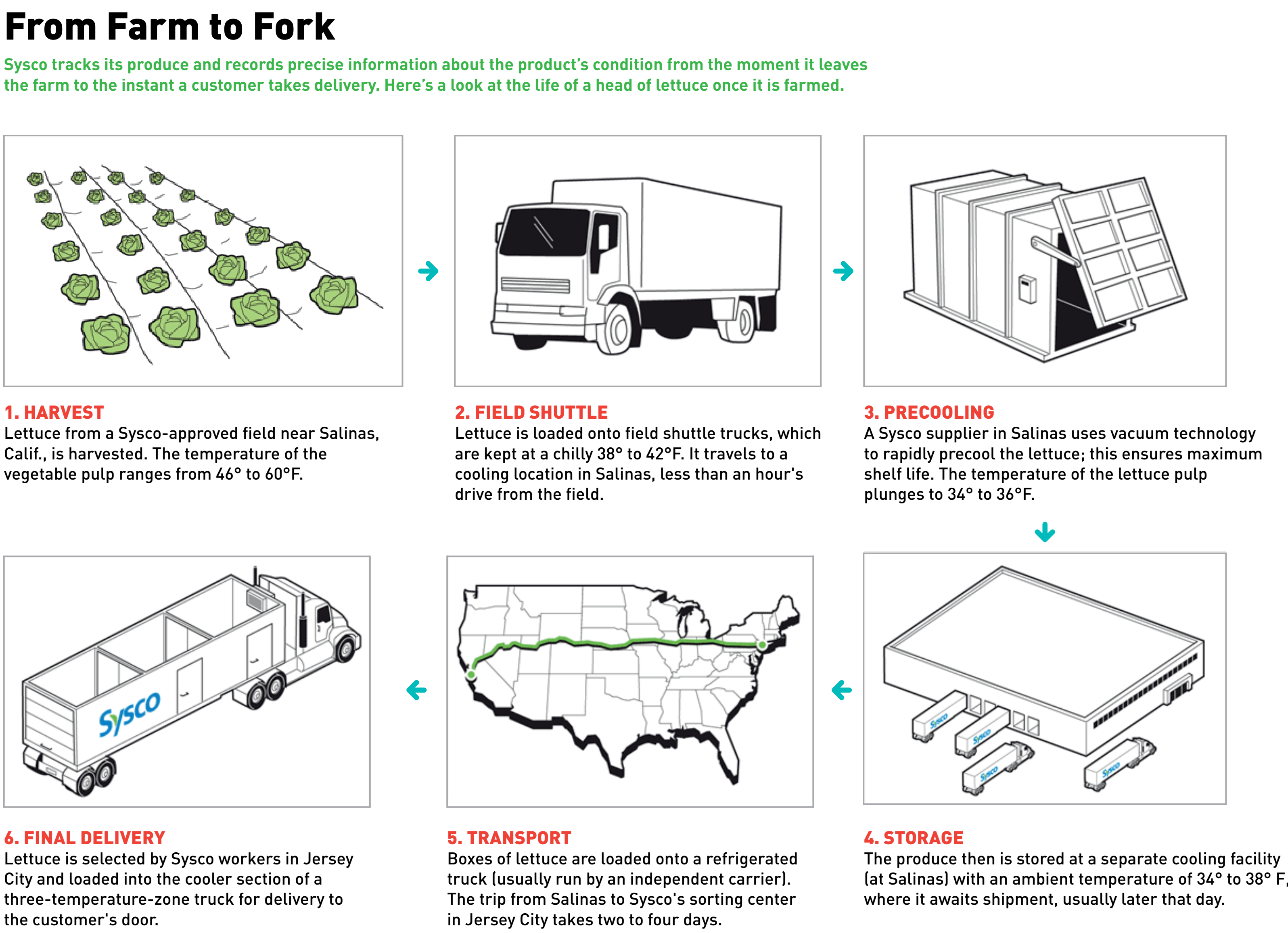


Figure 4.9: Sysco's from farm to fork
(Source: Sustaining Malaysia's Future The Mega Science Agenda: Agriculture, ASM, 2012)

Technology Enhances Agriculture Sector Contribution to Healthcare Industry

The application of emerging technologies in the agriculture sector is not limited to food sources but is also an avenue to significantly contribute to the healthcare industry. One of the ways is through biopharming, transgenic plants and genetically engineered animals are used to produce pharmaceutical substances for use in humans or animals. This often reduces cost and production time compared to conventional methods. Since cost and time to produce is reduced, the affordability, accessibility and availability of pharmaceuticals, indirectly the burden of healthcare costs are reduced for the people. Similarly, natural products extracted from plants or animals to be used for therapeutic purposes or as supplements for preventative healthcare. Tailoring a person's nutritional requirements to his or her genetic profile through nutrigenomics not only boosts health but also reduces one's chances of developing conditions such as cardiovascular disease, obesity, diabetes and inflammatory bowel disease.

Value Adding to Non-food Materials

Oil palm is a key crop that significantly contributes to the Malaysian economy since Malaysia is the second largest palm oil producer in the world. Despite the obvious benefits, an oil palm mill also significantly contributes to environmental degradation. The application of integrated bio-refinery in the oil palm mill enables waste to be turned into value-added products. For example, retrofitting of palm oil mills with bio-refinery for further processing of biomasses into biofuels, biochemical, and bio-based food would reduce waste and create new revenue streams. In line with sustainable practices, wastewater nutrient recovery technology enables nutrient effluents from wastewater to be turned to fertilizer for agriculture purpose.

Halal Industry

The Halal Industry is rapidly expanding business and there is immense opportunity for Malaysia to position itself as a global Halal supplier. The Islamic Economy estimated to be worth $1.9 trillion while the Islamic Finance sector has around $2 trillion in assets in 2015. (Thompson Reuters, 2016). At present, the Halal Market is represented by approximately 1.6 billion halal consumers worldwide (International Trade Centre, 2015). The global halal market is expected to reach 2.2 billion people by 2030 due to the increasing awareness among the Muslim and non-Muslim population on the quality of Halal products. The Halal industry is not just confined to food as it has diversified and expanded to other sectors such as services, namely finance and banking, insurance, education and training, research, certification, consultancy, logistics, healthcare as well as tourism.

The Halal Industry is a significant contributor to Malaysia's economy as in 2016, it accounted for 7.5% of Malaysia's GDP with 1,401 Malaysian companies exporting RM205.1 billion worth of halal products. Around 248,508 jobs were provided by the Halal Industry in Malaysia as of 2015. Malaysia has also seen an expansion of Halal products exporting companies to around 1,401 as of 2016 (Halal Industry Development Corporation, 2017).

The halal imperative began in Malaysia's Second Industrial Master Plan 1996-2005 and was further integrated into the Malaysian national agenda in the Third National Agriculture Policy 1998-2010 which highlighted the development of the halal food industry. Since then, halal has been featured in the 9MP 2006-2010, the New Economic Model (2010), the ETP as well as the 10th and the 11MP

Launched in 2008, the Halal Industry Master Plan (HIMP) is a comprehensive and complex blueprint that runs until 2020 to drive Halal Industry as a new source of economic growth. The HIMP aims to introduce high value-add into Malaysia's halal production, services and trade towards creating an industry with a high GDP value. One of the expected outcomes of HIMP is to increase Halal related industry's contribution to Malaysia's GDP to 8.7% by 2020 (Halal Industry Development Corporation, 2016).

The demand for better, more value added Halal products by ethically aware consumers is continuously increasing. The eco-ethical values contained in the terms 'halal and tayyib' are likely to play an increasingly relevant role as the halal sectors develop, and to become clear value-added components for manufacturers and marketers in the near future (International Trade Centre, 2015).

Leveraging emerging technologies to deliver safe, genuinely certified and diversified Halal products would be key for Malaysia to build on the nation's reputation for high-quality Halal standards and pursue aggressive branding as a leading global Halal supplier. A tremendous value proposition would be brought about for the Halal industry through the injection of more science, technology and innovation giving rise to another niche specialisation for Malaysia i.e. the science of Halal.

Besides the Halal food segment within the Halal industry, other niche areas in which Malaysia has a good leading position, value proposition and needed impetus to reengineer growth by leveraging emerging technologies are Fintech in Islamic Finance, Halal Tourism and Halal Medicine.

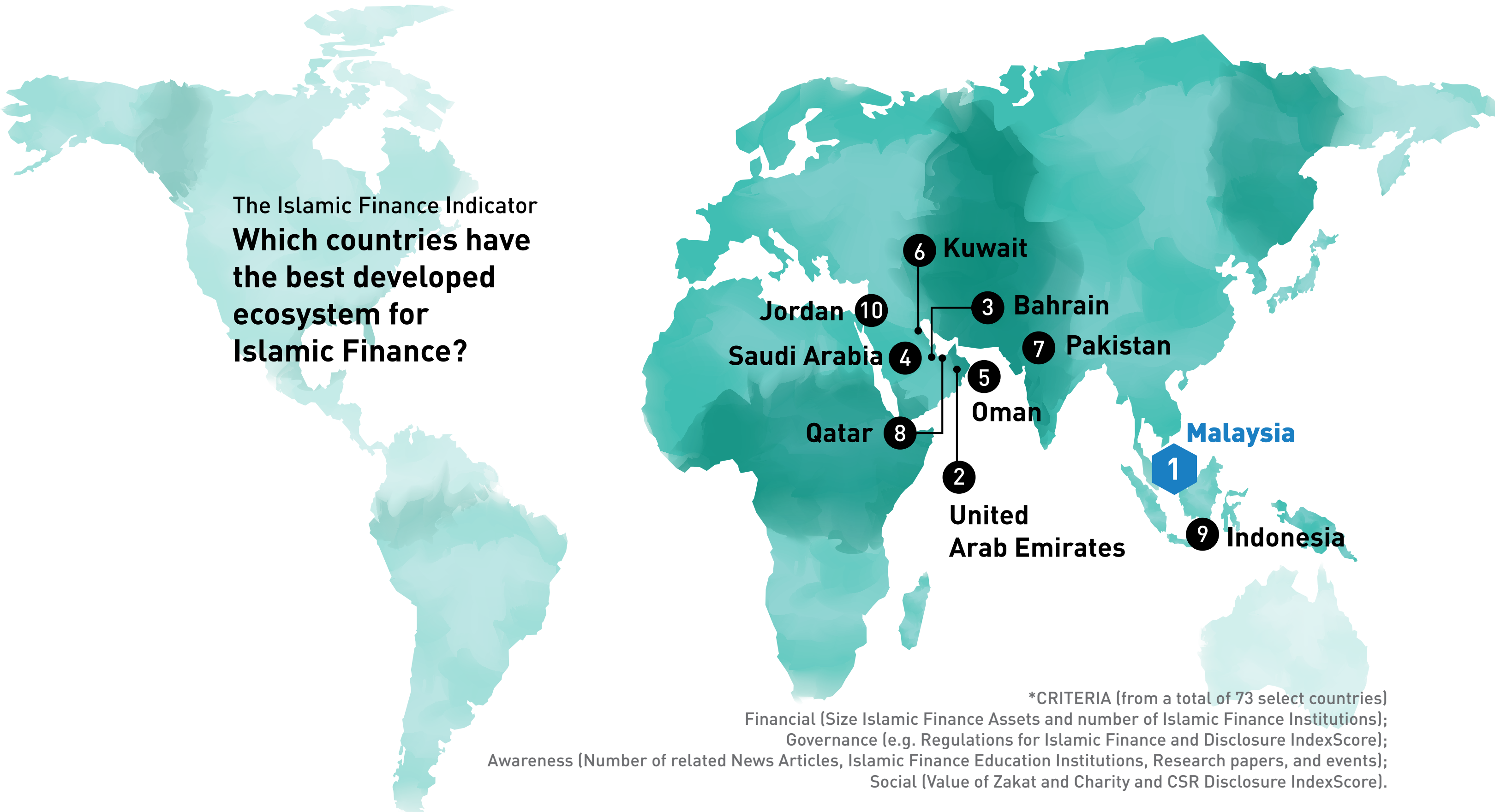


Figure 4.10: Countries with the best developed ecosystem for Islamic Finance (**Source:** Thomson Reuters, 2016)

Figure 4.10 shows that Malaysia is already considered as one of the leaders in Islamic Finance (IF) as a result of a large IF asset base, a large number of IF institutions and funds in addition to having one of the strongest regulatory frameworks for IF compared to other ranked countries. Malaysia could further strengthen the lead by encouraging the development of financial technology (Fintech) in this market segment.

In terms of governance and regulatory framework, the Central Bank of Malaysia (BNM) has taken several initiatives in providing a conducive regulatory environment for the adoption of innovative financial technology solutions by establishing the Financial Technology Enabler Group (FTEG) and introducing the Regulatory Sandbox Framework in 2016.

Potential Islamic Finance Offerings for Fintech

Banking
Regulatory technology solutions (or regtech) could be deployed to ensure that Islamic finance offerings are Shariah compliant

Credit
Provide alternative financing and investment sources that are Shariah compliant via platforms which match between investors and consumers, be it individuals or entities like SMEs.

Savings
Provide online platforms to save money on credit needs within the Shariah parameters. They can automatically review consumers' debts whereby consumers can maximize ways to save.

Remittance/Exchanges
Provide online platforms for the remittance and exchange of monies in accordance with Shariah principles, ie Bai Sarf.

Insurance
Provide Takaful products that can be bought by individuals using devices. P2P Takaful entails mutual cooperation among individual consumers and enterprises. The usage of technology would automate the claims process and this should result in reduced filing and faster payouts.

Wealth/Asset Management
Provide automated Islamic investment platforms, ie digital financial advisory services to access Halal portfolio management.

(**Source:** Nizam Ismail, 2017)

Several of the emerging technologies identified in this report as shown in Table 4.2 can be effectively deployed in the Islamic Finance space to enhance Malaysia's position. Islamic finance, through its core principles, advocates for a just, fair, and equitable distribution of income and wealth during the production cycle and provides mechanisms for redistribution to address any imbalances that may occur (World Bank and Islamic Development Bank Group, 2016). By deploying emerging technologies within Islamic Finance principles, it is hoped that economic inequalities in Malaysia can be further addressed.

Table 4.2: Emerging Technologies Relevant to Strengthening Islamic Finance Sector

Application	Emerging Technology Enablers	Outcomes
Security	Blockchain, Cyber Security Brain Fingerprinting	Better system to defend against unknown emerging threats and promote data integrity
Data Storage and processing systems	Cloud computing, big data analytics, AI, deep learning neural networks with AI	Perform advanced analysis of patterns or trends
Payment Service	Mobile payment system, Blockchain	System that could efficiently channel funds from investors to viable economic ventures, promote risk-sharing and support cross-border investments

Halal Tourism

Estimated revenues derived from Muslim Friendly Tourism (MFT) services have been estimated at $24 billion in 2015 across hotels, air travel and leisure activities (Thompson Reuters, 2016). Thompson Reuters also reported that Muslim populations globally have spent a total of $151 billion on travel in 2015 (excluding Hajj and Umrah), 11% of global market spending.

Malaysia is one of the pioneering countries to have a MFT ecosystem and to further boost this sector, the Islamic Tourism Centre was established in 2009. Malaysia is one of the leading countries for halal tourism as proved in the Mastercard-CrescentRating Global Muslim Travel Index 2017 (GMTI 2017) which covers a total of 130 destinations where Malaysia tops the Index for the seventh year in a row.

Table 4.3: OIC vs Non-OIC GMTI 2017 Comparison (Source: Mastercard and CrescentRating, 2017)

Rank	OIC Destination	Score	Rank	Non-OIC Destination	Score
1	Malaysia	82.5	10	Singapore	67.3
2	United Arab Emirates	76.9	18	Thailand	61.8
3	Indonesia	72.6	20	United Kingdom	60.0
4	Turkey	72.4	30	South Africa	53.6
5	Saudi Arabia	71.4	31	Hong Kong	53.2
6	Qatar	70.5	32	Japan	52.8
7	Morocco	68.1	33	Taiwan	52.4
8	Oman	67.9	34	France	52.1
9	Bahrain	67.9	36	Spain	48.8
11	Iran	66.8	37	United States	48.6
12	Jordan	66.3	39	Germany	48.2
13	Brunei	64.4	40	India	47.6
14	Egypt	64.1	41	Sri Lanka	47.5
15	Kuwait	63.9	42	Australia	46.7
15	Maldives	63.1	43	Philippines	46.5
17	Kazakhstan	62.0	44	Russian Federation	46.5
19	Tunisia	61.1	45	China	45.9
21	Bangladesh	59.8	47	South Korea	45.5
22	Algeria	59.4	49	Canada	45.1
23	Pakistan	57.6	51	Belgium	44.8

The virtual reality which was identified as one of the emerging technologies in this report can be deployed to facilitate virtual tours of Islamic heritage sites in Malaysia while MFT features in hotels and resorts (halal food options, availability of prayer areas, separated recreational facilities, etc.) can be further highlighted using this technology. Virtual Reality experts have projected that companies that embrace the technology now will have the ability to create simulated travel experiences that can act as a teaser for the real thing (COMCEC, 2016).

Halal Medicine

It is estimated that Muslims spending on pharmaceuticals is valued at USD78 billion in 2015 (7% of global expenditure) and with further innovations occurring in this sector, Muslims spending on pharmaceuticals could reach USD132 billion by 2021 according to Thompson Reuters (2016).

As many traditional markets reach saturation, the emergence of new markets based on halal values and principles is in effect creating waves by increasing consumer awareness and an entrepreneurial eye for new market opportunities and commercial paradigm (International Trade Center, 2015).

Several of the emerging technologies identified in this report can be developed to create new market opportunities in the halal market. Halal certification, with the stringent monitoring and care they represent, ensure only the highest quality control and quality standards. Consequently, now many non-meat food manufacturers see halal certification as an opportunity for new markets, even for naturally halal products.

Table 4.4: Emerging technologies relevant to create new market opportunities in the halal market

Application	Emerging Technology Enablers	Outcomes
Effective Drug Delivery System	Nano based drug delivery system	Efficient loading and delivery of drug molecules
Targeted delivery for additives and supplements	Nanoencapsulation	Delivery systems for additives and supplements using carrier systems for foods i.e. infant formula, vegetable oil
Natural Products	Natural product derived supplement and therapeutics	Supplement and therapeutic products using permissible, sharia-compliant elements

4.3

Current Status of ESET Areas in Malaysia

Malaysia has invested in biotechnology, digital technology, green technology, nanotechnology and neurotechnology areas for at least the past two decades in either the form of funding for R&D, development of talent by introducing specific courses in academic institutions at different levels, putting in place a national framework, policies, statements or roadmaps, promote business activities through government procurements and providing tax incentives.

STI Development for the Five Technology Areas Featured in Malaysia's Five-year Plans

5th Malaysia Plan (1986-1990)

The first Malaysia Plan to have a dedicated chapter on S&T

Several high technology activities such as microelectronic, laser technology and electro-optics, biotechnology, material technology, manufacturing technology and software technology were identified as high priority areas for government support in R&D activities.

6th Malaysia Plan (1991-1995)

Five key technology areas have been identified to enhance innovativeness and to further develop niche areas for domestic industries:

- Automated manufacturing technology
- Advance materials
- Biotechnology
- Electronics
- Information technology

7th Malaysia Plan (1996-2000)

Several advanced technologies were promoted to support the implementation of the technology-based industrial strategies and to create new investment opportunities for Malaysia's economy:

- Information technology and communication i.e. networking, digital imaging.
- Microelectronics i.e. sensor technology.
- Biotechnology and life sciences i.e. biotechnology materials and processes.
- Advanced manufacturing technology i.e. machine intelligence and robotics.
- Advanced materials i.e. composites, ceramics.
- Environment and energy-related i.e. green materials, renewable energy.

The first chapter on Information Technology was introduced in this Malaysia Plan.

8th Malaysia Plan (2001-2005)

35% of the Intensification of Research in Priority Areas (IRPA) budget was allocated to prioritised research in manufacturing, plant production and primary products, ICT, health as well as education and training.

Another 35% was allocated for strategic research areas to enhance future competitiveness in emerging areas such as optical technology, speciality fine chemicals technology, design and software technology as well as nanotechnology and precision engineering.

9th Malaysia Plan (2006-2010)

Greater emphasis was placed on targeted R&D to build competence and specialisation in emerging technologies to generate new sources of growth:

- Biotechnology with focus areas such as agricultural, healthcare and industrial biotechnologies.
- Information and Communications Technology with technology focus areas that include semiconductors and microelectronics; Internet Protocol version 6 (IPv6), grid computing and language engineering as well as information security.
- Advanced Materials and Manufacturing with R&D focus areas that include photonic materials for the telecommunications industry as well as metal and polymer composite materials for defence, aerospace, agriculture and automotive industries.
- Nanotechnology with high potential for application in local industries such as nanostructured catalysts for environment-friendly hydrocarbon fuels, nanostructured membranes for wastewater treatment and Microelectromechanical systems (MEMS) for medical diagnostic devices.

The first chapter on Biotechnology and Sustainable Energy was introduced in this Malaysia Plan.

10th Malaysia Plan (2011-2015)

The absence of a dedicated chapter on STI but elements of STI was embedded in the plan's "10 Big Ideas".

The four ideas directly relevant to STI-led growth (NSRC, 2013) were:

- Transforming to high-income through specialisation.
- Unleashing productivity-led growth and innovation
- Nurturing, attracting and retaining top talent.
- Supporting effective and smart partnerships.

In terms of technology, the 10th Malaysia Plan emphasised on:

- Information and communications technology as a mean to become a niche producer of selected ICT products and services.
- Green technology to address climate change issue.

11th Malaysia Plan (2016-2020)

Absence of a dedicated chapter on STI.

In the ICT industry, niche areas will be further promoted and export capabilities enhanced to ensure that Malaysia captures a bigger export market for ICT products and services. Within the identified niche areas – digital content, IoT, data centres and cloud services, cyber security, software development and testing, and big data analytics – the ICT ecosystem will be strengthened, including the capacity of start-ups, talent, infrastructure, R,D&C, and governance.

A dedicated chapter on green growth entitled "Pursuing green growth for sustainability and resilience" highlights that in order to pursue green growth, the enabling environment will be strengthened — particularly in terms of policy and regulatory framework, human capital, green technology investment, and financial instruments.

The policy, regulatory and institutional framework will be strengthened to encourage industries to shift their products and services by adopting green technologies as well as accelerating innovation and development of indigenous green technology.

Biotechnology

Malaysia has a good ecosystem for biotechnology; this is proven by the policy initiatives and establishment of Malaysian Bioeconomy Development Corporation (formerly known as Malaysia Biotechnology Corporation) to promote development of biotechnology locally through identifying value proposition in both R&D and commerce as well as supports these ventures via financial assistance and development services. As of December 2016, Bioeconomy Corporation has successfully built a network of 278 BioNexus status companies accounting for over RM6.5 billion in approved investments in BioMedical, AgBiotech and BioIndustrial sectors. Meanwhile, cost-competitive talents continue to attract foreign pharmaceutical firms to establish outsourcing and clinical trial points in Malaysia.

National Biotechnology Policy, introduced in 2005, has completed the first two phases - Capacity Building (2005-2010) and Science to Business (2011-2015) - with the third phase, developing Global Business, started in 2016 and ends 2020 aimed to turn the biotechnology sector into one of the nation's key economic drivers, contributing 5% of the nation's GDP by 2020. The opportunities for Malaysia predominantly lie in agrobiotechnology, industrial biotechnology and biologics, especially integrating scientific evidence-based traditional knowledge into healthcare.

The National Biotechnology Directorate (NBD) was established in 1995 under the purview of Ministry of Science, Technology and Environment (MOSTE) to spearhead the development of biotechnology in Malaysia through research and related activities directed at commercialising biotechnology. NBD was then restructured into the National Biotechnology Division (BIOTEK) in 2005.

On the talent development front, various educational and research programmes in the biotechnology area are offered by different universities in Malaysia leading to a significant increase in a number of biotech graduates. Malaysia has established world-class research institutions which house modern facilities and state-of-the-art equipment for biotechnology research such as the Center of Excellence (CoE) for agro-biotechnology located around the Malaysian Agriculture Research and Development Institute (MARDI) and Universiti Putra Malaysia (UPM). Centre for Genomics and Molecular Biology hosted by Universiti Kebangsaan Malaysia (UKM) while the Malaysian Institute of Pharmaceuticals and Nutraceuticals (IPharm) in Univesiti Sains Malaysia (USM) is a CoE exploiting the megadiversity of Malaysian natural resources for the development of new drugs.

Some of the policies, initiatives and organisations that are related to the national biotechnology sector are shown in Figure 4.11.

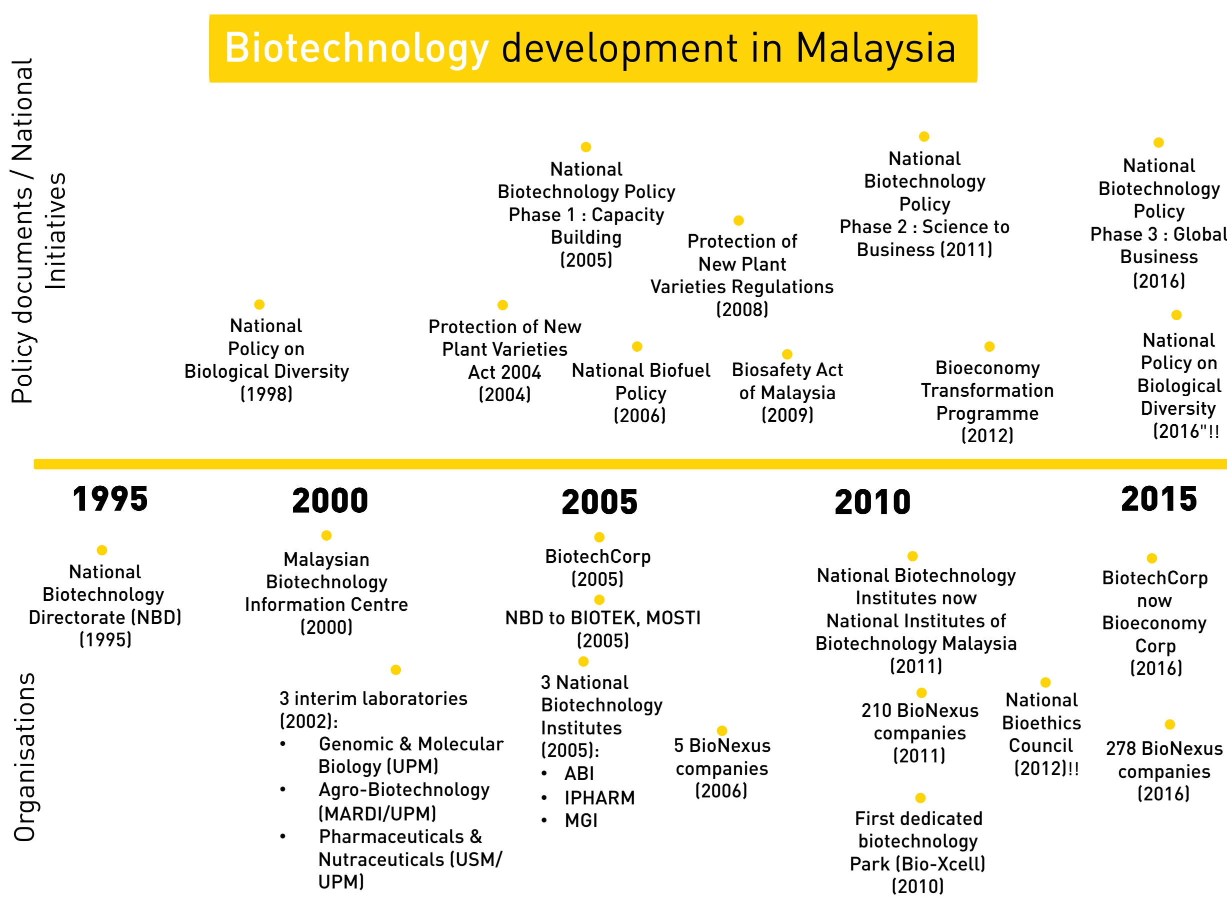


Figure 4.11: Biotechnology development in Malaysia (Source: compiled by ASM)

Digital Technology

Information and Communication Technology (ICT), or Digital Technology has been identified as "the engine of growth in all economic sectors" during the launch of the Multimedia Super Corridor in 1996. Malaysia Digital Economy Corporation (MDEC), formerly known as Multimedia Development Corporation Sdn Bhd was established in 1996 to strategically advise the Malaysian Government on legislation, policies and standards for ICT and multimedia operations. ICT is expected to play a critical role towards Malaysia achieving the Vision 2020. A comprehensive legal framework relating the use of the internet and digital technology has been developed. As part of the continuation plan, Digital Malaysia has been launched to drive Malaysia towards a digital economy. Digital Malaysia has targeted 17% GNI to be delivered by ICT by 2020. In Malaysia's digital economy, the ICT sector contributed 12% to the national GDP in 2012, amounting to RM113 billion out of the total national GDP of RM941 billion. At the national level, many ICT initiatives have been done by the Malaysian government, ministries and agencies. Going by the Networked Readiness Index (NRI) 2016 by World Economic Forum, Malaysia, ranked 31st out of 139 countries.

The Government's commitment to addressing the digital divide in Malaysia is undertaken through various digital inclusion programmes and initiatives. For example, companies involved in ICT research can apply for MSC status which grants tax exemptions for the entire business operation. Other tax grant schemes are also available for more established companies in areas related to ICT such as electronics or advanced manufacturing. Improvements in ICT skills and knowledge have enabled online usage for communications and business operations. In 2017, the Digital Free Trade Zone (DTFZ) was launched whereby the Kuala Lumpur Internet City will be established here with a lofty goal of housing 1,000 Internet-related companies as tenants, with the aim to become the region's digital hub. MDEC is the lead agency in driving the digital economy in Malaysia and their role is to build a vibrant digital economy and ensure that Malaysia plays a leading part in the global digital revolution.

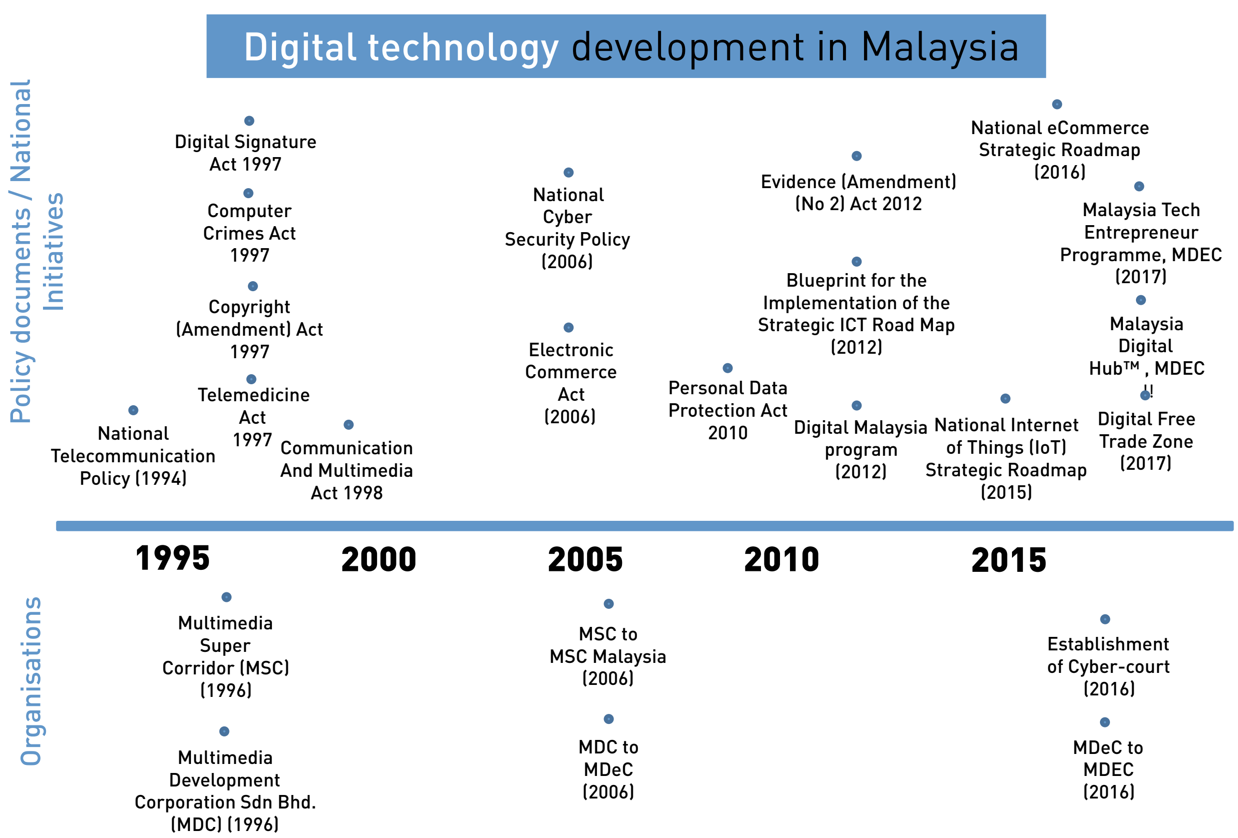


Figure 4.12: Digital technology development in Malaysia (Source: compiled by ASM)

Green Technology

In line with Malaysia's aim to become an inclusive and sustainable advanced nation by 2020, Green Technology has been identified as one of the drivers of the future economy for the nation that would contribute to the overall green growth and sustainable development agenda. Malaysia has in place an institutional framework, policies and regulations, fiscal instrument, promotion, industry & public awareness, certification and human capital development to further develop green technology locally.

Under the National Green Technology Policy, the cross-sectoral green technology focuses on four sectors namely energy, building, waste management and transportation (MIDA, 2017). Green technology is already a significant part of Malaysia's economy (it contributed RM7.9 billion or 0.8% of GDP in 2013), but the country has much larger goals in mind. By 2030, the country aims to have a green technology sector contributing RM60 billion to the GDP, with an interim target of RM22 billion in 2020. The National Green Technology Policy that was launched in 2009 sets out a framework for advancing green technology initiatives. Several initiatives in the form of awareness, tax exception and roadmaps have been initiated to achieve these targets and establish Malaysia as a green technology hub in the ASEAN region by 2030. Malaysian Green Technology Corporation (GreenTech Malaysia), a company limited by guarantee (CLBG) under the purview of the Ministry of Energy, Green Technology and Water (KeTTHA) is charged with catalysing green technology deployment as a strategic engine for socio-economic growth in Malaysia in line with the National Green Technology Policy.

Malaysia has been actively investing in green technology since 2009. The National Green Technology policy has made provisions for financial packages to assist with the commercialisation of new technologies and sets out incentives for students embarking on green technology related subjects (OECD Investment Policy Reviews: Malaysia 2013). An increasing trend of R&D as the percentage of revenue for Malaysia is also seen from 4% in 2007 to 6 % in 2009 (Frost & Sullivan). A projection by Green Tech Malaysia stated that Malaysia's R&D spending of green technology is expected to be around RM3,066 million by 2025.

Recognising the importance of green jobs, the Skills Development Department under the Ministry of Human Resources (MoHR) with the co-operation of the KeTTHA developed the National Occupational Skills Standards, National Competency Standards and Occupational Analysis for jobs in green technology sector (OECD, 2013) in 2010.

Some of the policies, initiatives and organisations that are related to the national green technology sector are shown in Figure 4.13.

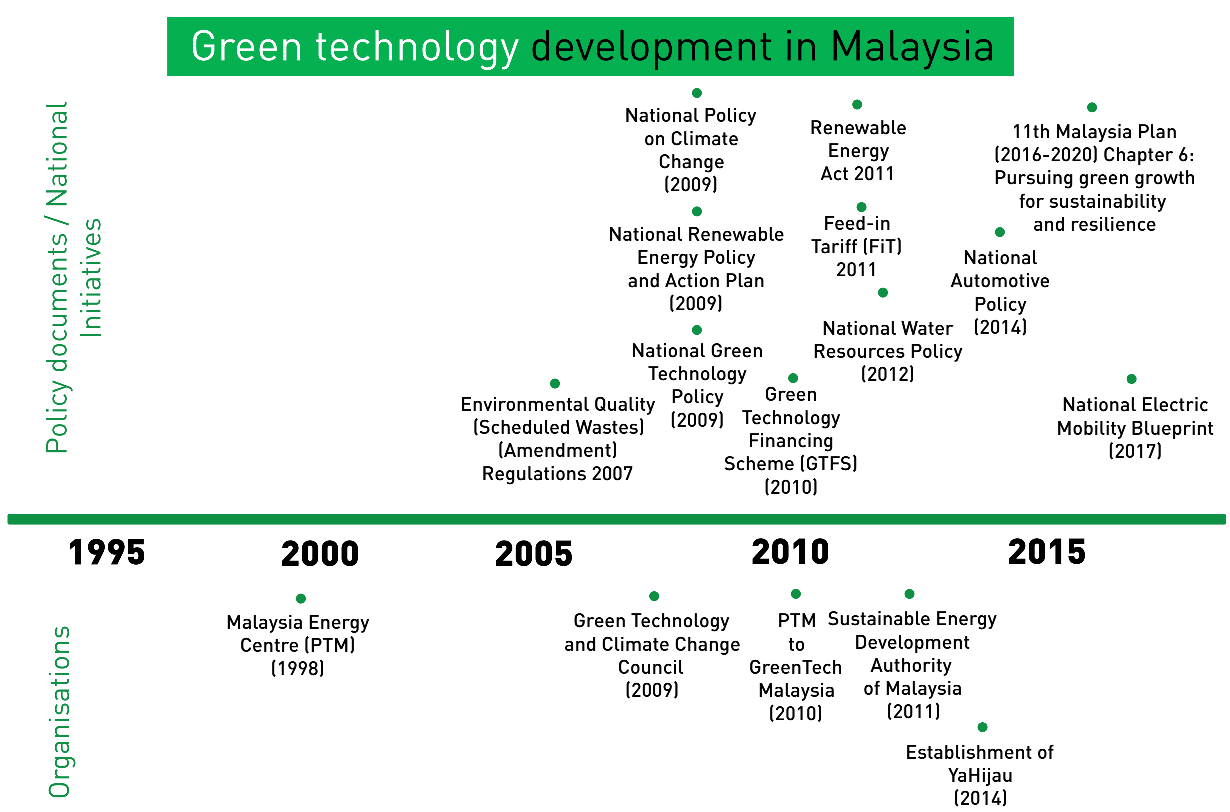


Figure 4.13: Green technology development in Malaysia (Source: compiled by ASM)

Nanotechnology

Nanotechnology offers rapid advances across many areas of science and engineering crucial to society. As of August 2017, there is neither a policy on nanotechnology in Malaysia nor legal framework. However, many initiatives on developing nanotechnology in Malaysia have taken place. In Malaysia's Third Industrial Master Plan (2005-2020), nanotechnology was recognised as the emerging field that can potentially generate technologies in a broad range of fields such as health, education, information technology, creation and usage of energy, biotechnology, defence, food and agriculture, aerospace, manufacturing and environmental rehabilitation. In 2010, the National Nanotechnology Directorate (NND) was established under MOSTI as a central coordination agency in Malaysia. NND serves as the National Focal Point for the coordination of research, development and all related activities of nanotechnology in Malaysia.

NanoMalaysia Berhad was incorporated in 2011 as a CLBG under the umbrella of MOSTI and acts as a business entity entrusted with nanotechnology commercialisation activities. NanoMalaysia has identified four jump start sectors namely electronic devices and system; energy and environment, food and agriculture; and healthcare, medicine and wellness and started its activities with an aim to increase Nanotechnology contribution to Malaysia's gross national income by RM15 billion to RM17 billion by 2020, which is about 1% of GNI. The establishment of the Centre of Excellence (NanoCoE) involved in nanotechnology R&D in Malaysia under the NanoMalaysia Programme reiterates the commitment to develop Nanotechnology in Malaysia. Examples of such CoEs include Institute of Microengineering and Nanotechnology at UKM, Centre of Innovative Nanostructures and Nanodevices at Universiti Teknologi Petronas (UTP), Institute of Nano Electronic Engineering (INEE) at Unimap, Razak School of Engineering and Advanced Technology Institut Ibnu Sina (IIS), Universiti Teknologi Malaysia (UTM) and Institute of Advanced Technology (ITMA), UPM. There are also many educational and research programmes in nanotechnology being offered by Malaysia's universities. NanoMalaysia Berhad also provides organisations and individuals with the technical and management skills needed to enhance future success in the nanotechnology industry.

Some of the policies, initiatives and organisations that are related to the national nanotechnology sector are shown in Figure 4.14.

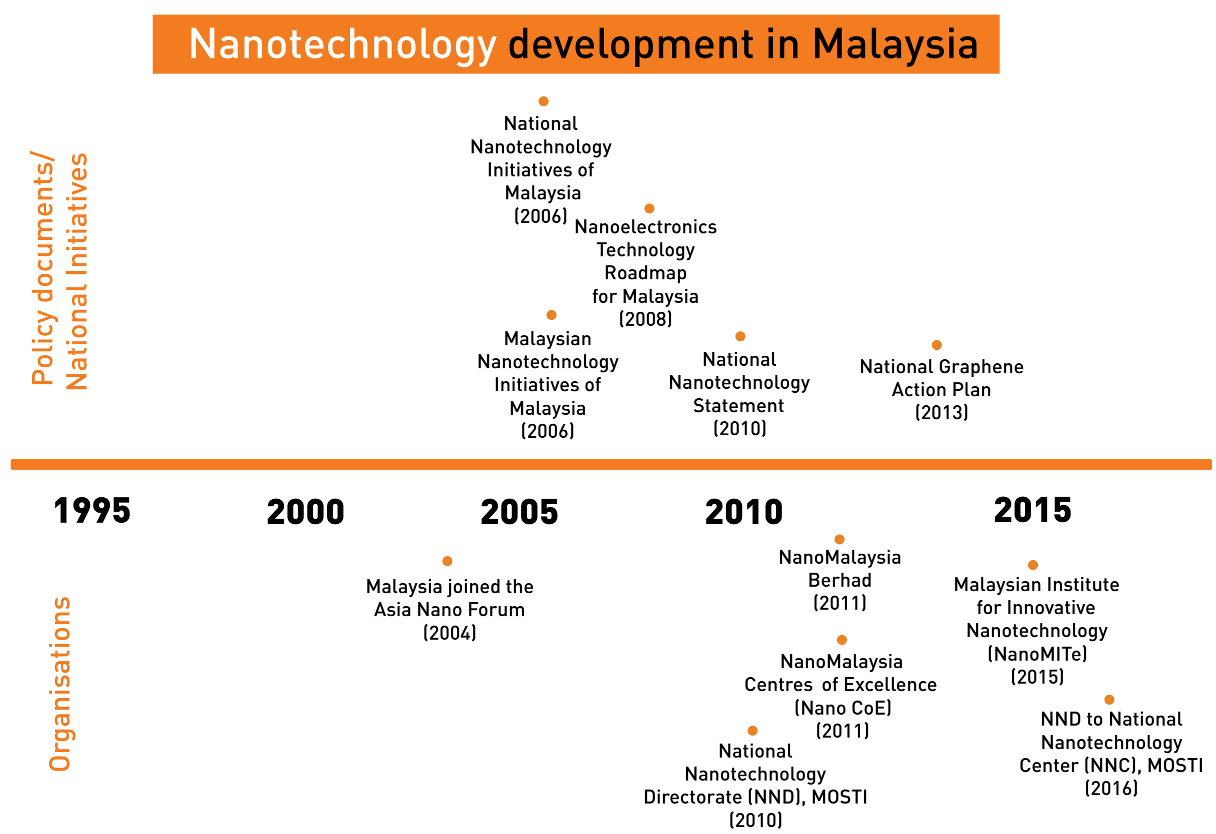


Figure 4.14: Nanotechnology development in Malaysia (Source: compiled by ASM)

NANOTECHNOLOGY-RELATED ORGANISATIONS IN SEVERAL COUNTRIES

Malaysia

NanoMalaysia Berhad

Incorporated in 2011, NanoMalaysia Berhad is a company limited by guarantee (CLBG) under the MOSTI to act as a business entity entrusted with nanotechnology commercialisation activities. Some of its roles include:

- Commercialisation of Nanotechnology Research and Development
- Industrialisation of Nanotechnology
- Facilitation of Investments in Nanotechnology
- Human Capital Development in Nanotechnology

Thailand

National Nanotechnology Center (NANOTEC)

NANOTEC is a research agency established in 2003 operating under the jurisdiction of the National Science and Technology Development Agency (NSTDA) and the Ministry of Science and Technology (MOST).

NANOTEC has the dual role of serving as a national R&D centre and a funding agency to support research activities in universities and public institutions. NANOTEC is also obligated to promoting understanding and awareness of nanosafety both within NANOTEC and the general public.

One of the major goals of NANOTEC is to be a "solution provider in nanotechnology", therefore a high percentage of the nanotechnology research is focused on industrial applications.

Japan

Nanotechnology Business Creation Initiative (NBCI)

Founded in 2003, NBCI is an industry-driven organisation run on annual-membership-fees.

NCBI mission:

- To create and advance business utilising nanotechnology
- To promote collaboration among different industry fields, among big enterprises and small-medium companies, among industries, academia and government
- To exchange up-to-date information of nano-related businesses

As of 2014, NBCI consists of around 180 industrial members and possess relationships with over 6,000 manufacturers in greater Tokyo, Central Japan, and Western Japan.

It is observed that the development of nanotechnology in several countries such as Russia and China involves a vital role by a dedicated corporation set up for this purpose. However, the role of oversight and national level coordination, as well as facilitation of different actors in the ecosystem, is effectively carried out by a government entity or directorate responsible for the development of the technology area. The corporation focuses on the industry development aspect. In China, the National Steering Committee for Nanoscience and Nanotechnology (NSCNN) chaired by the Minister of MOST was established in 2000 to coordinate and streamline all national research activities related to nanotechnology. As for Russia, the Ministry of Education and Science that is a federal state body is responsible for the public policy and legal regulation in the sphere of education, science, technology and innovation, nanotechnology, and intellectual property.

Iran

Iran Nanotechnology Initiative Council (INIC)

Established in 2003, INIC developed the first 10-year national nanotechnology initiative plan which was approved by the government in 2005. INIC was then tasked to determine general policies for the development of nanotechnology in the country.

INIC tasks are as follows:

- Approving goals, strategies, macro-scale policies and national initiatives for development of the nanotechnology in the country
- Description of the general tasks for governmental bodies and determination of missions for each sector and make coordination among them within the framework of a long-term national plan
- Supreme supervision in realisation of goals and programs

INIC is not only responsible for policy making in this field but also supporting, supervising and evaluating the activities, and outcomes as well.

China

Suzhou Nanotech, Nanopolis

Suzhou has been designated by the Ministry of Science and Technology (MOST) as the 'China Nanotech International Innovation Cluster'.

Suzhou Industrial Park (SIP) launched the 'Nanopolis Suzhou' initiative to provide a complete ecosystem support for the growth of nanotechnology and its enabling industries. Areas of focus include micro and nano-manufacturing technologies, energy and green technologies and nano-medicine.

As of 2015, there are 352 nanotech-related companies (6 public listed) and 22,000 skilled workers that include scientists, engineers, and technical staffs.

Russia

RUSNANO Group

For the purposes of promoting the national policy in the nanotechnology sector, the State Corporation "The Russian Corporation of Nanotechnologies" was established in 2007 and its reorganisation in 2011 resulted in the establishment of an Open Joint-Stock Company "RUSNANO" and the Fund for Infrastructure and Educational Programs (FIEP).

RUSNANO supports the implementation of state policy for the development of the nanotechnology industry by investing directly and through nanotechnology funds in financially efficient high-tech projects, facilitating the development of new industries in Russia.

The task of FIEP is to create innovative infrastructure for the nanotechnology industry, including the development of educational and infrastructure programs, which were initiated by RUSNANO.

RUSNANO and FIEP (known as RUSNANO Group) work closely together to achieve common objectives related to improving the competitiveness and effectiveness of the Russian nanotechnology industry.

Neurotechnology

Presently in Malaysia, we have limited capacity building focusing on neurotechnology even though there are traces to the early days of fundamental and clinical neurosciences in Malaysia, prior to independence. Various educational and research programmes in neuroscience have been offered by different universities in Malaysia leading to an increase in the number of neuroscientists in the past years signifying the growing needs of the community to address various issues related to the brain. At least 10 cognitive neuroscientists per 100,000 labour force workers must be produced by 2025 for Malaysia to enter the 4th Industrial Revolution (Putra S, Zamzuri I, Jafri Malin A., 2017).

Neuroscience research in Malaysia emphasises on the treatment of neurological disorders rather than initiatives on preventive care as well as educational research that improves lifestyle and general awareness and attitude towards the devastating effects of neurological disorders (IBRO, 2017). As of August 2017, there is neither a policy on neurotechnology in Malaysia nor legal framework. However, there are isolated pools of research from interested groups of scientists and engineers in universities or research institutes.

Some of the policies, initiatives and organisations that are related to the national neurotechnology sector are shown in Figure 4.15.

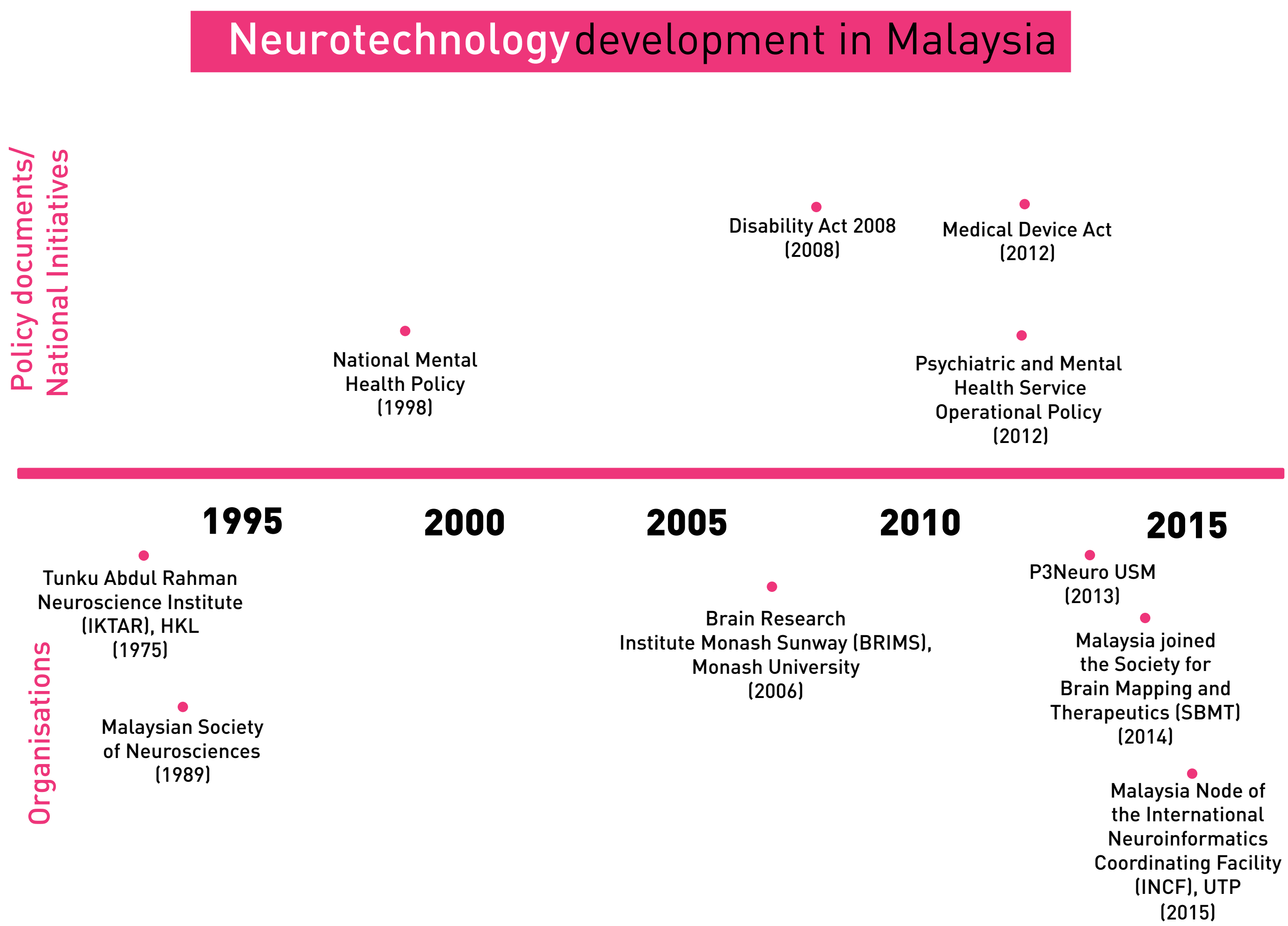


Figure 4.15: Neurotechnology development in Malaysia (**Source:** compiled by ASM)

In Malaysia, it is observed that corporations such as the Bioeconomy Corporation, MDEC, GreenTech Malaysia and NanoMalaysia Berhad were formed to spearhead industry development related to respective technology areas. If the intention behind this move was to draw and increase private sector participation in the development of respective technology areas, it is aligned to initiatives by several other nations. However, this should not negate the role of a national directorate at the relevant central agency of the government or relevant ministry that oversees the holistic national development of the technology area including strategic planning, national roadmap, talent development, resource allocation, etc. The respective corporations cannot be expected to undertake this national oversight and coordination role even if in part as observed in some instances.

Emerging technologies, if harnessed and utilised positively and effectively, offer great promise to bring about economic transformation and enhancement of different social aspects such as people's lifestyle, health, education etc. leading to a higher quality of life. This requires a comprehensive policy framework that strategically charts the development of a technology area in tandem with national needs and envisaged outcomes. One of the main challenges is that science and technology inputs and interventions are often seen as a prelude to policy development or a support for decision making, but not part of the whole value chain of policy implementation towards meeting targets.

In endeavouring to ensure that the nation is innovative, productive and competitive, Malaysia should not limit their focus to just emerging technology areas that offer the promise of quick wins or low-hanging fruits to resolve issues of today. We need to have an eye on the horizon and prepare for future demands today. There is a need to adopt a long-term outlook with development plans for the long haul in a sustained manner.

A case in point is that the United Nations Department of Economics and Social Affairs has projected that Malaysia will become an ageing nation by 2030. The OECD Horizon Scan of Megatrends and Technology Trends Report (2016) has highlighted that the ageing phenomena will dictate the types of innovations society demands in the future. Technological innovations are expected to transform the lives of the ageing population, extending their meaningful participation and contribution to society. As such, we should be thinking about the products or services required by an ageing population and how it would shape today's S&T agenda towards meeting future needs. Likewise, in many economic and societal aspects, we must consider global trends and risks and identify areas of impact to Malaysia and respond proactively.

4.4

Implication of Emerging Technology Development

Emerging technologies would have wide-ranging implications for individuals, society and the nation. Some level of risks and uncertainties that come with emerging technologies are also inevitable. As Malaysia advances in STI, implications to society and the environment also escalate. In this context, three national societal challenges that have emerged are highlighted as follows:

Waste Generation and Disposal by Malaysians

According to the Solid Waste Corporation Management, a government agency dealing with solid waste, in 2016, Malaysians generated about 38,000 tonnes of solid waste per day which includes household, industrial, commercial and institutional waste. By the year 2020, 49,670 tonnes of waste per day is expected to be generated by Malaysians. The amount of waste generated continues to rise due to increasing population and development and more importantly, less than 5% of the waste is being recycled.

As more Malaysians become more affluent and digitally literate, electrical and electronic waste that comes from household, commercial, institutional and other sources which are referred to as household e-waste also is also increasing rapidly. According to the Ministry of Natural Resources and Environment (NRE), due to the fact that household e-wastes mostly end up in the informal sector, there is no proper data captured by relevant authorities on the actual quantity of household e-waste generation in Malaysia. Based on a published project report on inventory of e-waste in Malaysia funded by the Ministry of Environment Japan (MOEJ), the projection of the total amount of discarded e-waste would increase by an average of 14% annually in Malaysia and by 2020, a total of 1.17 billion units or 21.38 million tons of e-waste will be generated. Televisions and mobile phones are among the largest contributors of e-waste in terms of volume and units.

Department of Environment, NRE describes Household E-waste as electrical and electronic waste that comes from household, commercial, institutional and other sources which because of its nature is similar to that from households. Examples of household e-waste are washing machine, refrigerator, air-conditioner, television, computer and hand phone. Other small household electrical and electronic appliances such as hair dryer, printer, oven, blender etc. are also categorized as household e-waste upon the end of its life.

Health Issues of Malaysians

As Malaysia's socio-economic transformation influences the well-being of citizens, the average lifespan of Malaysians increased from 50 years of age in the 1950s to the present age of 75. Technology and a sedentary lifestyle among other factors may have contributed to lack of physical activity.

The National Health and Morbidity Survey 2015 unveiled an alarming concern regarding the number of Malaysians suffering from non-communicable diseases (NCD) such as high cholesterol levels, diabetes and overweight. Out of 31 million Malaysians, 3.5 million have diabetes, 9.6 million people aged above 18 have high cholesterol levels, 3.3 million Malaysians are obese and 5.6 million are overweight. The Department of Statistics Malaysia revealed that Malaysia's senior citizens (aged 65 and above) would make up around 14.5% of the population in 2040 compared to 6.2% in 2017 (DOSM, 2017). This raises the possibility of an increase in the burden of disease.

The government has started to take steps to face the upcoming challenge of an ageing population including ensuring adequate healthcare services, financials as well as infrastructure that are senior-citizen friendly.

Narrowing Digital Divide and Improving Digital Literacy

According to the Internet Users Survey 2016 (MCMC, 2016), the number of Internet users in 2015 was approximately 24.1 million or 77.6% of all inhabitants in Malaysia. The survey also found that the ratio of urban Internet users against rural Internet users in Malaysia was around 60:40.
In 2015, among the popular Internet activities by Malaysian internet users were participating in social networks, getting information about goods and services, downloading images, movies, videos or music; playing or downloading games and sending or receiving e-mails (DOSM, 2016). Malaysian internet users penetration into the news, financial services, retail, and other potentially high-value activities remains comparatively low (McKinsey, 2012).

An advanced broadband infrastructure will enable Malaysian scientific community to elevate national and international collaboration to a much higher level. It will also assist small and medium-scale enterprises to leverage on the creative use of information and knowledge to innovate. Key development challenges that policymakers and development practitioners are faced with is the need to bridge the digital divide, in particular between urban and rural populations. Despite many efforts, rural communities still lack quality infrastructure, such as roads, health amenities, education facilities, housing and sanitation, including broadband (ASM, 2013).

In rural areas of Malaysia, development challenges are further exacerbated by the lack of access to affordable information and communication technology services including quality broadband (Nair, 2011). Due to poor connectivity, connectedness and networking among the poorer rural citizens, they continue to suffer deprivation in terms of access to knowledge, skills, information, resources and markets.

ESET FOR A PROGRESSIVE MALAYSIA 2050

5.0

Scientific and technological progress continues to impact society in unprecedented ways. The fusion of the physical, digital and biological world is a hallmark of the Fourth Industrial Revolution and it is impacting all disciplines, economies and industries, and even challenging what it means to be human.

Recent years have seen the advent of innovations such as Google's driverless car, Chauffeur; IBM's Jeopardy beating computer; Watson; a programmable robot named Baxter; and detailed knowledge of the human genome that provides new avenues for advances in medicine and biotechnology. With each industrial revolution, the level of complexity in terms of the science, technology, systems, networks and interactions increase.

Mega trends such as rapid urbanisation, demographic shifts and technological breakthroughs serve as game changers that would have far-reaching impacts on individuals, society, industries and nations.

At the same time, the world is facing unparalleled risks that need to be mitigated and complex challenges that need to be tackled effectively. According to the Head of the Centre for the Fourth Industrial Revolution of the World Economic Forum, "New technologies are redefining industries, blurring traditional boundaries and creating new opportunities on a scale never seen before. As such, public and private institutions must develop the correct policies, protocols and collaborations to allow such innovation to build a better future, while avoiding the risks that unchecked technological change could pose."

ASM envision a Progressive Malaysia 2050 that is harmonious, prosperous and sustainable. There is a compelling case to identify the emerging science, engineering and technology that can shape such a Malaysia. We must also consider the purposive and strategic action that must be taken today to realise our future aspiration.

This chapter elucidates the outputs of this study and offers insights on the possible interplay of emerging technologies in the five technology areas (Biotechnology, Digital Technology, Green Technology, Nanotechnology and Neurotechnology) towards a Progressive Malaysia 2050 through STI that is harmonious, prosperous and sustainable.

This study provides 3 landmark outputs:

i. A list of 284 products, services, technologies, possible applications and outcomes relevant to Malaysia towards 2050, (Appendix 2)

ii. Malaysia's Emerging Technology Timeline towards 2050 that showcases 95 emerging technologies and their interlinkages based on Malaysia's strengths and needs. This timeline depicts the 95 emerging technologies for Malaysia in three phases: present (2015-2020), probable future (2021-2035) and possible future (2036-2050).

iii. 21 Impactful Emerging Technologies towards realising Progressive Malaysia 2050 that are prioritised based on feasibility and attractiveness in Malaysia's context guided by global trends and global risks.

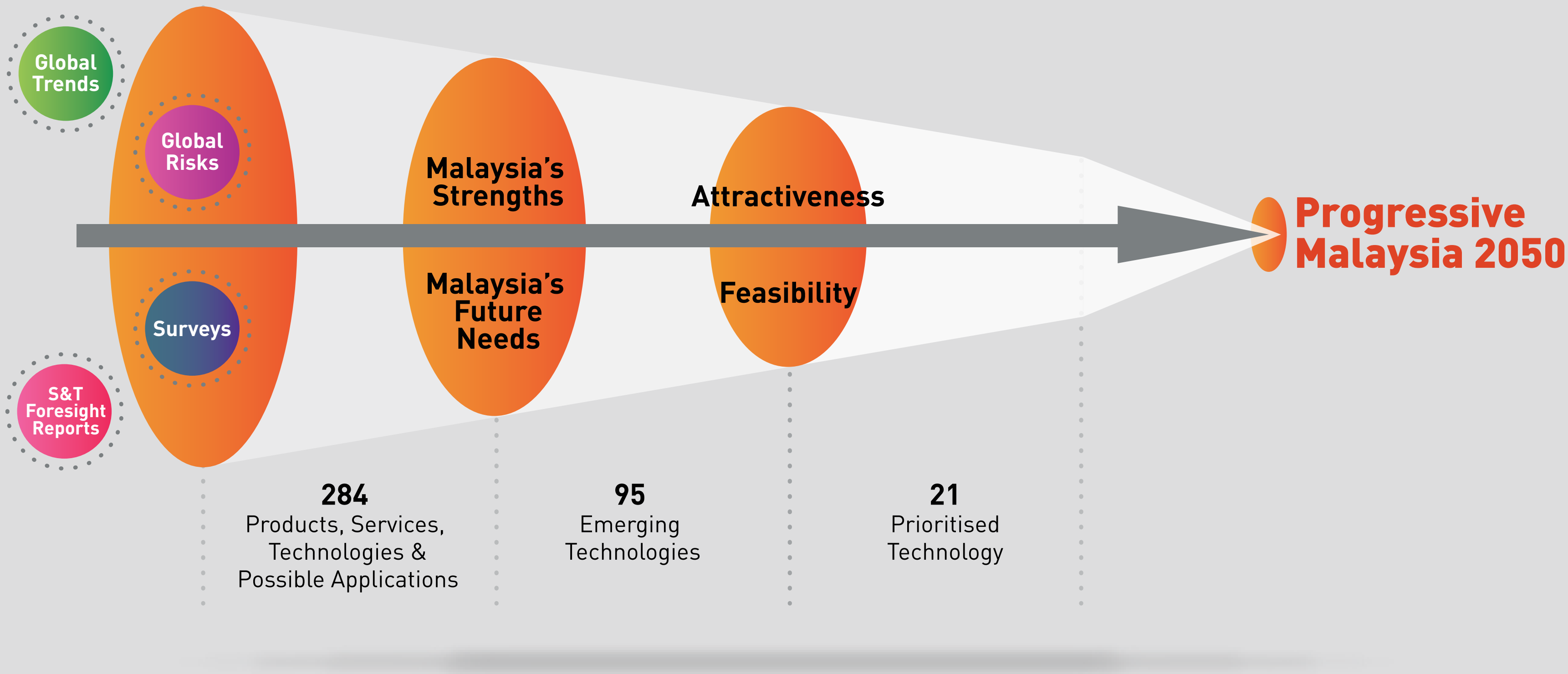


Figure 5.1: Three landmark outputs from ESET study

5.1 Products, Services, Platforms, Technologies Relevant to Malaysia Towards 2050

As we chart Malaysia's STI advancement towards 2050, ascertaining products, services, platforms and technologies required for applications and outcomes that are envisaged is imperative. This would serve as a first step towards identifying emerging technologies that hold greatest promise to shape a Progressive Malaysia 2050.

From the five technology area reports, a list of 284 products, services, platforms and technologies (refer Appendix 2) and their possible applications to realise envisaged outcomes for Malaysia towards 2050 were identified through horizon scanning, surveys and stakeholder engagements. Subsequently the list was mapped to Malaysia's current strengths and future needs in STI through a 'selection of emerging technologies' exercise. Through this exercise, 95 emerging technologies that are relevant towards ensuring a harmonious, prosperous and sustainable Malaysia were identified (Appendix 3). The 95 identified emerging technologies and their interlinkages or convergences are mapped to form Malaysia's Emerging Technologies Timeline from present until 2050.

5.2

Malaysia's Emerging Technologies Timeline

A technology timeline for Malaysia based on 95 emerging technologies identified from within the five technology areas (Biotechnology, Digital Technology, Green Technology, Nanotechnology and Neurotechnology) has been developed under this study as shown in Figure 5.2. The Emerging Technology Timeline for Malaysia is categorised into three phases: present (2015-2020), probable future (2021-2035) and possible future (2036-2050). The 95 emerging technologies relevant to Malaysia were identified based on Malaysia's strengths and future needs.

As technology accelerates and gains computational power, technology convergence and complexity also increases with many possible applications in various fields. Emerging technologies are often dependent on other technologies for their future development and exploitation (OECD, 2016). This spurs technology convergence that has a profound impact on research activities in laboratories and companies, talent development, institutional framework for R&D as well as resource allocation.

The technology timeline also reinforces that as we move towards the future, more and more technology convergence would occur. Even today, technological advances are increasingly attributed to multi-disciplinary platforms. For example, nanomaterials based sensors that enhance sensitivity and specificity are already being combined with digital technology to gives rise to nanoscale environmental surveillance in the form of dust sized particles also known as smart dust networks. Further into the future, somewhere in the 2036-2050 time horizon, 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 systems.

Another example shown in the technology timeline is the convergence of neurotechnology with digital technology. Cognitive neuroscience and neuroimaging of the active brain area is crucial for a better understanding of the human brain. This will positively impact healthcare particularly from a preventive healthcare perspective as it would be very useful for monitoring the progression of brain-related diseases like dementia and epilepsy.

Although R&D advances in cognitive neurosciences and neuroimaging are presently available, the ability to read specific thoughts through brainwave technology is not expected to manifest until the year 2036-2050. When it does, it could lead to applications such as brain fingerprinting. However, this can also be controversial as there are concerns about brain fingerprinting and its use in court by the FBI (Farwell et al., 2013).

With rapid advances in computer science and artificial intelligence, computers are increasingly able to simulate a wide variety of human behaviours and cognitive functions. For this reason, deep learning neural networks with artificial intelligence is being researched for future industry applications.

The exponential expansion of cyberspace and the value of using it have triggered escalating exposure to cyber threats. The growth and pervasiveness of network-ready technologies such as Internet of Things (IoT) and Artificial Intelligence (AI) are poised to fuel disruption at an accelerated pace globally. The fabric of society, data, devices and analytics have created an ecosystem rich in information, mechanisms and tools that have widely impacted the way people live and work. This new ecosystem has simultaneously widened and deepened the risks of security and privacy, demanding the need to strengthen cyber security and safety. Towards 2050, the convergence of digital technology and neurotechnology is expected to present alternative solutions such as mind reading technology for security and enforcement from a pre-emptive standpoint.

The examples above show that the technology development trend is inclined towards greater convergence, complexity and wide-ranging, versatile applications. The Emerging Technology Timeline would serve as a useful reference for Malaysia to chart its STI agenda towards 2050 to be prepared for futures needs and demands.

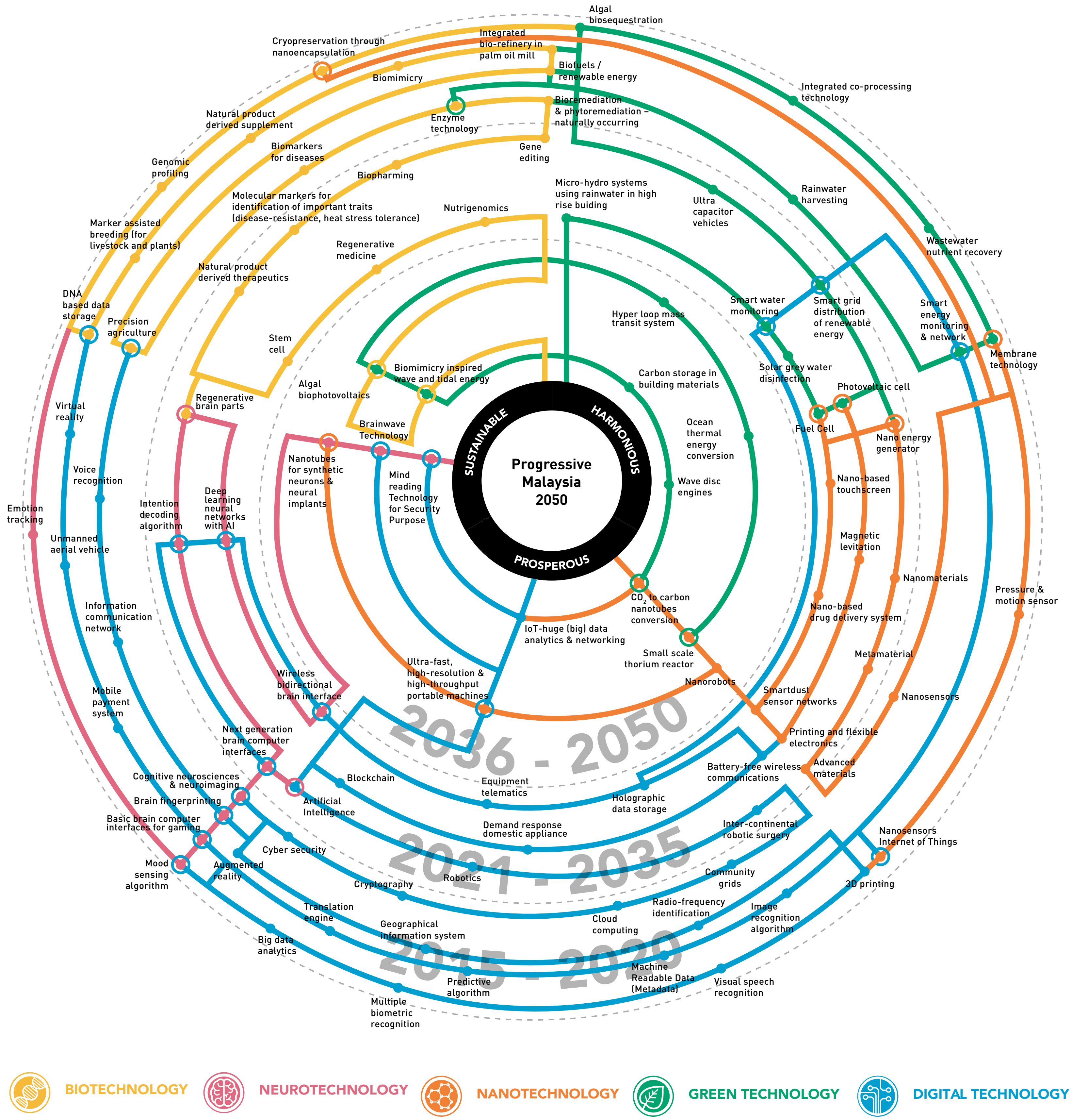


Figure 5.2: Malaysia's Emerging Technology Timeline towards 2050.

5.3

A Snapshot of Progressive Malaysia 2050 Driven by STI

Futurists observe that the fusion of the physical, cyber and biological world will result in greater convergence of four key technology areas: *nanotechnology*, *biotechnology*, *digital technology (ICT)* and *neurotechnology (cognotechnology)* as shown in Figure 5.3. Green technology would be crucial in mitigating impact on the environment in the face of rapid technological advancement.

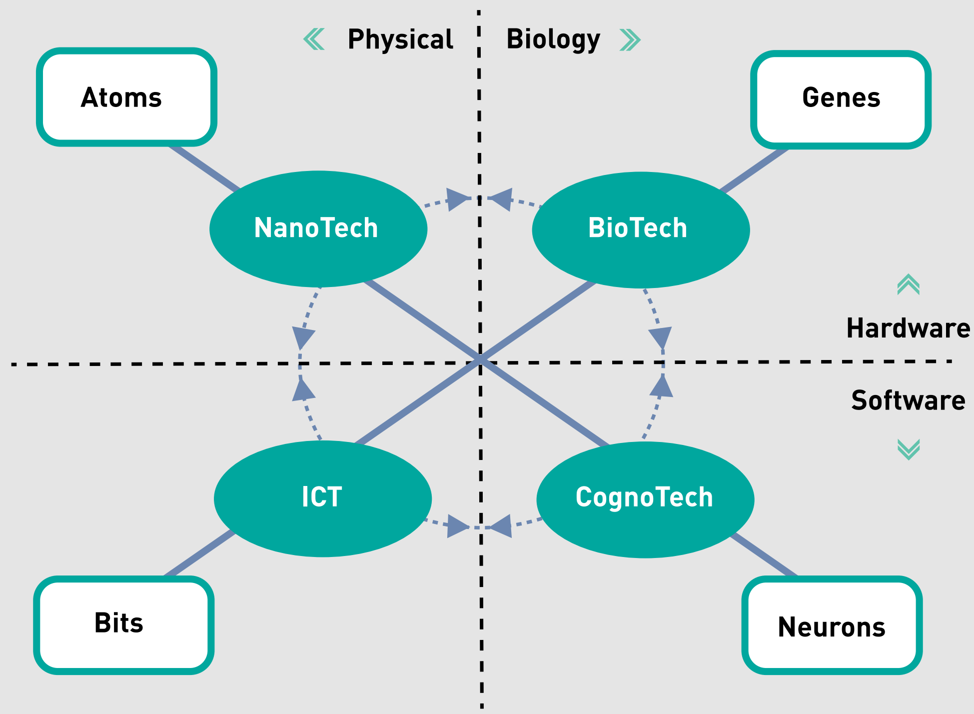


Figure 5.3: Convergence of nanotechnology, biotechnology, digital technology and neurotechnology (**Source:** David Wood, 2015).

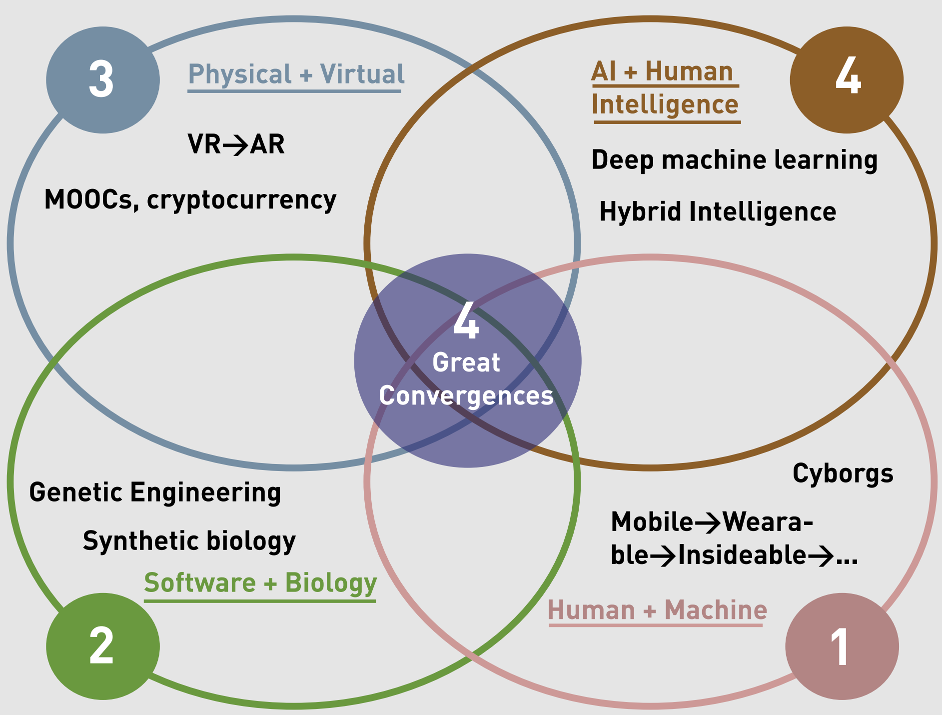
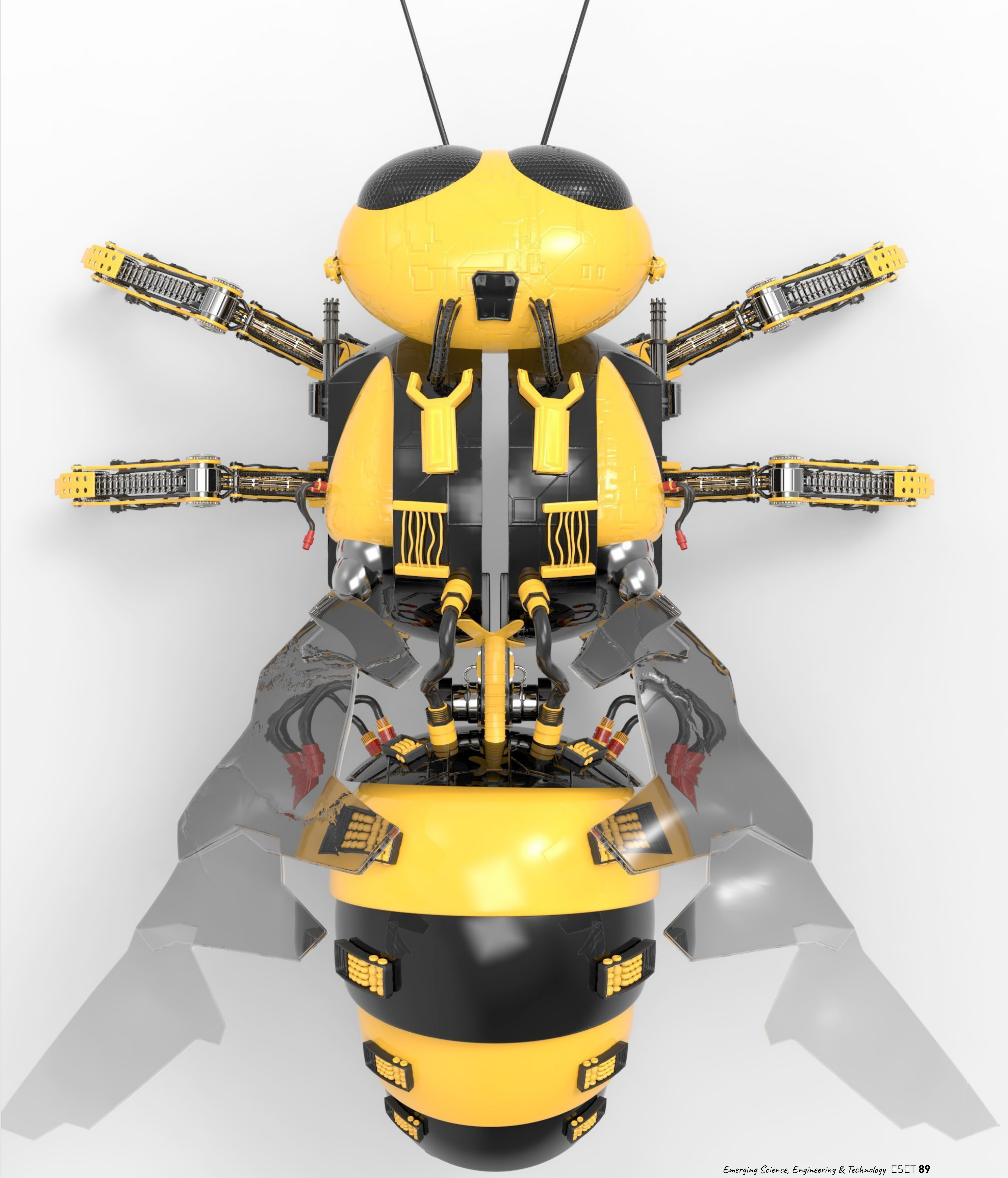


Figure 5.4: Four great convergences postulated by Futurist David Wood (**Source:** David Wood, 2015)

These developments will amplify the interlinkages between humans and machines, software and biology, physical and virtual worlds as well as artificial intelligence and human intelligence, respectively (Figure 5.4). The main driver of such convergences is grand societal challenges that demand integrated solutions. Each of the five technology areas plays a significant role in shaping a harmonious, prosperous and sustainable Malaysia towards 2050.



5.4

Reimagining the Future: Key Aspects of Progressive Malaysia 2050 through STI

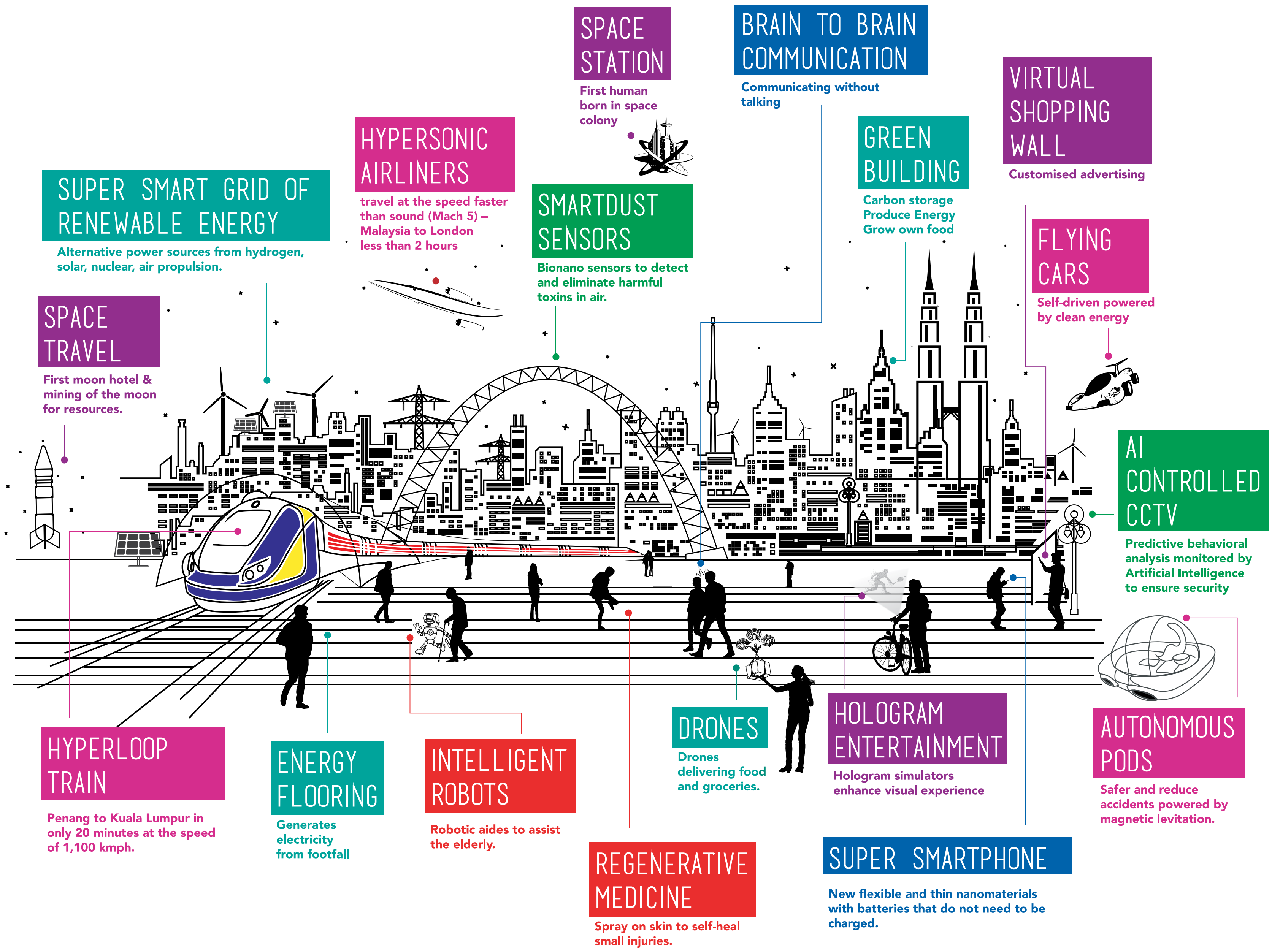


Figure 5.5: A snapshot of Progressive Malaysia 2050 driven by STI.
(**Source:** ASM, 2017)

Water-Food-Energy Security

- Malaysia is self-sustaining in terms of water, food and energy.
- Energy will be generated from renewable energy sources such as solar, nuclear, OTEC, hydro and fuel cell supplied and monitored across the country through a super smart grid of renewable energy.
- Energy will also be generated through pedestrian walkways equipped with energy flooring whereby footsteps will generate electricity through an electromechanical system which will be supplied to the nearest power grid.
- Green buildings are designed with the aim to reduce overall impact on environment and human health through efficient use of energy, water and minimal waste production.
- Buildings will be powered by energy harvested from solar panelled rooftops; micro-hydro systems provide catchment of rainwater in high rise buildings, carbon emission will be captured and stored in building materials; vertical farming make it possible for growing our own food inside buildings.
- Food can be bought directly from farms and groceries from retailers; these can be delivered by drones to our doorstep. This service will not only be limited to urban areas as digital connectivity has been expanded throughout Malaysia; deliveries to rural areas are possible.

Well-being of Malaysians

- As a scientifically literate society, Malaysians will lead a healthier lifestyle.
- Health will be monitored through wearable technology connected to a national healthcare database that collates and monitors health data of every Malaysian.
- Ageing population (above 60 years of age) will still contribute proactively to Malaysia's development. Advancement in medicine enables tissues and organs damaged due to ageing, diseases or trauma to be regenerated and healed through affordable regenerative medicine.
- Senior citizens are able to live independently thanks to the smart home concept and services available in an area are interconnected through an app.
- Senior citizens who have mobility issues can utilise affordable intelligent robots to assist in their daily lives.

Mobility

- Travelling to other countries and states will be faster with advancement in the transportation sector.
- Travel from Malaysia to London will take less than 2 hours with hypersonic airliners flying at above Mach 5 (five times the speed of sound about 3,800 mph or 6,100km/h) speed (Purch, 2017).
- Travel from Penang to Kuala Lumpur in only 20 minutes at the speed of 1,100 km/h using hyperloop mass transit system, a high-speed train system which enables faster commutes between states.
- Faster transportation system in urban area will spread population evenly throughout Malaysia and most business activities will no longer be concentrated in certain cities only.
- Autonomous flying cars powered by renewable energy will be an alternative option for private cars in 2050.
- For short distance travel, driverless low speed vehicles known as autonomous pods will be an ideal option as it is designed to navigate through pedestrian areas while ensuring the safety of passengers, pedestrians, road users and other vehicles with the aid of sophisticated 3D-imaging systems and sensors located in the pod.

Environment and Security

- Malaysia will experience minimal effect from climate change thanks to our proactive initiatives such as zero carbon emission programmes, recycling waste, smart planning of land usage and forestry.
- Real-time surveillance of the environment and surroundings (such as weather, business activities and security) through 'dust size' particle sensors connected to computer systems and wireless radios. This enables real time observation and on what is going on in an area.
- Artificial intelligence will enhance CCTV monitoring; images from video surveillance cameras are analysed and predictive behavioural analysis will be applied for crime prevention.

Connectivity

- Technology enables full spectrum of connectivity among people made possible through 100% internet accessibility, affordability and availability in Malaysia by 2050,
- Every Malaysian will be digitally connected through smartphone, tablets, etc.
- The next generation of super smartphones would be affordable, flexible due to single layered nanomaterials, do not require batteries to be charged and easy to use.
- Overcome communication barrier in multi-cultural and multi-ethnic Malaysian through brain to brain communication that allows information between two people to be exchanged through reading of one's thoughts.This technology may also benefit people who are not able to speak and no longer need sign language or devices to communicate.

Leisure

- Advancement in technology brings new experience for leisure activities.
- In entertainment industry, hologram simulators enhance viewer's visual experience or shopping through virtual shopping wall that allows customisation of one's purchase according to preference.
- In 2050, travelling to space for recreational purpose would be possible as humans would be able to inhabit other planets.

5.5
Technology Prioritisation

Technology can contribute to a nation's harmony, prosperity and sustainability in many ways. Due to limited resources for R&D even in developed countries, neither government nor industry can afford to invest in every known technology. To have a clear direction on R&D investment and setting of research priority areas, a number of nations have initiated foresight exercises aimed at identifying national critical technologies (UNIDO Technology Foresight Manual, 2005).

In order to ensure that Malaysia is harmonious, prosperous and sustainable towards 2050, future needs and envisaged outcomes must be anticipated for us to prioritise, adopt and adapt relevant emerging technologies.

In most S&T foresight exercises, technologies are ranked based on two characteristics: attractiveness and feasibility. The attractiveness of the technology is determined by its potential socio-economic benefits as well as scientific and technological opportunities it could provide. On the other hand, the feasibility of technology is identified in terms of research and technology potential and the societal ability to effectively utilise new technology.

A technology prioritisation survey among experts in related technology areas in Malaysia was carried out from October to December 2016 (Appendix 4). From this survey, 446 responses were received and 71 emerging technologies from the five technology areas were selected by respondents and assessed on attractiveness and feasibility as well as current status of the emerging technologies in Malaysia. These responses were analysed and the two parameters for each technology were compiled and graphically represented in a two-dimensional graph (attractiveness-feasibility matrix) ranking emerging technologies for each technology area as illustrated in Appendix 5.

A RANKING OF TOP FIVE EMERGING TECHNOLOGIES BY AREA

BIOTECHNOLOGY

1. Enzyme technology
2. Biopharming
3. Precision agriculture
4. Biomarkers for diseases
5. Molecular markers for identification of important traits of livestock and crops

DIGITAL TECHNOLOGY

1. Big data analytics
2. Artificial intelligence
3. Cloud computing
4. IoT big data analytics and networking
5. Nanosensors IoT

GREEN TECHNOLOGY

1. Wastewater nutrient recovery
2. Ocean thermal energy conversion
3. Integrated bio-refinery in palm oil mill
4. Biofuels
5. Fuel cell

NANOTECHNOLOGY

1. Nanomaterials
2. Photovoltaic cell
3. Nanosensors IoT
4. Nano based drug delivery system
5. Fuel cell

NEUROTECHNOLOGY

1. Brain wave technology
2. Cognitive neurosciences and neuroimaging of active brain areas
3. Regenerative brain parts

The top five emerging technologies ranked in each technology area (except for neurotechnology where experts only ranked top three emerging technologies) were identified as prioritised technologies. From the 23 identified emerging technologies, two of the technologies namely fuel cell and nanosensors IoT were redundant as they were ranked in two technology areas. As such, only 21 prioritised technologies were identified as having potential applications in many sectors towards realising a Progressive Malaysia 2050.

21 impactful emerging technologies towards realising Progressive Malaysia 2050, prioritised based on feasibility and attractiveness in Malaysia's context. These emerging technologies were also determined with global trends and global risks taken into account.

21 IMPACTFUL EMERGING TECHNOLOGIES TO ELEVATE MALAYSIA'S WELL-BEING, WEALTH CREATION AND GOVERNANCE

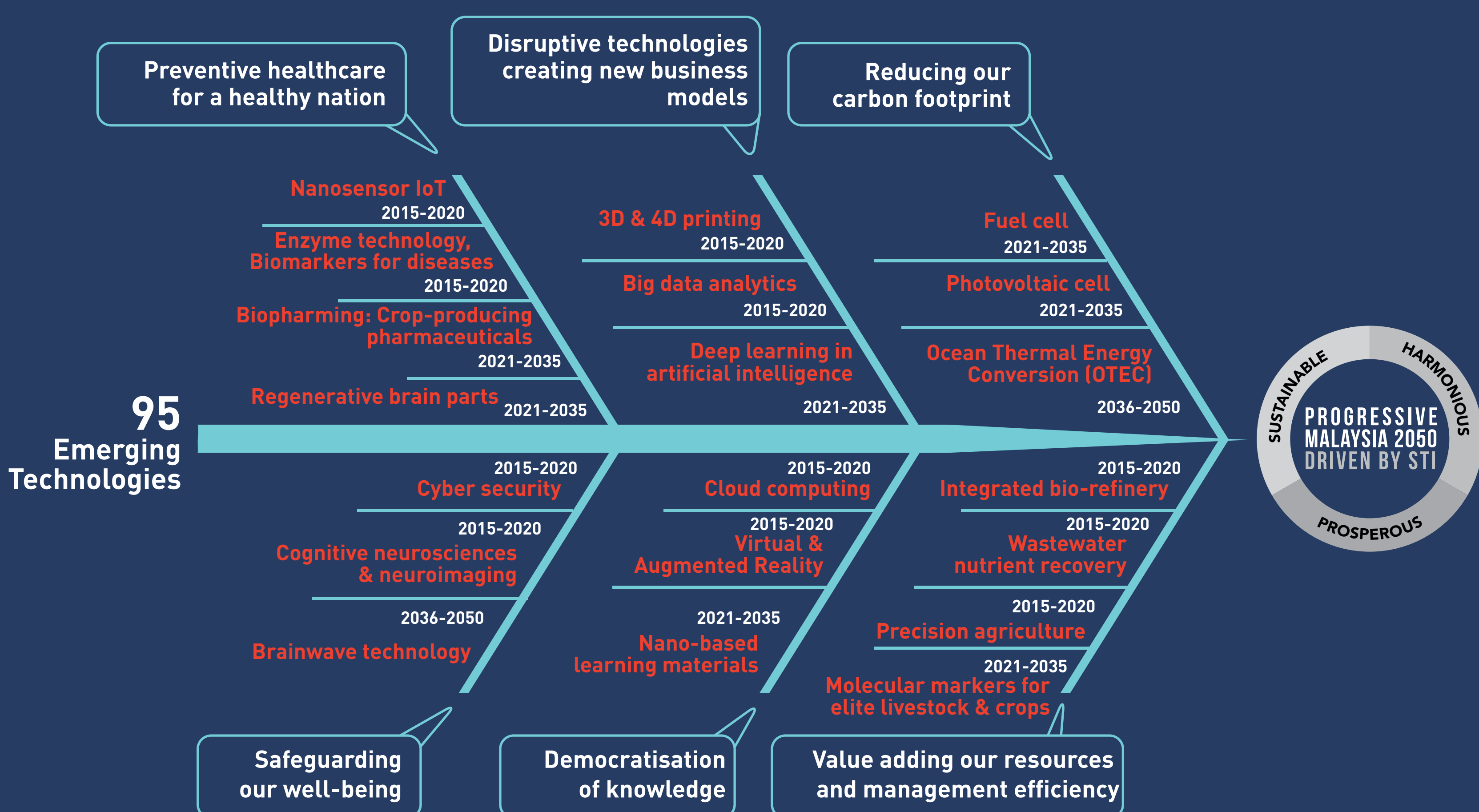


Figure 5.6: 21 Impactful Emerging Technologies towards realising Progressive Malaysia 2050.

Preventive Healthcare for a Healthy Nation

Tomorrow's technologies will be able to cure you even before you are ill

In 2050, Malaysia's population is projected to reach 42 million, with one out of five Malaysians aged 60 years old and above (The World Population Ageing, UN 2015). This silver tsunami will bring along several concerns to our healthcare system and societal well-being. Not only that, with our current lifestyle behaviours that increases our risks of non-communicable diseases (NCDs), we are indeed looking towards a very unhealthy future. However, our current healthcare system is still ill-equipped to deal with this demographic transformation.

Even today, we are seeing such worrying outcomes manifesting itself in our healthcare expenditure. According to the Ministry of Health (MOH), health spending per capita in Malaysia has increased two and half times in 17 years, from RM641 in 1997 to RM1,626 in 2014. Shockingly, healthcare spending had outpaced our economic growth, and this is mostly due to the rise in NCDs, an ageing population and technological impacts which raises concerns of economic sustainability towards meeting the increasing needs of Malaysians.

To keep Malaysians healthy and to treat them more effectively, solutions need to come from outside traditional healthcare. With the increasing dependency ratio where a smaller number of productive age group (15 – 64 years old) need to support a larger number of dependents (0 – 14 and over 65 years old), we need to ensure that Malaysians are living healthy and productive lives.

To realise this, emerging technologies that are currently being developed will enable self-monitoring solutions that will revolutionise the healthcare industry. Today, it is estimated that 73% of total deaths in Malaysia are caused by preventable NCDs; with the biggest contributor being cardiovascular diseases that include heart attacks and strokes. Even more worrying is that an estimated 35% of deaths occur in individuals aged less than 60 years, which are mainly our working population and should be 'healthy'. However, due to the lack of awareness and importance of preventive healthcare and self-monitoring of their health, we see such worrying statistics.

Nonetheless, this trend can be upturned by emerging technologies in healthcare such as the introduction of real-time health monitoring via nanosensors IoT wearables. These devices are becoming more sophisticated by the day and now go beyond tracking our footsteps. It now tracks critical activities, vital signs, medications, mental and physical state of a person on a daily basis from the comfort of their home or workplace to ensure the continuity of health professionals' care for early intervention (if needed). Such monitoring devices are becoming more common place and due to its affordability have become a necessity in maintaining a healthy lifestyle to ensure we achieve our target steps, maintain a healthy blood pressure and track calorie and sugar intake which will reduce our risks of NCDs.

Preventive healthcare goes beyond just NCDs. For the past decades, biomarkers for diseases have been applied as a diagnostic tool for certain diseases or medical conditions for humans and animals. Nowadays, a shift of application is seen towards preventing diseases even before it develops. In the coming years, a person's a genetic makeup can be sequenced in a day and analysed for genetic risks thus allowing preventative measures to be taken in order to delay the development of a particular disease to which they are predisposed. Affordable biomarker kits for diseases will be available over-the-counter thus making screening of a particular disease easier and faster as well as allowing for early intervention. This is especially important for diseases such as cancer where early diagnosis improves survival rate. Imagine one day, going into a pharmacy to get tested for cancer will be as easy, fast and affordable as getting a pregnancy test kit today.

However in today's world, many advanced technologies in healthcare and pharmaceutical products are currently too expensive and thus will have little effect on alleviating the health crisis for the bottom 40% of Malaysians for whom advanced healthcare and expensive medications are simply out of reach. If we accept that this divide cannot be bridged with advanced technology designed for the rich healthcare consumer, then we must find ways that technology can provide vastly lower-cost solutions to vastly more people. One such solution is the production of affordable pharmaceutical products through surrogate animal or plants or also known as biopharming that is cheaper and faster (Encyclopaedia of Food and Agricultural Ethics, 2014). For example, a biopharmaceutical company in North Carolina is able to produce about 10 million flu vaccines in 30 days through biopharming using tobacco plants. It is estimated that the company is able to produce about 100 million doses for as little as USD36 million, thus reducing cost of care to consumers. Another solution that is being looked at is through enzyme technology which is advancements in the biotechnology field using the 'omics'-based tools (genomics, metagenomics, protein expression and proteomics). Advances in enzyme technology could contribute to environmentally friendly solutions, less cost, shorter time frame for production of compounds and increased yields

Another rising concern in the healthcare sector today and tomorrow is the increase of neurological diseases. The number of cases is expected to rise in the next 10 years, making this the second leading cause of morbidity and mortality after heart disease in Malaysia. This has been attributed to the increase in lifespan, significant changes in lifestyle and the environment such as the increased use of food additives and chemicals as well as new technologies that emit radiation. The lack of human resources and cutting-edge treatment in Malaysia's neurological field may cause a deficiency in specialised care, especially in rural areas where neurological and neurosurgical care may be lacking. As such, by placing focus on developing locally available neurogenerative treatment, it would be possible for Malaysians with neurological disorders such as Alzheimer's, Parkinson's, multiple system atrophy and other diseases find a technological solution in the future.

It is envisioned that through the advancements of technologies in the healthcare sector and its applications to change our lifestyles, we would be able to shift from our current approach of disease treatment and reactive healthcare to preventive healthcare for a healthy Nation. This not only enables the realisation of a healthy society that will be harmonious but also its economic benefits and increase in productivity that will ensure our prosperity and sustainability as technology will make healthcare solutions more affordable, accessible and available.

Safeguarding Our Well-being

Safety and security is no longer confined to the physical world

As connectivity between machines and humans increase and real-time data is widely available, our privacy and security are at stake. According to the Global Risks Report 2017 by the World Economic Forum, massive data fraud and theft is among the top five global risks. With more Malaysians entering the virtual space, we now see personal safety no longer limited to the physical world but most certainly includes the virtual world. Many nations have recognised cyber space as the fifth dimension of national security. As we move to support more e-businesses and e-government initiatives, there is a need for Malaysia to have a strong cyber security ecosystem. It is estimated that globally, USD3 trillion will be lost in productivity and growth by 2020 as an impact of cyber threats (McKinsey Risk and Responsibility in Hyperconnected World Report, 2014). To safeguard the prosperity of our Nation and its people, emerging technologies in the cyber security sector will be able to protect our critical national information infrastructure and our cyber presence.

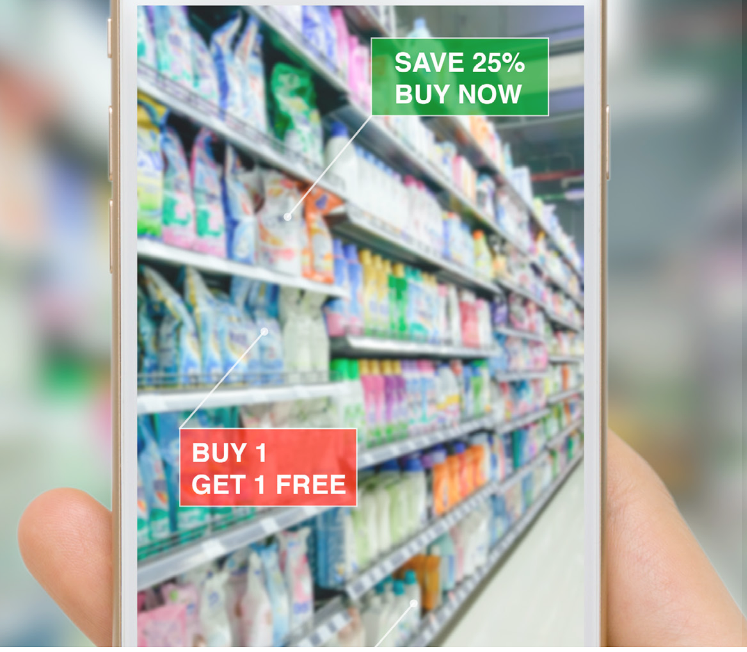
Technology today is integral to almost all aspects of our lives and most of the time it's a force for good. Yet the potential adverse consequences are spreading faster and cutting deeper. The threat to our security, privacy and the spread of fake news in social media is a threat to Malaysia's social harmony especially to its multiracial and multicultural society. Sometimes the very technology that is meant to connect us divides us. Therefore, ethical and responsible internet policing through advancements in cyber security technology will prevent such an outcome that will disrupt our Nation's harmony, prosperity and sustainability.

In terms of physical security, the current common practice to secure a person's identification authenticity is via fingerprint recognition or iris scanning. With the advancement of technology, even fingerprints can be stolen, 3D printed iris scans can be spoofed and facial recognition software fooled. What we see in the movies is now being translated to reality. To overcome this, applications of emerging technologies in law enforcement such as cognitive neurosciences and neuroimaging of active brain areas is being applied to function as a lie detector. In the future however, as neurotechnology continues to weave into our daily lives, brainwave technology will be able to read a person's semantic memory for authentication or security purpose. We will no longer just have a physical fingerprint but will even have a brain fingerprint.

With advancements in technology, never has humanity had such power over itself, yet nothing ensures it will be used wisely. Humans are ultimately the ones who decide if the power that technology wields will be used for safeguarding people's well-being or its destruction.

Disruptive Technologies Creating New Business Models

Incumbent business models are fast becoming obsolete



Since the earlier Industrial Revolutions of the late 18th and early 19th centuries, technology has had a unique role in powering growth and transforming economies. In many cases, when a technology first emerges, its disruptive potential is not readily apparent. In other cases, however, a disruptive technology can be the result of scientific or technological breakthrough. Some of these technologies are specific and target a niche market, while others possess the potential for widespread use and may open new markets. On the contrary, technology often disrupts, displacing older ways of doing things and rendering old skills and organisational approaches irrelevant.

Today, we see a rise of disruptive technologies which are innovative technology that triggers sudden and unexpected effects in established technologies and markets not only just disrupting the market share but associated value networks. Take for example how the introduction of digital photography disrupted the business model of Kodak which was a well-known brand for photographic film but saw its revenues fall from USD16 billion in 1999 to just a mere USD6 billion in 2011 and filed for bankruptcy in 2012. In 1988, Kodak employed over 145,000 workers worldwide however, at the last count, barely one-tenth as many. All this happened in less than two decades.

Without a doubt, the acceleration of technology is reshaping production, consumption and delivery systems in industries and disrupting incumbent business models. To ensure Malaysia's economic growth and prosperity as well as its sustainability and competitiveness, we need to leverage on the opportunities created by these disruptive technologies and mitigate its risks.

Today's industry and businesses are not like yesterday and will be even more different tomorrow. With the increase in computational power and connectivity, it allows availability of data from real-time sensory data to be fed into the entire value chain of a business. Through the IoT, big data analytics and cloud computing, data driven decision-making related to businesses can now be executed with real-time data instead of depending on projected or forecasted data. Take for example a public relations firm that will need to be aware of what people are talking about their clients' brands in real-time in order to mitigate bad or false messages by nipping them in the bud. A few minutes too late and viral messages might be uncontainable. In the financial world, investors need to stay abreast of geo-political and socio-economic situations to make the best investment decisions with a global-macro strategy aided by these big data analytics. All these involved many variables and tonnes of data that we humans can no longer compute but rely on technology to assist in our decision making.

The emergence of analytics and business-intelligence capabilities due to deep learning in artificial intelligence allows machines to make decisions where once human intelligence was required. Deep learning and artificial intelligence (AI) shocked the world in 2016 after AlphaGo developed by DeepMind and Google beat a human professional Go player for the first time. Considering the complexity of the game, it was indeed a monumental feat. Google even put DeepMind's AI to good use by managing the power usage in parts of its data centres. The result was a 40% reduction of electricity consumption and will translate to savings of hundreds of millions of dollars over the years. This will quickly offset the price that Google paid to purchase DeepMind for USD600 million.

Today, we see early attempts of deep learning in the mass market through Apple's Siri voices and also IBM's Watson that can perform tasks in the banking industry and even replace lawyers to give simple legal advice. Moving towards 2050, will we get closer to technology singularity where artificial superintelligence will abruptly trigger runaway technological growth, resulting in unfathomable changes to human civilisation?

Another disruption that we witness in the manufacturing sector is the shift from mass production to mass customisation as per request and specification by customers that will become a norm through the emerging technologies of 3D and 4D printing. This will bring disruptive changes to the invention, production and dispersion of products' value chain for industries and consumers. Imagine the impact of commercially mass available 3D or 4D printer kiosks that will enable us to purchase our goods online via blueprints and it is printed in front of our eyes at the comfort of our own homes or nearby centres. This will potentially disrupt large factories and logistics supply chain but also bring down the costs of the goods, customisable and reduce our carbon footprint.

Disruptive technologies would continue to evolve in the coming decades. Hence, it is in the hands of Malaysia's policy makers, entrepreneurs, business leaders and citizens to maximise application of these technologies to propel our economy while dealing with the challenges. In this digital world, the collaborative economy model becomes increasingly popular as connectivity makes it possible for partners to work remotely while enhanced transparency with aid of technology overcomes the trust issue among strangers. This facilitates collaboration towards mutually beneficial goals and will lead to a progressive Malaysia 2050 that has positive economic growth as well as equitable wealth distribution and fair opportunities for all Malaysians.

Democratisation of Knowledge

The world is becoming a buffet spread of learning

While technologies have provided innovative solutions to many of humanity's problems, they have also introduced new challenges and risks, including security and privacy concerns, polarising opportunities and job displacement. McKinsey Global Institute, 2013 forecasts that machine learning algorithms could do the work of 140 million knowledge workers by 2025, while 30% of middle-income jobs could be eliminated due to innovation in artificial intelligence (The Guardian, 2017). In Malaysia, just based on existing technologies, about 51% of current jobs could be automated and this will affect the livelihood of over 6.3 million Malaysians. Therefore, we as humans would need to adapt to the changes that technology brings by upgrading our knowledge.

In today's world, lifelong learning becomes a norm as technology continues to accelerate and brings about profound changes in the way we live and work. This is aided by technology-enhanced learning methods, such as controlled and immersive learning environments through the application of virtual learning and augmented reality, gamification (education tools that use game elements to increase understanding and information retention such nanomaterials based learning materials and 3D printing) while personalised learning (learning analytics through cloud computing) will collect and use data during student's learning process to dynamically assess progress and adjust materials, pace and difficulty (Foresight network fiches 2030, European Commission 2014). Imagine our learning experience aided by these technologies as a completely immersive one where if we are learning about the solar system, we can 'see-touch-feel' the conditions of outer space, touch the rings of Saturn, count the 63 moons of Jupiter and feel the heat of the sun's solar flares.

Today, we also see the rise of on-demand learning that enables our talents to learn, unlearn, relearn and co-learn. We no longer need to enrol for a three-year long degree programme in a university or pay for a one-month intensive course by training companies. Today, individuals have access to knowledge that was once available only to elites. The digital revolution and democratisation of knowledge for anyone, anywhere has increased knowledge flows at an unprecedented rate creating a more knowledgeable society. The rise of multiple online courses, maker spaces, cloud and subscription-based software tools as well as crowd sourcing for knowledge have given individuals the opportunity to seek for knowledge and disrupt the formal education system.

Realising the potential of digital technology, the number of Malaysians becoming tech savvy is increasing yearly. In 2016, Malaysia Digital Association reported Malaysia's internet penetration is 68.5 %, which accounts for 20.4 million people accessing the internet in Malaysia and projected to grow to 24.6 million in 2021. It is imperative to consider what needs to be done to reach 100% internet penetration in Malaysia so that everyone can be digitally connected and become more knowledgeable. To achieve a Progressive Malaysia 2050, we need to be digitally united to ensure equal opportunities for all Malaysians to fully reach their potential.

Reducing Our Carbon Footprint

Humanity is adopting green and sustainable practises to save the planet

Many of the actions we undertake on a daily basis can be measured by their carbon footprint. As our power usage increases, so does its environmental impact. Cars, homes and possessions all contribute to this impact by using energy, most of which is produced by burning fossil fuels. In Malaysia, our electricity is still generated primarily by thermal stations reliant on coal, oil and natural gas as much as 86% in 2012. Meanwhile, Malaysia's CO_2 emissions in 2015 were at a level of 246.95 metric tonnes, up from 236.14 metric tonnes in 2014. Our strong dependency on fossil fuels for electricity generation in Malaysia causes energy security and environmental concerns and the increasing demand for electricity is in tandem with our population growth and expansion of economic activities.

Moving towards 2050, it is estimated that nine out of ten Malaysians will be living in urban areas. This will see an increase in the demands for quality of life and efficiency of transport and energy provisions. With such a high urbanisation rate, greenhouse gas emissions are likely to increase as well. In line with Malaysia's commitments to the Paris Agreement under the United Nations Framework Convention on Climate Change, we have pledged to reduce greenhouse emissions by 45% by 2030 and cut 32 million tonnes of carbon emissions by 2020. To achieve this, we require the solutions from emerging technologies that will enable us to reduce our carbon footprint.

In today's global world, we see advances in renewable energy, electric vehicles and hybrid technology have led to significant reductions in emissions and waste with further improvements currently being made in the areas of biofuels, organic photovoltaics and hydrogen cars. In Malaysia's emerging technology context, three possible renewable energy technologies were identified. These can reduce Malaysia's dependence on fossil fuel for generation of energy. This is particularly important as fossil fuel is non-renewable and continuously depleting besides leading to a large carbon footprint.

Over the last decade, investment in renewable energy technologies such as fuel cell and photovoltaic cell are increasing in Malaysia's landscape. Another potential renewable energy for Malaysia in the coming decade is Ocean Thermal Energy Conversion (OTEC), having the capacity of generating electricity up to 100,000 MW by converting the ocean thermal energy stored in the deep waters off the States of Sabah and Sarawak, wherever the depth of the seas is 700 meters or deeper. By adopting a diverse energy mix in our electricity generation, this will enable us to avoid emitting about 92 billion tonnes of CO_2 which is equivalent to the burning of 44 petagrams of coal (Carbon Free Energy Report, ASM 2015).

With emerging renewable technologies such as those above being developed, we now have the best opportunity to make our nation green. Compared with coal which emits between 1.4 and 3.6 pounds of CO_2E/kWh, solar photovoltaic cells emit only 0.07 to 0.2 CO_2E/kWh. This is a clear distinction in the reduction of carbon footprint if we adopt renewable energy technologies. By coupling increases in funding for low-carbon technologies with practical support for the entrepreneurs and companies developing them, emerging renewable technologies would be more likely to become part of our cities, reducing emissions and paving the way for a sustainable and greener urban life.

Value Adding our Resources and Management Efficiency

More for less - making the most of limited resources

As depletion of natural resources, climate change and environmental degradation become more intense and significantly impact our economy, societal well-being and quality of life, actions should be taken to manage resources efficiently and increase value-add to our resources and waste. Waste recovery through emerging technologies is becoming commonplace today as the amount of waste generated by Malaysians has increased to alarming levels. It is projected that by 2020, Malaysians on average will produce 30,000 tonnes of waste daily. This amount of waste can cover five football fields at 1.5 metres height per day.

Such waste is not only impacting the environment but also reducing our land space and quality of life. Emerging technologies have the potential to enable proper waste management as well as conversion of waste into wealth. Take for example, the conversion of biomass from oil palm to biofuel and nutrients recovered from wastewater into becoming fertiliser. This will not only provide sustainable solutions but also generate wealth at the same time.

Malaysia is one of the largest producer and exporter of palm oil in the world. However, almost 70% of processed oil palm is removed as waste in the form of empty fruit bunches, fibres and shells as well as liquid effluent and generates 168 million tonnes of green waste annually. These palm biomass waste could potentially contribute RM30 billion to the gross national income (GNI) by 2020 if properly managed using STI interventions but are currently left to rot.

Hence, to leverage on this opportunity, technological solutions of establishing an integrated bio-refinery in the oil palm mill would enable generation of new value-added products from solid biomass residues and liquid effluent in-line with zero emission systems. The liquid final discharge can be further treated to meet river water quality, making it suitable to be recycled and indirectly achieve zero emission. Such an integrated approach creates revenue, solves the issue of proper biomass disposal and effluent treatment.

According to data from the World Bank, in 2014 Malaysia's fertiliser consumption was at 2,063 kg per hectare of arable land. This is almost 280 times more than the world average. Considering our vast agriculture sector especially in the commodity sector, we import most of our fertiliser requirements and the Department of Statistics Malaysia estimates that this amounts to almost four million tonnes of mineral fertilisers costing around RM4 million. To prevent an outflow of Malaysia's capital, technological solutions that create waste to wealth can be applied here.

By adopting wastewater nutrient recovery technologies, we would be able to recover large amount of nutrients particularly phosphorus, that can pose a harmful threat to infrastructure and the environment but is an important element in fertilisers and increasingly scarce natural resource. By utilising nutrient recovery, wastewater treatment can mitigate environmental impacts by improving water quality and meeting stringent phosphorus discharge limits while creating an extra stream of revenue in the agricultural business. Furthermore, the application of this technology in resource recovery facilities will decrease energy consumption and greenhouse gas emissions associated with current methods of fertiliser production (The University of Queensland, 2015). Not only does this technology benefit the industry and environment but also the consumer and government as this will potentially lower the costs of fertilisers making it more available to smallholder farmers that are unable to afford high priced fertilisers but also reduce the government burden on subsidies.

Technological solutions are not only important to generate economic benefits but also to ensure it meets the basic needs of individuals. One of our most basic physiological needs is the need for sustenance to survive. In terms of water-food-energy security, Malaysia has started exploring alternative resources to meet the increasing demands. Local farmers will need to produce more food to feed the growing population in the limited and decreasing land acreage they have as well as mitigate climate change. In terms of food security, Malaysia is still very reliant on imports to feed the population as seen from our trade deficit of RM18 billion for food items. For staples such as rice, chicken and fish, we are more self-sufficient where we produce 70% of the population's needs. However, in terms of meat and milk production our local farmers can only produce 20% of the population's needs.

One of the technological solutions to tackle this problem is through the application of molecular markers for identification of elite crops and livestock for breeding. This would enable crops and animals to be sustained amid changes in temperature and weather, be adaptable to be grown in vertical farming environment and have shorter breeding time. This is particularly important in view of the increasing global temperature, erratic weather patterns and high urbanisation rate reducing agricultural land. Furthermore, through technologies that select elite crops and livestock, it is possible to reduce the amount of water, fertiliser and pesticides while increasing crop productivity which in turn keeps food prices down and decreases the stress on the environment.

Through technological advancements, modern farms and agricultural operations work far differently than those a few decades ago. With the introduction of precision farming that combines sensors, devices, machines, and information technology, it is now a different approach for farmers. No longer involving the low skilled manual labour work under the hot sun, today's agriculture routinely uses sophisticated technologies such as robots, temperature and moisture sensors, aerial images, and GPS technology. These advanced devices and precision agriculture and robotic systems allow businesses to be more profitable, efficient, safer, and more environmentally friendly. Furthermore, land usage can be maximised through precise amounts of water, fertiliser, pesticides etc. for crops at the correct time to increase its productivity and maximise its yields. Through automated and precision agriculture, farmers will even be able to monitor their farms remotely and would not have to leave the comforts of their urban homes.

Undoubtedly, the 21 emerging technologies identified can lead to the realisation of a Progressive Malaysia 2050 that is harmonious, prosperous and sustainable. Nonetheless, a key question is what is their current status of maturity in Malaysia and how long before we can benefit from its pervasive adoption for the whole of society?

To answer this, the 21 emerging technologies identified were assessed on their current status (concept/theory, R&D, prototype and commercialisation) in Malaysia and possible manifestation range for technology maturation. In Figure 5.7, the position of each emerging technology represents its current status in Malaysia and each emerging technology is colour coded according to its technology area. Possible manifestation range to fully develop as matured technology is also indicated for each emerging technology. At present, most of the emerging technologies in Malaysia are at R&D, prototype and commercialisation phase. As such, Malaysia has a long way to go to be at par with other advanced countries in terms of applications of emerging technologies. Therefore, we need to make changes now to ensure the nation catches-up and eventually take the lead. The opportunity is before us and our strengths and needs have been identified to create the Progressive Malaysia 2050 we aspire.

Emerging Technologies Positioning in Malaysia

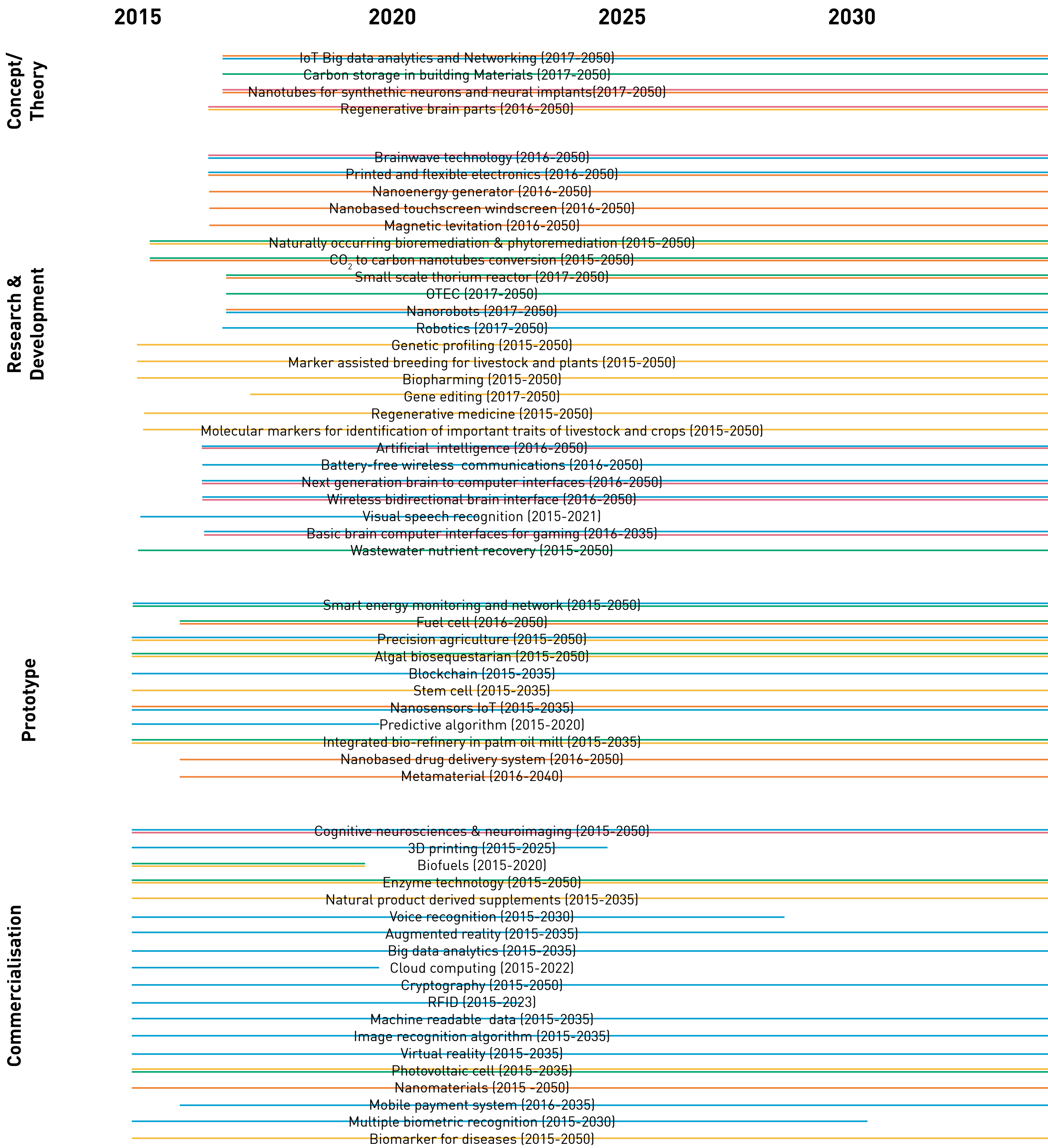
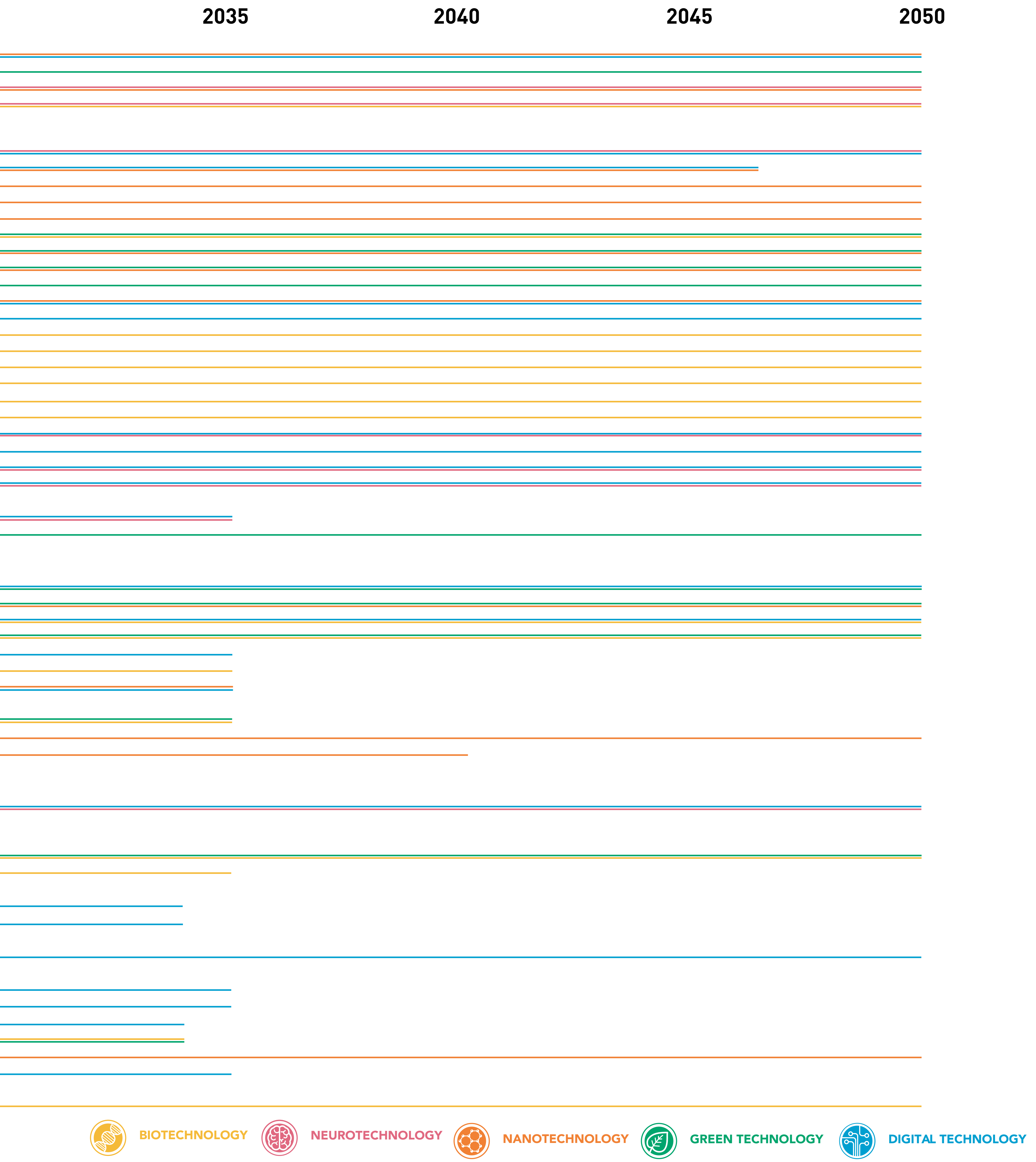


Figure 5.7: Position of each emerging technology represents its current status in Malaysia


2035
2040
2045
2050
BIOTECHNOLOGY
NEUROTECHNOLOGY
NANOTECHNOLOGY
GREEN TECHNOLOGY
DIGITAL TECHNOLOGY

6.0 CHALLENGES IN ADVANCING ESET IN MALAYSIA

STI has underpinned the pillars of Malaysia's economic growth for the last six decades since independence. There has been a shift of focus from rubber and tin that was once twin pillars of Malaysia's economy, to oil palm and hi-tech industries, to an emphasis on digital technology, biotechnology, nanotechnology and green technology.

Malaysia has focused on increasing innovation and productivity to transform itself from an input-driven economy to a knowledge-based since the 8MP starting from 2001. The role of STI is increasingly significant to propel economic growth and societal well-being.

As Malaysia transitions to an innovation-led economy, some of the crucial factors that need to be addressed are STI governance, integrated and effective STI ecosystem, talent development (high skilled, knowledge workers), Gross Expenditure on Research and Development (GERD)/ Gross Domestic Product (GDP), value creation from R&D as well as STI culture among others.

6.1 STI Governance and Emerging Technology Policies and Implementation

Lack of alignment among numerous policies, strategies and initiatives make it challenging to coordinate their implementation in the technology areas. Science Outlook (ASM, 2015) stated that there were around 458 agencies and institutions involve in promoting or implementing various policies, strategies and initiatives. Oftentimes, these agencies and institutions are not working in synergy but seen to be competing to get their voices heard. This has proved to be counterproductive to fully harnessing our STI potential. As such, even with robust policy frameworks, government's support and private sector participation, the implementation of policy measures seem to be fragmented and eclectic yielding poor results.

OECD finding shows three roles of government – policy leadership, developer and implementer. However, it is advocated that clear functional separation between policy development and policy implementation be maintained in order to promote clear core business for respective government entities. In the Malaysian R, D, C & I landscape, when lines between policy developer and implementer become blurred, it becomes a challenge as it may lead to a conflict of interest. This also prevents effective execution, independent monitoring and evaluation of such policy.

According to the OECD Horizon Scan of Megatrends and Technology Trends in the Context of Future Research Policy (OECD, 2016), timely and responsive government policies play an important role in facilitating research funding and catalysing innovation around emerging technologies. In this context, an example of a long overdue policy is Malaysia's Nanotechnology Policy. Although the importance of nanotechnology is well recognised for the nation's STI advancement, a policy for nanotechnology is yet to be in place. Likewise, there is also a policy gap for neurotechnology in Malaysia although related emerging technologies such as artificial intelligence, augmented reality, virtual reality, cognitive technologies etc. are expected to forge the next wave of disruptive technologies. In the green technology area, although there are policies and initiatives set in place by the government, experts have stressed that these government policies need to be revisited and strengthened particularly in terms of support for R&D funding, talent development, community awareness and advocacy.

6.2

Gross Expenditure on Research and Development (GERD)/ Gross Domestic Product (GDP) and Funding for R&D

Although Malaysia's GERD/ GDP has steadily increased over the years with the latest published figure of 1.3% in 2015 (Figure 6.1), it is still far from reaching the target of GERD/ GDP of 2.0% by the year 2020 as targeted in the National Policy on Science, Technology and Innovation (NPSTI, 2013). In terms of global ranking, Malaysia's percentage of GERD/ GDP is ranked 29th (Figure 6.2). Nations with the highest GERD/GDP are also prominently featured among the top 10 nations in the Global Innovation Index.

One of the questions posed in the surveys and interviews on the five technology areas was on assessing the current state of R&D towards the advancement of five technology areas in Malaysia. Funding for R&D was highlighted as a major challenge since the advancement of technology requires consistent and sustained funding over the long term.

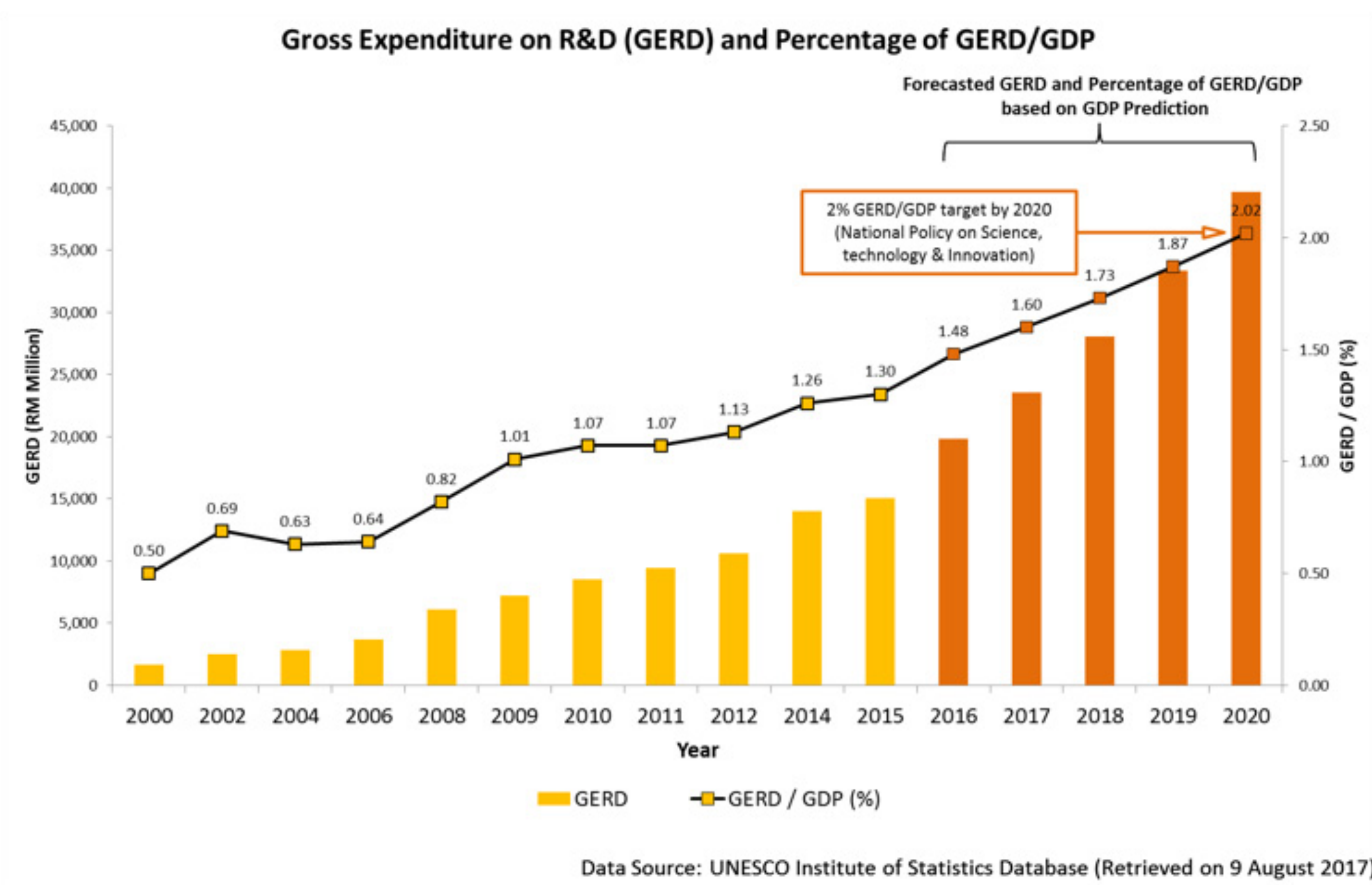


Figure 6.1: Malaysia's Gross Expenditure on R&D (GERD) and Percentage of GERD/GDP, 2000-2020

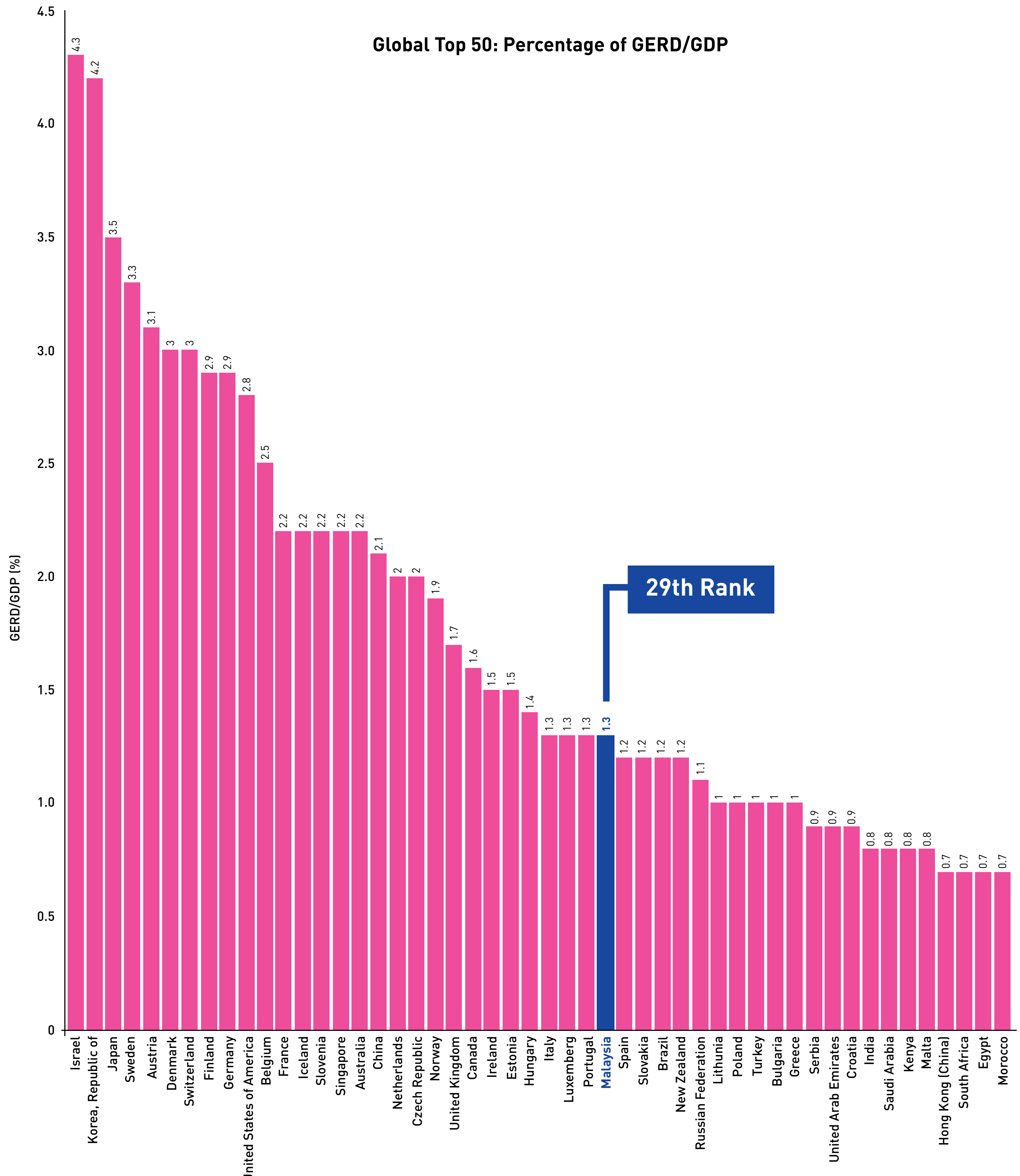


Figure 6.2: Malaysia's ranking in terms of GERD/GDP (percentage)
(Data Source: The Global Innovation Index 2017**)**

In 2014, it was reported that there are a total of 14 agencies under eight ministries that provide grants for R&D activities (SEA-EU-NET, 2014). The abundance of institutional actors and overlapping funding mechanisms has made proper coordination, implementation as well as monitoring and evaluation a difficult task.

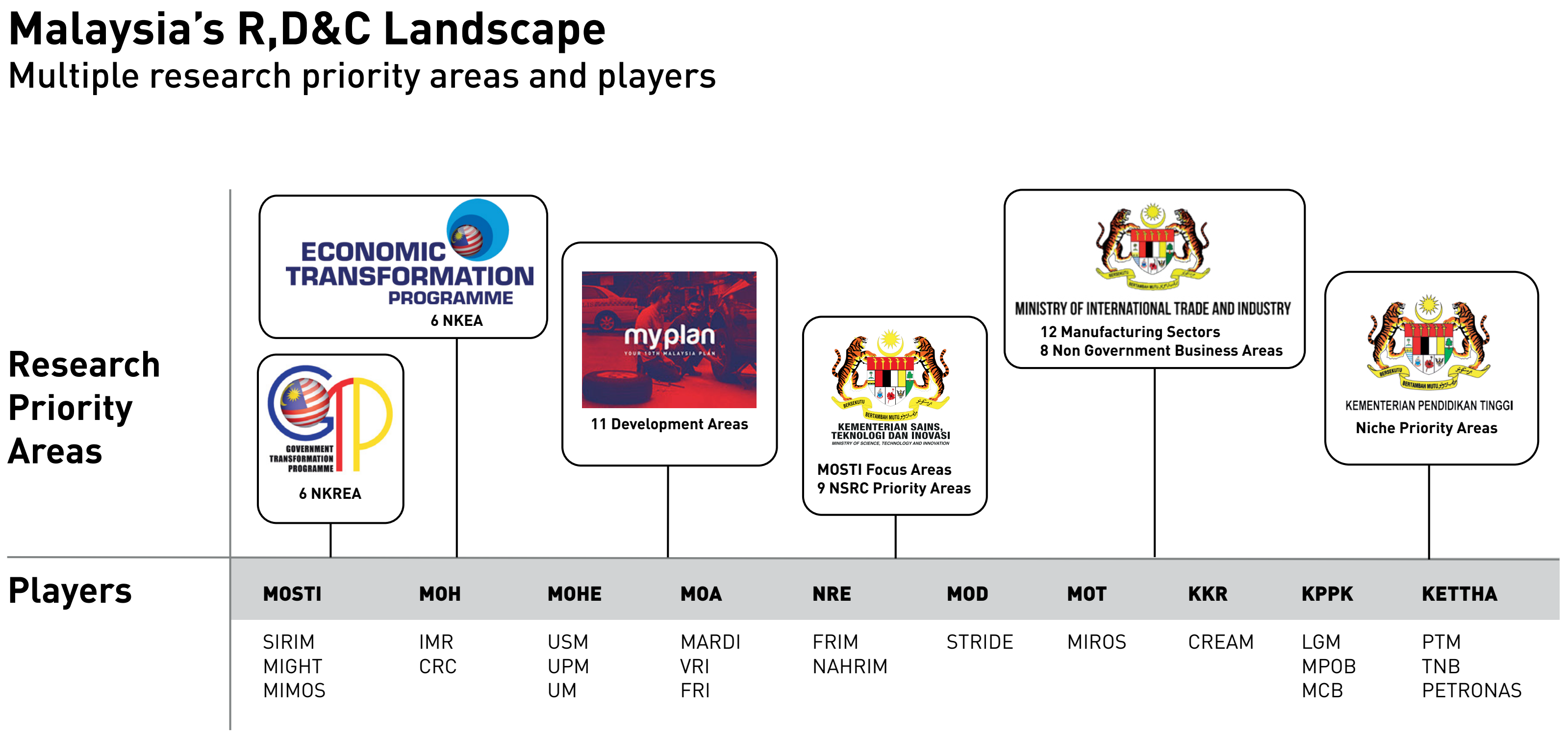


Figure 6.3: Snapshot of Malaysia's R, D & C Landscape

In terms of R&D, although there has been a steady increase in R&D fund allocation from the 1st to the 11MP, multiple priority areas, players and grants dilute the net effect of enhanced R&D allocation and impedes impact as shown in Figure 6.3.

The diversification of R&D funds without a single coordination agency raises concerns as follows:

- Fragmented research and working in silo activities within the ministries and related agencies
- Non-optimal utilisation of R&D allocation
- No centralised database on research activities
- Lack of commercialisation of research output
- Lack of linkages between research institutes and industry

6.3
Lack of Singular National Priority Areas

The manner in which national R&D funds are being disbursed seemingly lacks focus and not well aligned to the current national agenda. Although various roadmaps have been developed in the past, the integration of these roadmaps with the various funding sources has not been done efficiently. Examples of those related to emerging technologies are the National IoT Strategic Roadmap and National Graphene Action Plan 2020.

Experts observe that Malaysia is currently too dependent on foreign technologies despite a significant commitment from the government to support indigenous technology development. Both basic and applied research should be treated with equal importance to cultivate and encourage home-grown technologies. For example in neuroscience research, it is emphasised that the focus should be on preventive care that improves lifestyle and attitude towards the devastating effects of neurological disorders and its impacts rather than just treatment of neurological disorders.

6.4
The Talent Conundrum

In today's landscape of exponential technological advancement, the ability to compete in the global market would depend heavily on proficiency in STI. Jobs of the future increasingly require STEM talent. Hence, governments all over the world are now spearheading purposive and strategic initiatives to develop and utilize STEM talent to advance their socio-economic goals. Similarly, Malaysia also needs to build a critical mass of STEM talent to realise our aspiration of becoming a developed, high-income and sustainable nation by 2020.

Since people are the prime movers of innovation, talent would be a critical factor in harnessing the emerging technologies. In the consultations with experts and industry players, it was highlighted that talents with cutting-edge technology skills were lacking in most of these emerging science, engineering and technology areas in Malaysia. For example, in the neurotechnology area, there are only approximately 150 neuroscientists in Malaysia (including postgraduate students) (IBRO, 2017). This number is relatively small as compared to other nations and this would be severely limit neuroscience research initiatives.

Based on the National Study on Human Capital (2012), it has been projected that Malaysia would need eight million STEM workers by 2050. The critical question is whether Malaysia has a pipeline of STEM talent and will it be sufficient and competitive enough to meet the country's future human capital needs. Despite substantial expenditure on education and many infrastructural and talent enhancement support since 1967, there seems to be a decline in interest in science among Malaysians, contributing to STI talent depletion. Unfortunately, barely around 30% of our students are currently in the science stream. Undoubtedly, if this trend continues, we will not be able to produce the much needed future researchers, scientists, engineers, technologists and innovators. As a result, future Malaysians will remain merely as consumers of technology and not transcend to become producers of technology for wealth creation.

6.5
Lack of Collaboration Within Quadruple Helix

This is the age of collaboration. The premise of control and conquer is no longer relevant. Today, it is about platforms, networks and connectivity in a shared value ecosystem. One of the challenges is lack of impetus and vigour collaborative efforts to foster innovation and co-creation involving government, academia, industry and community to enable rapid applications of emerging technology.

Lack of demand-driven R&D is hindering commercialisation of R&D outputs. Related issues of effectiveness of technology transfer programmes, acquisition of intellectual property (IP) for commercialisation, the creation of spin-off companies etc. needs to be addressed in the effort to overcome the disconnect between industry and academia and give rise to STI enterprises (Rajalingam, 2013).

Emerging technologies, particularly in the digital space, have made the collaborative economy not only possible but economically viable. Digital technologies have enabled effective engagement and collaboration to form mutually-supporting as well as value-creating systems. Ultimately, the collaborative economy is a socio-economic system built upon resource sharing in supply and value chains that empower all participants in the quadruple helix through ICT-enabled networks to produce value-added goods and services. There is a need to synergise various aspects to deliver value for the nation and people. We need dynamic collaborative platforms across sectors and regions to generate impact.

6.6
Lack of Support for Technology-based Start-ups

Currently, technology-based start-ups to harness emerging technologies are not emphasised and incentivised enough. This may be due to lack of a healthy venture capital ecosystem which may hinder the growth of start-ups in Malaysia. Most initiatives will run out of their initial government grants before their products are mature enough for a successful market penetration.

Start-ups are bringing forth new business models that integrate technology and services to provide greater efficiency and flexibility. However, a robust ecosystem for start-ups to flourish is needed. Besides that, social financing models such as angel investors and crowdfunding should be better explored, expanded and regulated to give rise to successful start-ups.

6.7
STI Culture

A complacent attitude towards the development of emerging technologies is apparent at various levels such as policy makers, fund providers, researchers etc. where STI culture and short-term perspective is lacking. While society demands for various applications of technology, there is no realisation of the investment of resources required to provide such advancements. As such, society must transform to embrace science as a culture and learn to appreciate the role of science. Efforts are needed to ensure the development of science literate and scientifically engaged society that will understand and support science, leverage on STI to overcome economic and social challenges, and believe in the local science and technology capabilities.

Building on Malaysia's Strengths and Preparing for Future Needs by Harnessing Emerging Technologies

7.1 Taking Malaysia's Strengths to the Next Level through Mastery of Emerging Technologies

Emerging technologies have a major role in enabling key economic sectors of the nation to move to the next level through value creation and enhancement of innovation capacity. Three sectors that are fundamental strengths of the Malaysian economy as elaborated in Chapter 4 under Malaysia's positioning are E&E, agriculture and halal industry.

Electrical & Electronics Sector

In terms of outlook and trends in the E&E sector, International Labour Organisation through its report published in 2016 stated that enterprises in ASEAN are looking into automated solutions (robotics) to weather continued increases in labour cost. IoT is also expected to create significant opportunities for semiconductor companies by stimulating demand for sensors, connectivity and memory thus representing a direct growth opportunity for semiconductor players in ASEAN who currently dominate global production. Additive manufacturing or 3D printing through its ability to print multi-material objects will further streamline production, thus becoming a major disrupter to the industry.

E&E is the backbone of Malaysia's manufacturing sector. Malaysia is set to embrace smart manufacturing processes and technologies to enhance production flexibility and efficiency. By adopting smart manufacturing in Malaysia, the manufacturing and services industry could be further optimised through new innovation opportunities. This optimisation will enable improved product quality, energy efficiency and safer plant floors (MIDA, 2017).

One of the key challenges of the E&E sector is to move from a predominantly manufacturing focus into higher value chain activities such as demand-driven R&D to give rise to disruptive innovation.

Agriculture

Emerging technologies are well poised to increase land productivity in a more sustainable way, improve the environmental performance of farms and enhance the quality of agricultural products (OECD 2016).

Malaysia has a heritage of leveraging STI to boost its agriculture sector. A case in point is Malaysia's premier plantation industry that has been a long-standing world leader, particularly in the oil palm and rubber sectors.

In this age of convergence, emerging technologies related to biotechnology, digital technology, nanotechnology, green technology and neurotechnology are providing integrated solutions and value propositions for the agriculture sector. This enables scope, scale and speed at unprecedented levels. For example, in order to bring about precision agriculture, emerging technologies such as Nanosensor IoT, unmanned aerial vehicle, cloud computing, big data analytics stand to revolutionise the farming management concept by enabling interconnected, automated observation, measurement and response to inter and intra-field variability in crops. Marker-assisted breeding, genetic profiling, gene editing and molecular markers for identification of superior traits have the potential to increase agricultural production yields and quality as well as reduce uncertainties due to weather changes.

Emerging technologies also revolutionise the marketing and supply chain management of agricultural produce by farmers and plantation owners. Access to digital technology would enable them to participate in the collaborative economy through online platforms and do away with the need for middlemen. Geographical Information System (GIS) and Radio Frequency Identification (RFID) trackers bring to reality the Farm to Fork concept whereby advanced tracking and monitoring of the agriculture produce is carried out throughout the supply chain from the source to the end user. The application of emerging technologies in the agriculture sector is not limited to food sources but also enables the agriculture sector to contribute to the healthcare industry as well as a value-add to non-food materials.

One of the key challenges for Malaysia is to develop agritechnology and agribusiness, particularly in the agro-food sector to reduce the escalating food import bill of the nation and enhance self-sufficient levels to attain national food security.

Halal Industry

Malaysia aims to be a leading global Halal hub by 2020 (HDC, 2016). Based on Malaysia's potential to be a global halal supplier, Malaysian products are set to cater for the world market as well as meet local needs. Malaysia's efficiency standards and halal certification have received global consumer recognition for high quality and safety. Hence, Malaysia is well positioned to strengthen its lead in the global Halal market not only in the agri-food segment but also in Islamic Finance, Halal Tourism and Halal Medicine segments.

It is imperative for Malaysia to invest and develop emerging technologies in niche halal-related sectors to strengthen its lead in the global halal market. It would be worth re-engineer growth of the halal industry by leveraging value added through application of emerging technologies.

One of the key challenges for Malaysia is to ensure a world-class Halal supply chain that enables Halal products to be well traced to source for authenticity, tracked and monitored anywhere, anytime in the world. This requires the application of emerging technologies in an innovative manner.

Value Proposition 1

In order to build on Malaysia's strengths and position Malaysia globally in niche areas, it is recommended that strategic STI intervention and investment in relevant emerging technologies be considered to realise the following:

i. Make Malaysia a powerhouse for high-value chain activities in E&E sector to bring about disruptive innovations through endogenous development of technologies by 2030.

ii. Make Malaysia a regional leader in Agrotechnology and Agribusiness to increase food security through enhancement of self-sufficiency levels by 2030.

iii. Make Malaysia a premier global Halal hub to expand global market revenue and reach by 2030.

7.2

To Ensure Malaysia is Harmonious, Prosperous and Sustainable through localisation (adoption and adaptation to local context) of emerging technologies

This study has identified the following:

i. *Malaysia's Emerging Technology Timeline towards 2050 that showcases 95 emerging technologies* and their interlinkages based on Malaysia's strengths and needs.

This timeline depicts the 95 emerging technologies for Malaysia in three phases: present (2015-2020), probable future (2021-2035) and possible future (2036-2050). Please refer to Figure 12 for Malaysia's Emerging Technology Timeline.

ii. *21 Impactful Emerging Technologies towards realising Progressive Malaysia 2050* prioritised based on feasibility and attractiveness in Malaysia's context guided by global trends and global risks. Please refer to Figure 18 for the 21 impactful emerging technologies.

Based on the above outputs of this study, Malaysia can chart its R&D agenda to address three major challenges faced by Malaysia and be prepared for future needs as follows (the challenges are elaborated in Chapter 6):

Value Proposition 2

The 21 impactful emerging technologies identified for Malaysia to be adopted as a guide for research area priority setting at the national level to realise following outcomes among others:

i. Ensure well-being and health of the people of Malaysia by:
   - Turning the tide from reactive to preventive health care to reduce burden of disease.
   - Ensuring a high quality of life by maximising safety and security in terms of how people live, work and play.
   - Investing in the brain science R&D to advance knowledge and application to positively impact mental health, learning and social interaction.

ii. Accelerate socio-economic transformation leveraging the digital tsunami towards:
   - Reducing the inequality divide between the rural and urban population by increasing accessibility, affordability and availability of technological interventions.
   - Enhancing livelihood through creation of new business models utilising disruptive technologies.
   - Democratisation of knowledge to empower people to make informed decisions.

iii. Move to a low waste, resource efficient society by deploying emerging technologies to better balance production and consumption. This is in line with the global shift to a circular economy that expects to improve GDP per material input ("doing more with less"), reduce municipal waste and increase recycling rates among others (OECD, 2015).
   - Balance people, planet, and profit elements through a water-food-energy nexus approach
   - Reduce carbon footprint and fulfil Malaysia's commitment to reduce GHG emission intensity (per unit of GDP) to 45% by 2030, relative to emissions intensity in 2005.
   - Value-add resources and their management efficiency to mitigate resource scarcity and climate change impact.
   - Enhance generation and utilisation of renewable energy and materials.

7.3

Getting the Act Together – A Call for Dynamic Strategy and Synergy

Good Governance

Good governance is paramount to establishing a robust ecosystem for effective development and deployment of emerging technologies. It integrates responsive policy framework, catalytic leadership, intensive STI knowledge and collaborative strategies.

Participative and Proactive governance of emerging technologies is crucial and involves policy direction, strategy plan including cost-benefit assessment and shaping of future exploitation pathways, talent development as well as industry development among others.

It is observed that in Malaysia, four out of the five technology areas namely, Biotechnology, Digital Technology, Green Technology, Nanotechnology seem to be largely driven by corporations specifically set up by the government to develop and drive the agenda for respective technology areas. Examples of this are Bioeconomy Corporation, Malaysian Digital Economy Corporation, Green Technology Corporation and NanoMalaysia.

While this corporatisation strategy may augur well for industry development it cannot take the place of a national directorate at the relevant central agency of the government or relevant ministry to drive the agenda for each emerging technology area.

It would be vital for such a government directorate to carry out the following functions:

i. Provide centralised coordination to facilitate national level strategic planning and implementation.

ii. Strategising, planning and developing requisite talent roadmap.

iii. Streamline multiple entities and players in order to avoid overlapping initiatives and roles.

iv. Carry out the outcome-driven development of ESET areas with long-term view.

v. Conduct monitoring and evaluation of performance in emerging technologies at regular intervals, for example, every two years. This would provide a basis to adjust strategy, respond to global trends and be prepared for change. It should also be mandatory for actors in each technology area to report initiatives, progress and impact to the national directorate.

vi. Navigating through risks and uncertainties of emerging technologies as they may pose ethical issues. This also emphasised the role of the social sciences and humanities in developing and harnessing emerging technologies given their implications for society.

This study recognises that this is the age of technology convergence that we are seeing at an unprecedented level. On the global scene, this has given rise to the term NBIC that relates to Nanotechnology, Biotechnology, Information and communication technology (ICT) and cognitive sciences (OECD, 2014). According to David Wood (2015), four great convergences that the world is witnessing are between humans and machines, software and biology, the physical and virtual worlds as well as artificial intelligence and human intelligence. The main driver of such a convergence is grand societal challenges that demand integrated solutions. Escalating technology convergence raises the need for trans-disciplinary institutional set-ups to address, in particular, R&D and talent development.

Strategic Intervention:

- There is a need to revisit practice of companies being designated to drive the technology agenda for areas that have been identified as the nation's engine of growth.
- A government anchored directorate should be in place to lead the way in partnership with relevant corporations.
- This age of unprecedented technology convergence necessitates transdisciplinary institutional set-ups aimed at providing integrated solutions for societal challenges besides technology advancement and economic growth.

Institutionalising S&T Foresight to Future Proof the Nation

A long-term S&T foresight spanning 20 years or more can provide valuable insights on expected technological breakthroughs in the most important S&T areas highlight promising scientific milestones as well as outline the development of innovative products and services.

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Although short-term plans are good because they enable focus and quick wins to be realised, in the case of harnessing emerging technologies a longer-term outlook is necessary. This is particularly important when it comes to developing people and requisite infrastructure as it requires strategic interventions and investments way ahead of time to seize future opportunities and be ahead of the curve.

Identification and setting of national R&D priority areas is a natural follow-through of S&T foresight exercises with the aim of providing singular, unifying focus and channelling of resources to a common cause. It is about turning challenges into opportunities, finding STI solutions for national issues, providing local solutions for global challenges, accelerating economic growth and addressing people's well-being.

When it comes to global best practices, long-term S&T foresight exercises are closely aligned to the setting and fine-tuning of national priority areas and critical technologies (L. Gokhberg et al. (eds.), 2016). S&T foresight exercises should be regularly updated such as every two to three years as technology is rapidly advancing and constantly changes. Hence the need to institutionalise S&T foresight as part of an organisational structure with clearly defined objectives, functions and responsibilities. S&T foresight exercises should be carried out through an inclusive approach with the participation of key government ministries and agencies closely linked to national STI and economic development, industry partners, institutions of higher learning, learned bodies such as academies of science as well as civil society.

Strategic Intervention:

- Malaysia would benefit immensely from institutionalising S&T foresight to enhance future technological readiness and innovation capacity of the nation.
- Unpredictability of changes brought about by emerging technologies calls for the adoption of a long-term outlook and open perspective that supports a multiplicity of technology developments and applications.
- A setting of national level R&D priority areas is crucial to effectively harness the promise of emerging technologies and get all stakeholders on board with a unified focus in terms of resources, talent, strategic investment and collaboration among others.

Talent the Winning Factor

"Today's educators are preparing students for jobs that don't yet exist using technologies not yet invented to solve problems not yet identified." — Rick Stephens, Senior Vice-President, HR, Boeing, 2008.

The above quote encapsulates the fact that emerging technologies keep changing the paradigm of jobs of the future. Due to the rapid changes on an exponential scale driven by advances in technology, the core skills of future talent are centred on learning. Talents in the future need to be able to learn, unlearn, re-learn, co-learn and co-create. In the future, it is projected that jobs will be offered based on roles and evaluation for such jobs will not be just qualification but badges i.e. what the individual has accomplished, solved, areas that showcase translation of knowledge into desired outcomes that spur economic growth as well as address societal needs.

Many multinational companies have embarked on determining what skills and capabilities their workforce will need in the future. Based on industry and corporate direction, they identify key areas and define a set of rules that map to these areas, determine the associated competencies and evaluated employees against the future landscape.
One of the shifts targeted under the Malaysian Higher Education Blueprint is to nurture more job creators rather than job seekers i.e. nurturing entrepreneurs, technopreneurs, service providers etc.
It is no longer relevant to ask children today what their ambition is but more importantly, what kind of problems they wish to solve in the future. This instils a sense of purpose, values and leadership.

Strategic Intervention:

- It has to be talent by design and not by chance.
- The core competency of the 21st century is the ability to learn and this must be embedded, nurtured, reinforced and incentivized throughout the talent development value chain.
- Need to invest in building the workforce of the future, in particular by strengthening and expanding the science, technology, engineering and mathematics (STEM) talent pool.
- Priorities high-level STEM specialisation in cutting edge, disruptive technology ahead of time taking the cue from foresight intelligence.
- Sharpen talent pool competencies in the 4Cs: critical thinking, creativity, collaboration and communication.
- Create opportunities and resources for talent in cutting edge technology areas to collaborate with the brightest and best globally.

Collaborative Networks for Dsruptive Innovation

The collaborative network mechanism with a shared value ecosystem at its core is gaining significance globally and is responsible for disrupting conventional industry incumbents in many instances. Drivers (industry players and researchers) are connected with enablers (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.

Malaysia's primary challenge in innovation is to bridge the chasm between industry players and the R&D community. One of the ways to close the gap is to facilitate industry to formulate demand-driven R&D in order to draw the participation of researchers through open research calls within a collaborative network. By this means knowledge-rich products could be developed, while also extending the market reach of the industry concerned. Many advanced nations have successfully enhanced their innovation capacity and capability through such collaborative networks.

A collaborative network makes it possible for market information as well as S&T knowledge especially in emerging technologies to be applied creatively to realise value and result in products and services that are unique and differentiated. Collaboration enables risk sharing 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.

Strategic Intervention:

- The need to establish collaborative networks in Malaysia's priority sectors. The 21 impactful technologies identified in this study to bring about six impactful outcomes could serve as a guide for the areas to establish collaborative networks.

- Carry out industry led strategic planning to enable demand-driven R&D and mobilise emerging technology applications.

Enhancing Private Sector Participation, Social Financing Models and Technology Start-ups

In many OECD countries that have successfully harnessed the potential of emerging technologies early on, the government or public sector role in the targeted development of promising technologies within a societal challenge framework has been crucial. This entails strategic funding and incentives for impactful emerging technology areas based on national priorities. Public sector funds are channelled more into basic research and experimental development while private sector participation is more significant in commercialisation and innovation activities. As such, funding mechanisms should facilitate a healthy balance of funding ratio for basic, applied and experimental development areas.

Private sector partnership to mobilise the application of emerging technologies to provide solutions for industry challenges could be modelled after the successful cess fund mechanism for R&D related to oil palm, rubber and timber industries in Malaysia. This would involve channelling a fixed percentage of the sales tax from GLCs, Large Local Companies (LLCs) and SMEs into a cess fund specifically set aside for funding research, development and innovation (R, D & I) activities.

Conventionally due to emerging technologies being associated with greater risks and uncertainties, there was higher dependence on public sector funding for the development of emerging technology areas. However, this is changing as more and more angel investors and social financing models such as crowdfunding platforms are more actively participating in supporting the development and application of emerging technologies. Many of these investment platforms are becoming more formalised and the support is particularly visible in the technology start-up space.

Technology-Based Start-ups are seen as a launch pad for application of emerging technologies and this platform is drawing more investment from venture capitalists, angel investors and ordinary people. Malaysia should facilitate such investment platforms and encourage more technology-based start-up initiatives as done in nations such as South Korea, Israel and Singapore.

Strategic Intervention:

- There is a need to facilitate, diversify and increase private sector and social financing platforms for the development and application of emerging technologies. This will not only reduce dependence on public sector funds but maximize social impact by generating a measurable, beneficial social or environmental deliverable alongside financial returns.
- Encourage and incentivise technology-based start-ups with private sector and community partnership to harness emerging technologies.

Data is Power

Data-driven decision making is key to developing emerging technologies. As such, data gathering, data sharing and data analytics must become part of the DNA of managing emerging technologies.

Strategic Intervention:

- National Technology Data Centre to be established by empowering existing entity with expanded mandate.
- The Data Centre not only collects data but carries out homogenisation, integration and analytics of the data.
- Should be carried out by Data Scientists who work in concert with experts to churn out relevant data.
- Analysed data should be made available through a public domain.

7.4
Conclusion

The three key outputs of this study: (i) 284 products, services, technologies, possible applications and outcomes relevant to Malaysia towards 2050, (ii) 95 emerging technologies that form Malaysia's Emerging Technology Timeline towards 2050 and (iii) The 21 Impactful Emerging Technologies to realise six technology-enabled outcomes for Malaysia to provide a basis to chart the course towards a Progressive Malaysia 2050 that is harmonious, prosperous and sustainable.

This study highlights the importance of building on Malaysia's strengths and preparing for future needs by harnessing emerging technologies. Proficiency in emerging technologies will take Malaysia's strengths to the next level. At the same time, it is imperative to build Malaysia's own model of socio-economic transformation in in response to anticipated future implications through the adoption and adaptation of emerging technologies to the local context.

People are the prime movers and drivers of technology. As such, both in terms of the talent pool for Malaysia to be at the forefront of emerging technologies and the uptake by industry and society, we must address the people factor to foster dynamism and synergy. Malaysia must be adept at deploying the right strategy at the right time.

International collaboration is also very important in positioning Malaysia's strengths, value propositions, competencies and uniqueness in the eyes of the world. A Progressive Malaysia 2050 through STI that is not only about economic growth but more importantly human development as well as social well-being must be realised and showcased.

Further Reading

Appendix 1: UK Technology Foresight by Watson and team from Imperial College, 2014.
Appendix 2: 284 products, services, technologies, possible applications and outcomes relevant to Malaysia towards 2050.
Appendix 3: 95 emerging technologies for Malaysia towards 2050.
Appendix 4: Technology prioritisation survey.
Appendix 5: Technology prioritisation analysis.

The five Emerging Science, Engineering and Technology (ESET) Area reports

1. Biotechnology
2. Digital Technology
3. Green Technology
4. Nanotechnology
5. Neurotechnology

The above are available for reference at www.akademisains.gov.my

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133. Universiti Pendidikan Sultan Idris (Malaysia)
134. Universiti Teknologi MARA (Malaysia)
135. Universiti Pertahanan Nasional Malaysia (Malaysia)
136. Universiti Utara Malaysia (Malaysia)
137. University of Nottingham Malaysia Campus (Malaysia)
138. University of Surrey (United Kingdom)
139. University College London (United Kingdom)
140. UTM Ocean Thermal Energy Centre (Malaysia)
141. UTM Razak School of Engineering & Advanced Technology (Malaysia)
142. Virginia Tech (United States)
143. Warwick University (United Kingdom)
144. Yayasan Hijau Malaysia (Malaysia)

GREEN TECHNOLOGY

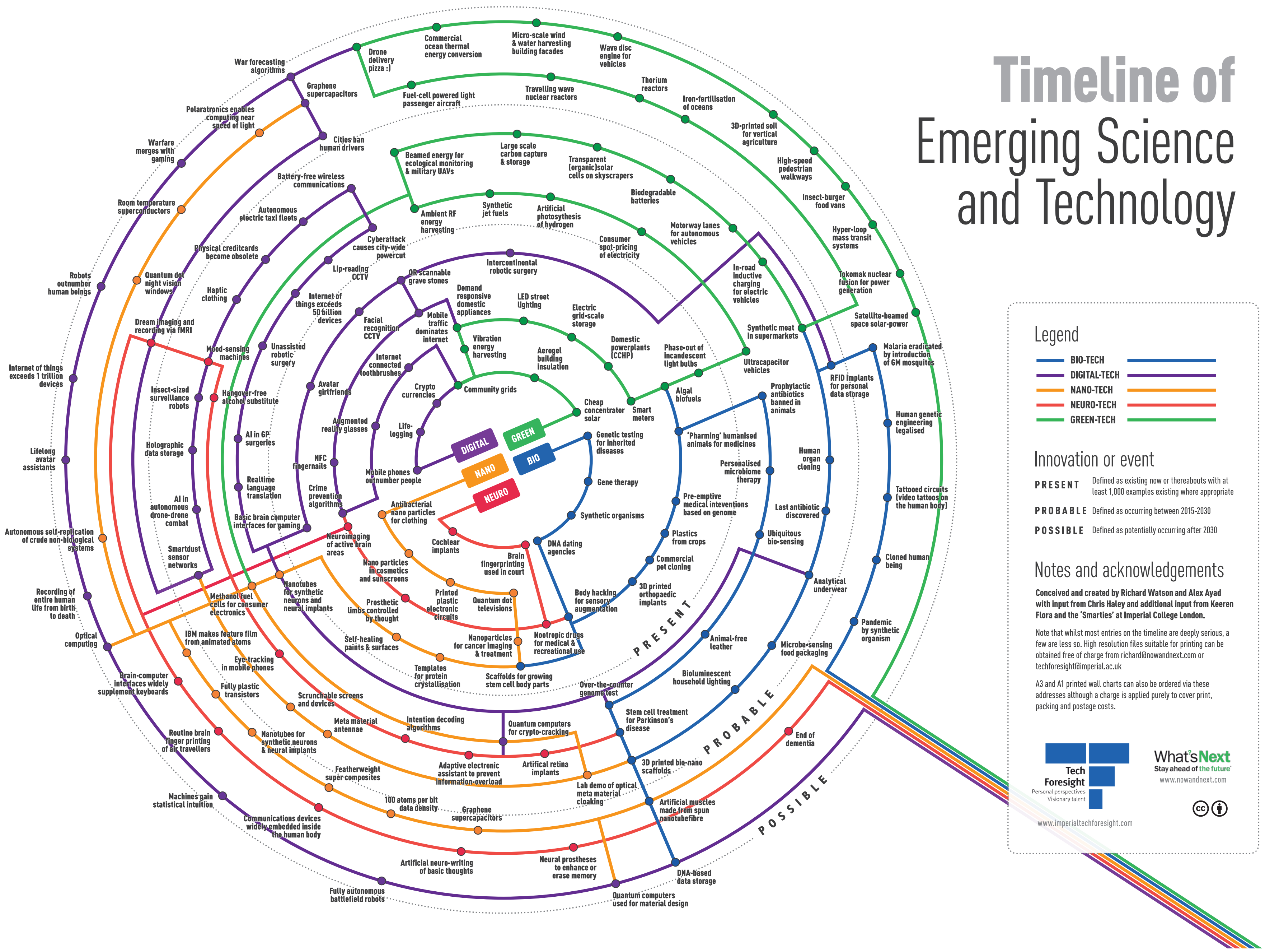
NEUROTECHNOLOGY

BIOTECHNOLOGY

APPENDICES

Appendices

Appendix 1: Timeline of Emerging Science of Technology



Appendix 2: 284 products, services, technologies, possible applications and outcomes relevant to Malaysia towards 2050.

NO.	ITEM	TIMELINE	CATEGORY	CLASSIFICATION
1	Genetic testing of inherited diseases for everyone	2015-2020	Biotechnology	Scenario
2	Rapid on-site diagnostic kits	2015-2020	Biotechnology, Digital technology	Scenario
3	Novel vaccines and delivery systems	2015-2020	Biotechnology, Nanotechnology	Scenario
4	Sustainable agriculture	2015-2020	Biotechnology, Digital Technology, Nanotechnology	Scenario
5	Improved detection of environmental toxic residues (food safety)	2015-2020	Biotechnology	Scenario
6	Valorisation of agricultural and industrial residue /biochemicals	2015-2020	Biotechnology, Green technology	Scenario
7	Digitised classroom	2015-2020	Digital Technology	Scenario
8	Super lightweight, fabric based transportation	2021-2035	Nanotechnology	Scenario
9	Nano-catalyst for transformation of hazardous material into fertilizer	2021-2035	Green technology, Nanotechnology	Scenario
10	Over-the-counter genome testing and pre-emptive medical interventions	2015-2020	Biotechnology	Scenario
11	Closed ecological systems (Urban farming & vertical farming)	2021-2035	Biotechnology, Digital technology	Scenario
12	Utilisation of wildlife species as alternative genetic materials for livestock improvement	2021-2035	Biotechnology	Scenario
13	Industrial scale insect farms as protein source for famine relief. More control on microfloras.	2021-2035	Biotechnology	Scenario
14	Teleportation	2036-2050	Digital technology, Nanotechnology	Scenario
15	Self-chargeable energy source	2036-2050	Green technology, Nanotechnology	Scenario
16	Lab demo of optical meta material cloaking	2036-2050	Nanotechnology	Scenario
17	Dream imaging and recording via fMRI	2036-2050	Digital technology, Neurotechnology	Scenario
18	Routine brain fingerprinting of air travellers	2036-2050	Digital technology, Neurotechnology	Scenario
19	Accurate virtual experimentation and full physiological simulation	2036-2050	Digital technology	Scenario
20	Virtual or augmented reality in the treatment of neurological disorders	2036-2050	Digital technology, Neurotechnology	Scenario
21	Augmentation of human capabilities beyond the normal biological and physical limitations	2036-2050	Digital technology, Neurotechnology	Scenario
22	Functional food/ designer food	2015-2020	Biotechnology	Scenario
23	Biohacking abuse of biological manipulation	2036-2050	Biotechnology, Digital technology	Scenario
24	Bioluminescent household and street lighting through bio-mimicry	2021-2035	Biotechnology, Green technology	Scenario
25	Communication devices widely embedded inside the brain	2036-2050	Digital technology, Neurotechnology	Scenario
26	Fully autonomous battlefield robots	2036-2050	Digital technology	Scenario
27	Fully body stimulation	2036-2050	Digital technology	Scenario
28	Hyper fast crime scene analysis	2036-2050	Digital technology	Scenario
29	Machines gain statistical intuition	2036-2050	Digital technology	Scenario
30	Gene therapy	2015-2020	Biotechnology	Scenario
31	Integration of medical knowledge, research discoveries and patients' medical history in a highly integrative network infrastructure	2036-2050	Digital technology	Scenario
32	Improved neuropharmacology for public health	2021-2035	Neurotechnology	Scenario
33	Psychiatry as clinical neuroscience	2021-2035	Neurotechnology	Scenario
34	Improved neuropharmacology as psychomotor stimulant	2021-2035	Neurotechnology	Scenario

NO.	ITEM	TIMELINE	CATEGORY	CLASSIFICATION
35	Predictive crime prevention	2021-2035	Digital technology, Neurotechnology	Scenario
36	Enhancing intelligence	2036-2050	Neurotechnology	Scenario
37	Brain computer interface widely supplements keyboards	2036-2050	Neurotechnology	Scenario
38	Artificial neuro-writing of basic thoughts	2036-2050	Digital technology, Neurotechnology	Scenario
39	3D printing of an artificial mind	2036-2050	Neurotechnology	Scenario
40	Precision agriculture	2015-2020	Biotechnology, Digital technology, Nanotechnology	Technology/ Platform
41	Biopharming ('Pharming' humanised animals/plants for medicines)	2015-2020	Biotechnology	Technology/ Platform
42	Hyper loop mass transit systems	2036-2050	Green technology	Technology/ Platform
43	Nano-sensorsIoT	2015-2020	Digital technology, Nanotechnology	Technology/ Platform
44	Nano-sensors	2015-2020	Digital technology, Nanotechnology	Technology/ Platform
45	Novel antimicrobial products	2015-2020	Biotechnology	Technology/ Platform
46	Biomarkers for diseases	2015-2020	Biotechnology,	Technology/ Platform
47	DNA based data storage	2015-2020	Biotechnology, Digital technology	Technology/ Platform
48	Biofuels/ Renewable energy	2015-2020	Biotechnology, Green technology	Technology/ Platform
49	Enzyme technology	2015-2020	Biotechnology, Green technology	Technology/ Platform
50	Basic brain computer interfaces for gaming	2015-2020	Digital technology, Nanotechnology	Technology/ Platform
51	Rainwater harvesting	2015-2020	Green technology	Technology/ Platform
52	Membrane technology	2015-2020	Green technology	Technology/ Platform
53	Wastewater nutrient recovery	2015-2020	Green technology	Technology/ Platform
54	Integrated co-processing technology	2015-2020	Green technology	Technology/ Platform
55	Algal biosequestration	2015-2020	Green technology	Technology/ Platform
56	Magnetic levitation	2021-2035	Nanotechnology	Technology/ Platform
57	100 atoms per bit data density	2021-2035	Nanotechnology	Technology/ Platform
58	Nanoelectrmagnetic communication (Terra-hertz band device)	2021-2035	Nanotechnology	Technology/ Platform
59	Nano-energy generator	2021-2035	Nanotechnology	Technology/ Platform
60	Quantum lighting	2021-2035	Nanotechnology	Technology/ Platform
61	Nano-based drug delivery system	2021-2035	Nanotechnology	Technology/ Platform
62	AI in GP surgeries	2021-2035	Digital technology, Neurotechnology	Technology/ Platform
63	Inter-continental robotic surgery	2021-2035	Digital technology	Technology/ Platform
64	Robots in farming	2021-2035	Biotechnology, Digital technology	Technology/ Platform
65	Holographic data storage	2021-2035	Digital technology	Technology/ Platform
66	Battery-free wireless communications	2021-2035	Digital technology	Technology/ Platform
67	Demand responsive domestic appliances	2021-2035	Digital technology	Technology/ Platform
68	Equipment telematics	2021-2035	Digital technology	Technology/ Platform
69	Eye-tracking in mobile phones	2021-2035	Digital technology	Technology/ Platform
70	Intention decoding algorithms	2021-2035	Digital technology	Technology/ Platform
71	Wireless bidirectional brain interface (sensing/stimulation)	2021-2035	Digital technology, Neurotechnology	Technology/ Platform
72	Ultra capacitor vehicles	2021-2035	Green technology	Technology/ Platform
73	Micro-hydro systems using rainwater in high rise building	2021-2035	Green technology	Technology/ Platform
74	Solar grey water disinfection	2021-2035	Green technology	Technology/ Platform
75	CO_2 to carbon nanotubes conversion	2036-2050	Green technology	Technology/ Platform
76	Brain wave technology	2036-2050	Neurotechnology	Technology/ Platform
77	Optical computing	2036-2050	Digital technology, Nanotechnology	Technology/ Platform

NO.	ITEM	TIMELINE	CATEGORY	CLASSIFICATION
78	Genetic profiling	2015-2020	Biotechnology	Technology/ Platform
79	Gene editing	2021-2035	Biotechnology	Technology/ Platform
80	Nanorobots	2036-2050	Digital technology, Nanotechnology	Technology/ Platform
81	Ultra-Fast, High-Resolution and High-Throughput Portable Machines	2036-2050	Digital technology, Nanotechnology	Technology/ Platform
82	Natural product derived therapeutics	2021-2035	Biotechnology	Technology/ Platform
83	Natural product derived supplements	2015-2020	Biotechnology	Technology/ Platform
84	Mindreading technology for security purpose	2036-2050	Digital technology, Neurotechnology	Technology/ Platform
85	Wave disc engines	2036-2050	Green technology	Technology/ Platform
86	Ocean thermal energy conversion	2036-2050	Green technology	Technology/ Platform
87	Biomimicry inspired wave and tidal energy	2036-2050	Biotechnology, Green technology	Technology/ Platform
88	Algal biophotovoltaics	2036-2050	Biotechnology, Green technology	Technology/ Platform
89	Small scale thorium reactor	2036-2050	Green technology, Nanotechnology	Technology/ Platform
90	Carbon storage in building material	2036-2050	Green technology, Nanotechnology	Technology/ Platform
91	Cognitive neurosciences & Neuroimaging of active brain areas	2015-2020	Digital technology, Neurotechnology	Technology/ Platform
92	Electrical neurostimulation	2015-2020	Neurotechnology	Technology/ Platform
93	Neural network image recognition	2015-2020	Digital technology, Neurotechnology	Technology/ Platform
94	Emotion tracking	2015-2020	Neurotechnology	Technology/ Platform
95	Regenerative brain parts	2021-2035	Biotechnology, Neurotechnology	Technology/ Platform
96	Restoration/regeneration of spinal cord	2036-2050	Neurotechnology	Technology/ Platform
97	Reverse engineering of the brain	2036-2050	Neurotechnology	Technology/ Platform
98	Nano-ferrite for electromagnetic shielding	2015-2020	Nanotechnology	Technology/ Platform
99	Nano-particles as carriers	2015-2020	Nanotechnology	Technology/ Platform
100	Bioremediation & phytoremediation – naturally occurring	2015-2020	Biotechnology, Green technology	Technology/ Platform
101	Marker assisted breeding (for livestock and plants)	2015-2020	Biotechnology	Technology/ Platform
102	3D printing	2015-2020	Digital technology, Nanotechnology	Technology/ Platform
103	Community grids	2015-2020	Digital technology	Technology/ Platform
104	Nano-based oncotherapy	2021-2035	Nanotechnology	Technology/ Platform
105	Nutrigenomics	2021-2035	Biotechnology	Technology/ Platform
106	Molecular markers for identification of important traits (disease-resistance, heat stress tolerance)	2021-2035	Biotechnology	Technology/ Platform
107	Protein engineering	2015-2020	Biotechnology	Technology/ Platform
108	Next generation brain to computer interfaces	2021-2035	Digital technology, Neurotechnology	Technology/ Platform
109	Smartdust sensor networks	2021-2035	Digital technology, Nanotechnology	Technology/ Platform
110	Smart grid distribution of renewable energy	2021-2035	Digital technology, Green technology	Technology/ Platform
111	Smart water monitoring	2021-2035	Digital technology, Green technology	Technology/ Platform
112	Integrated bio-refinery in palm oil mill	2015-2020	Biotechnology, Green technology	Technology/ Platform
113	Nanotubes for synthetic neurons and neural implants	2036-2050	Nanotechnology	Technology/ Platform
114	Quantum computers for crypto-cracking	2036-2050	Digital technology	Technology/ Platform
115	Quantum computers used for material design	2036-2050	Digital technology, Nanotechnology	Technology/ Platform

NO.	ITEM	TIMELINE	CATEGORY	CLASSIFICATION
116	Internet of Things (IoT)-Huge (big) data analytics and networking	2036-2050	Digital technology	Technology/ Platform
117	Deep learning neural networks with artificial intelligence	2021-2035	Digital technology, Neurotechnology	Technology/ Platform
118	Prosthetic limbs controlled by thought	2015-2020	Digital technology, Neurotechnology	Product/ Service
119	Cochlear implants	2015-2020	Neurotechnology	Product/ Service
120	Nootropic drugs for medical and recreational use	2015-2020	Neurotechnology	Product/ Service
121	Next generation neuroprosthetics	2021-2035	Digital technology, Neurotechnology	Product/ Service
122	Artificial retina implants	2021-2035	Neurotechnology	Product/ Service
123	Adaptive electronic assistant to prevent information overload	2021-2035	Digital technology, Neurotechnology	Product/ Service
124	Bidirectional interface for vegetative/coma patients	2036-2050	Digital technology, Neurotechnology	Product/ Service
125	Neural protheses to enhance or erase memory	2036-2050	Digital technology, Neurotechnology	Product/ Service
126	Brain fingerprinting to be used in court	2015-2020	Digital technology, Neurotechnology	Product/ Service
127	Improved treatment of dementia	2021-2035	Neurotechnology	Product/ Service
128	Predictive group sentiment analysis	2021-2035	Digital technology, Neurotechnology	Product/ Service
129	In-vitro meat for public consumption in Malaysia	2021-2035	Biotechnology	Product/ Service
130	Biologics	2015-2020	Biotechnology	Product/ Service
131	3D printed soil for vertical farming	2036-2050	Biotechnology, Digital technology	Product/ Service
132	Microbial fuel cell	2021-2035	Biotechnology, Green technology	Product/ Service
133	Nano-fibre for tissue engineering	2015-2020	Biotechnology, Nanotechnology	Product/ Service
134	Nano-nutraceutical	2015-2020	Biotechnology, Nanotechnology	Product/ Service
135	Antibacterial nano-particles for clothing	2015-2020	Nanotechnology	Product/ Service
136	Nano-catalyst	2015-2020	Nanotechnology	Product/ Service
137	Nano-cellulose	2015-2020	Nanotechnology	Product/ Service
138	3D printing of edible films	2015-2020	Digital technology, Nanotechnology	Product/ Service
139	Gene manipulated gamete	2021-2035	Biotechnology	Product/ Service
140	Human organ cloning	2021-2035	Biotechnology	Product/ Service
141	Semantic Web (Web 3.0)	2015-2020	Digital technology	Product/ Service
142	Methanol fuel cells for consumer electronics	2021-2035	Green technology, Nanotechnology	Product/ Service
143	Quantum solar cells	2021-2035	Nanotechnology	Product/ Service
144	Nano-based solid oxide ion fuel cells	2021-2035	Green technology, Nanotechnology	Product/ Service
145	Bullet-proof nanocomposite material	2015-2020	Nanotechnology	Product/ Service
146	Graphene-based batteries	2015-2020	Nanotechnology	Product/ Service
147	Nano-lubricant for engines	2015-2020	Nanotechnology	Product/ Service
148	Nano-coolant for the engines	2015-2020	Nanotechnology	Product/ Service
149	Nano-coating	2015-2020	Nanotechnology	Product/ Service
150	Scrunchable screens and devices	2015-2020	Nanotechnology	Product/ Service
151	Nanowire LED	2015-2020	Nanotechnology	Product/ Service
152	Dye-sensitized solar cell (DSSC)	2015-2020	Green technology, Nanotechnology	Product/ Service
153	Nano biodegradable material	2015-2020	Nanotechnology	Product/ Service
154	Nano-fertilizer	2015-2020	Nanotechnology	Product/ Service
155	3D printed orthopaedic implants	2015-2020	Biotechnology	Product/ Service
156	Micro-sensing food packaging	2015-2020	Biotechnology	Product/ Service

NO.	ITEM	TIMELINE	CATEGORY	CLASSIFICATION
157	Augmented reality glasses	2015-2020	Digital technology	Product/ Service
158	Facial recognition CCTV	2015-2020	Digital technology	Product/ Service
159	Livestock biometrics	2015-2020	Digital technology	Product/ Service
160	NFC fingerprints	2015-2020	Digital technology	Product/ Service
161	Real-time language translation	2015-2020	Digital technology	Product/ Service
162	RFID implants for personal storage	2015-2020	Digital technology	Product/ Service
163	Smart meters	2015-2020	Digital Technology	Product/ Service
164	Aerogel insulation	2015-2020	Green technology, Nanotechnology	Product/ Service
165	Electric vehicles and public transportation	2015-2020	Green technology	Product/ Service
166	Hybrid vehicles	2015-2020	Green technology	Product/ Service
167	Controlled release fertilizers	2015-2020	Green technology	Product/ Service
168	Autonomous vehicle	2015-2020	Digital technology, Green technology	Product/ Service
169	Solid biofuel	2015-2020	Biotechnology, Green technology	Product/ Service
170	Nanotech improved LED lightbulbs	2015-2020	Green technology, Nanotechnology	Product/ Service
171	3D printed bio-nano scaffolds	2021-2035	Biotechnology, Nanotechnology	Product/ Service
172	Artificial muscles from spun nano-fibre	2021-2035	Biotechnology, Nanotechnology	Product/ Service
173	Quantum dot televisions	2021-2035	Digital technology, Nanotechnology	Product/ Service
174	3D printed body panels	2021-2035	Nanotechnology	Product/ Service
175	Nano based touchscreen windscreen	2021-2035	Nanotechnology	Technology/ Platform
176	Meta-material antennae	2021-2035	Nanotechnology	Product/ Service
177	Printed and flexible electronics	2021-2035	Digital technology, Nanotechnology	Technology/ Platform
178	Scaffolds for growing stem cell body parts	2021-2035	Biotechnology, Nanotechnology	Product/ Service
179	Nano-based health diagnostic kits	2021-2035	Biotechnology, Nanotechnology	Product/ Service
180	Nano-implants	2021-2035	Nanotechnology	Product/ Service
181	Self-healing paints and surfaces	2021-2035	Nanotechnology	Product/ Service
182	Featherweight super composites	2021-2035	Nanotechnology	Product/ Service
183	Synthetic simple organisms (microorganism)	2021-2035	Biotechnology	Product/ Service
184	Autonomous vehicles	2021-2035	Digital technology, Green technology	Product/ Service
185	Analytical underclothing	2021-2035	Digital technology	Product/ Service
186	Crop sensors	2015-2020	Biotechnolgu, Digital technology	Product/ Service
187	Crypto currencies	2021-2035	Digital technology	Product/ Service
188	Haptic clothing	2021-2035	Digital technology, Neurotechnology	Product/ Service
189	Insect-sized surveillance robots	2021-2035	Digital technology	Product/ Service
190	Interconnected tooth-brushes	2021-2035	Digital technology	Product/ Service
191	Lip reading CCTV	2021-2035	Digital technology	Product/ Service
192	Mood-sensing machines	2021-2035	Digital technology	Product/ Service
193	Over-the-counter genome test	2015-2020	Biotechnology, Digital technology	Product/ Service
194	QR scannable grave stones	2021-2035	Digital technology	Product/ Service
195	Single global e-currency	2021-2035	Digital technology	Product/ Service
196	Hydrogen fuel cell vehicles	2021-2035	Green technology	Product/ Service
197	Photovoltaic thermal hybrid solar collectors	2021-2035	Green technology, Nanotechnology	Product/ Service
198	Carbon nanotubes light bulbs	2021-2035	Green technology, Nanotechnology	Product/ Service

NO.	ITEM	TIMELINE	CATEGORY	CLASSIFICATION
199	Quantum dot night vision windows	2036-2050	Digital technology, Nanotechnology	Product/ Service
200	Room temperature superconductors	2036-2050	Digital technology, Nanotechnology	Product/ Service
201	Nano-robots for diagnostic	2036-2050	Digital technology, Nanotechnology	Product/ Service
202	Nano superfood	2036-2050	Biotechnology, Nanotechnology	Product/ Service
203	Unassisted robotic surgery	2036-2050	Digital technology	Product/ Service
204	Wearables and gamification of health tracking	2036-2050	Digital technology	Product/ Service
205	Designer crop	2036-2050	Biotechnology	Product/ Service
206	Designer livestock	2021-2035	Biotechnology	Product/ Service
207	RFID implants for 'big' data storage	2036-2050	Biotechnology, Digital technology	Product/ Service
208	High-speed pedestrian walkaways	2036-2050	Digital technology, Green technology	Product/ Service
209	Virtual/Physical studios	2036-2050	Digital technology	Product/ Service
210	War forecasting algorithms	2036-2050	Digital technology	Product/ Service
211	Warface merges with gaming	2036-2050	Digital technology	Product/ Service
212	Jet fuel via hydrothermal liquefaction	2036-2050	Green technology	Product/ Service
213	CO2 collector for vehicles	2036-2050	Green technology	Product/ Service
214	Bioplastics (Plastic from crops)	2015-2020	Biotechnology, Green technology	Product/ Service
215	Personalised microbiome therapy for general diseases	2015-2020	Biotechnology	Product/ Service
216	Biobanking (DNA, tissues, etc.)	2015-2020	Biotechnology	Product/ Service
217	Immunotherapy (targeted) therapy	2015-2020	Biotechnology	Product/ Service
218	Life-logging	2015-2020	Digital technology	Product/ Service
219	Gene therapy and stem cell treatment for degenerative diseases	2021-2035	Biotechnology, Neurotechnology	Product/ Service
220	Avatar girlfriends	2036-2050	Digital technology	Product/ Service
221	Lifelong avatar assistants	2036-2050	Digital technology	Product/ Service
222	Data encryption	2015-2020	Digital technology	Product/ Service
223	Secure, usable and transparent internet voting system	2036-2050	Digital technology	Product/ Service
224	On-line self-registration	2021-2035	Digital technology	Product/ Service
225	End-to-end verifiable internet voting system	2021-2035	Digital technology	Product/ Service
226	Brain wave scanner	2036-2050	Digital technology, Neurotechnology	Product/ Service
227	Cyber security	2015-2020	Digital technology	Technology/ Platform
228	Cryptography	2015-2020	Digital technology	Technology/ Platform
229	Multiple biometric recognition	2015-2020	Digital technology	Technology/ Platform
230	Blockchain	2021-2035	Digital technology	Technology/ Platform
231	Brain fingerprinting	2015-2020	Digital technology, Neurotechnology	Technology/ Platform
232	On-line biometric recognition payment system	2021-2035	Digital technology	Product/ Service
233	Online digital signature	2015-2020	Digital technology	Product/ Service
234	Mobile payment system	2015-2020	Digital technology	Technology/ Platform
235	Pressure and motion sensor	2015-2020	Nanotechnology	Technology/ Platform
236	Open data platform	2015-2020	Digital technology	Product/ Service
237	Distributed digital ledger	2021-2035	Digital technology	Product/ Service
238	Cloud computing	2015-2020	Digital technology	Technology/ Platform
239	Big data analytics	2015-2020	Digital technology	Technology/ Platform
240	Firewall network security	2015-2020	Digital technology	Product/ Service
241	Digital crowdsourcing platform	2015-2020	Digital technology	Product/ Service
242	Digital and open tendering system	2021-2035	Digital technology	Product/ Service
243	Machine readable data (metadata)	2015-2020	Digital technology	Technology/ Platform
244	Holographic memory	2021-2035	Digital technology	Product/ Service
245	DNA digital data storage	2021-2035	Biotechnology, Digital technology	Product/ Service

NO.	ITEM	TIMELINE	CATEGORY	CLASSIFICATION
246	Public sentiment analysis	2015-2020	Digital technology	Product/ Service
247	Predictive algorithm	2015-2020	Digital technology	Technology/ Platform
248	Mood sensing algorithm	2015-2020	Digital technology, Neurotechnology	Technology/ Platform
249	Data analytics	2015-2020	Digital technology	Product/ Service
250	Artificial intelligence	2021-2035	Digital technology	Technology/ Platform
251	Digital paper	2021-2035	Digital technology	Product/ Service
252	Smart data collection devices	2015-2020	Digital technology	Product/ Service
253	Cloud network	2015-2020	Digital technology	Product/ Service
254	RFID	2015-2020	Digital technology	Technology/ Platform
255	Plant disease biosensor	2021-2035	Biotechnology, Digital technology, Nanotechnology,	Product/ Service
256	Intelligent and precision agriculture solutions	2021-2035	Biotechnology, Digital technology, Nanotechnology,	Product/ Service
257	Next generation wireless internet connection	2021-2035	Digital technology	Product/ Service
258	Virtual reality	2015-2020	Digital technology	Technology/ Platform
259	Desktop 3D printer	2015-2020	Digital technology	Product/ Service
260	3D printing cartridge	2015-2020	Digital technology, Nanotechnology	Product/ Service
261	AI assisted medical diagnosis and decision	2036-2050	Digital technology, Neurotechnology	Product/ Service
262	Cryopreservation	2015-2020	Biotechnology, Nanotechnology	Technology/ Platform
263	Smart energy monitoring and network	2015-2020	Digital technology, Green technology, Nanotechnology,	Technology/ Platform
264	Information communication and network	2015-2020	Digital technology	Technology/ Platform
265	Voice recognition	2015-2020	Digital technology	Technology/ Platform
266	Augmented reality	2015-2020	Digital technology	Technology/ Platform
267	Robotics	2021-2035	Digital technology	Technology/ Platform
268	Translation engine	2015-2020	Digital technology	Technology/ Platform
269	Geographical information system	2015-2020	Digital technology	Technology/ Platform
270	Image recognition algorithm	2015-2020	Digital technology	Technology/ Platform
271	Unmanned aerial vehicle	2015-2020	Digital technology	Technology/ Platform
272	Nanomaterials	2021-2035	Nanotechnology	Technology/ Platform
273	Fuel cell	2021-2035	Green technology, Nanotechnology	Technology/ Platform
274	Biomimicry	2015-2020	Biotechnology, Green technology	Technology/ Platform
275	Photovoltaic cell	2021-2035	Green technology, Nanotechnology	Technology/ Platform
276	Metamaterial	2021-2035	Nanotechnology	Technology/ Platform
277	Visual speech recognition	2015-2020	Digital technology	Technology/ Platform
278	Stem cell	2021-2035	Biotechnology	Technology/ Platform
279	Regenerative medicine	2021-2035	Biotechnology	Technology/ Platform
280	Quantum encryption	2036-2050	Nanotechnology	Technology/ Platform
281	Quantum photocells	2036-2050	Green technology, Nanotechnology	Technology/ Platform
282	5G internet	2021-2035	Digital Technology	Technology/ Platform
283	Self-energy generation system	2021-2035	Green technology, Nanotechnology	Product/ Service
284	4D Printing	2015-2020	Digital technology, nanotechnology	Technology/ Platform

Appendix 3: 95 Emerging Technologies for Malaysia Towards 2050.

NO.	LIST OF EMERGING TECHNOLOGIES	TECHNOLOGY AREA	TIMELINE	DEFINITION	REFERENCE
1	Algal biosequestration	Biotechnology, Green technology	2015-2020	Sequestration of carbon dioxide emitted from atmospheric CO_2 and flue gases such as coal, petroleum or natural gas-fired electricity generation by algae	https://en.wikipedia.org/wiki/Biosequestration
2	Integrated co-processing technology	Green technology	2015-2020	Turning waste into alternative fuels for energy intensive industrial processes	ASM ESET study, 2017
3	Wastewater nutrient recovery	Green technology	2015-2020	Practice of recovering nutrients such as nitrogen and phosphorus from wastewater and converted into an environmental friendly fertilizer used for ecological and agricultural purposes.	http://www.waterworld.com/articles/print/volume-31/issue-2/features/nutrient-recovery-technology-transforms-world-s-largest-wastewater-treatment-plant.html
4	Membrane technology	Green technology, Nanotechnology	2015-2020	Membrane filtration capable of treating almost any type of contaminated water, to purify it to any desired product-water quality	http://www.wcponline.com/2016/01/15/membrane-separation-and-filtration-tried-and-true-technologies/
5	Smart energy monitoring and network	Digital technology, Green technology	2015-2020	Smart energy systems as a prime pervasive computing application area, dynamically mitigating energy use by measuring, inferring, manipulating, and leveraging human behaviour and context across various domains and environments	https://web.eecs.umich.edu/~prabal/pubs/papers/paradiso11ses.pdf
6	Smart grid distribution of renewable energy	Digital technology, Green technology	2021-2035	The cooperation of many systems of renewable energy is possible through management of systems, called “Smart Grid”.	http://zpue.com/smart-energy-management-system-smart-grid
7	Rainwater harvesting	Green technology	2015-2020	The practice of collecting rainwater from a roof or other surface and using it to augment freshwater supplies.	http://www.sustainabletechnologies.ca/wp/home/urban-runoff-green-infrastructure/low-impact-development/rainwater-harvesting/
8	Ultra capacitor vehicles	Green technology	2021-2035	Storing energy for vehicles in electric fields rather than chemical cells. Capacitors are preferable to batteries because of their energy storage characteristics. As nanomaterials improve, it is realistic to expect that electric vehicle batteries could be replaced by ultra-capacitors.	ASM ESET study, 2017
9	Integrated bio-refinery in palm oil mill	Biotechnology, Green technology	2015-2020	Retrofit palm oil mills with biorefinery for further processing biomasses into higher value products, such as biofuels, biochemicals, and bio-based food while reducing waste.	ASM ESET study, 2017
10	Biofuels/ Renewable energy	Biotechnology, Green technology	2015-2020	Renewable fuels, or "biofuels" like ethanol and biodiesel, are liquid transportation fuels made from agricultural crops like corn and soybeans.	http://www.25x25.org/index.php?option=com_content&task=view&id=16&Itemid=45
11	Bioremediation & phytoremediation – naturally occurring	Biotechnology	2015-2020	Cleaning up contamination using biological organisms such as microbes or plants	http://pubs.sciepub.com/plant/1/3/4/
12	Micro-hydro systems using rainwater in high rise building	Green technology	2021-2035	Hydro power is a renewable, non-polluting and environmentally source of energy. Moving water fall on turbine the turbine spins a generator and electricity is produced	https://www.irjet.net/archives/V3/i2/IRJET-V3I2294.pdf

NO.	LIST OF EMERGING TECHNOLOGIES	TECHNOLOGY AREA	TIMELINE	DEFINITION	REFERENCE
13	Solar grey water disinfection	Green technology	2021-2035	Recycling of greywater (wastewater from sinks, bath tub shower drains and etc.) using solar energy for disinfection for non-potable use	ASM ESET study, 2017
14	Smart water monitoring	Digital technology, Green technology	2021-2035	A smart water network is an integrated set of products, solutions and systems that enable utilities to remotely and continuously monitor and diagnose problems, prioritize and manage maintenance issues and use data to optimize all aspects of the water distribution network.	http://sensus.com/smart-water-network/
15	Photovoltaic cell	Green technology, Nanotechnology	2021-2035	A specialized semiconductor diode that converts visible light into direct current.	http://whatis.techtarget.com/definition/photovoltaic-cell-PV-Cell
16	Nano-energy generator	Green technology, Nanotechnology	2021-2035	Nanogenerators are generators that harvest energy from the environment for nanosystems	sign.com/blog/what-all-nanogenerator-stuff-anyway
17	Fuel cell	Green technology, Nanotechnology	2021-2035	A cell producing an electric current directly from a chemical reaction.	ASM ESET study, 2017
18	Ocean thermal energy conversion	Green technology	2036-2050	A method of converting part of the heat from the Sun, which is stored in the surface layers of a body of water into electrical energy or energy product equivalent	US Public Law 1980
19	Wave disc engines	Green technology	2036-2050	A new implementation of wave rotor technology. Wave rotors are unsteady-flow devices that utilize shock waves to transfer energy directly between a high-energy fluid to a low-energy fluid, thereby increasing both temperature and pressure of the low-energy fluid. Wave rotor technology has shown a significant potential for performance improvement of thermodynamic cycles.	http://www.greencarcongress.com/2009/10/michigan-state-university-receives-25m-arpae-award-to-build-wave-disc-enginegenerator-for-series-hyb.html
20	Carbon storage in building material	Green technology	2036-2050	Carbon capture technology that uses building materials such as bricks as physical carbon sinks	ASM ESET study, 2017
21	Hyper loop mass transit system	Green technology	2036-2050	A mode of transportation that moves freight and people quickly, safely, on-demand and direct from origin to destination through a low-pressure tube which accelerate gradually via electric propulsion. The vehicle quickly lifts above the track using magnetic levitation and glides at airline speeds for long distances due to ultra-low aerodynamic drag.	https://hyperloop-one.com/
22	Algal biophotovoltaics	Biotechnology, Green technology	2036-2050	Energy generation using oxygenic photoautotrophic organisms that converts harvested light energy into electricity	ASM ESET study, 2017
23	Biomimicry inspired wave and tidal energy	Biotechnology, Green technology	2036-2050	Technology that seeks optimization through emulating nature's time-tested patterns and strategies to increase productivity	ASM ESET study, 2017
24	CO2 to carbon nanotubes conversion	Green technology, Nanotechnology	2036-2050	Use of solar thermal electrochemical process to provide both the electrical and thermal energy needed to break down carbon dioxide into carbon and oxygen and to produce carbon nanotubes, which are stable, flexible, conductive and stronger than steel.	http://www.kurzweilai.net/converting-atmospheric-carbon-dioxide-into-carbon-nanotubes-for-use-in-batteries
25	Small scale thorium reactor	Green technology, Nanotechnology	2036-2050	Thorium is a radioactive chemical element that could in theory be used to generate large quantities of low-carbon electricity in future decades. The construct small size reactor that could produce around 600MW each.	https://www.linkedin.com/pulse/20140608135512-97196790-nanotechnology-can-aid-in-developing-small-size-thorium-fuelled-ads-reactors
26	Nanorobots	Nanotechnology	2036-2050	Nanorobotics is the technology of creating machines or robots at or close to the scale of a nanometre (10^{-9} metres).	https://www.sciencedaily.com/terms/nanorobotics.htm

NO.	LIST OF EMERGING TECHNOLOGIES	TECHNOLOGY AREA	TIMELINE	DEFINITION	REFERENCE
27	Nano based touchscreen windscreen	Nanotechnology	2021-2035	For emerging touchscreen applications, including large-area touchscreens, as well as miniature, flexible, wearable displays, silver nanowires offer a significant advantage in both cost and performance. The material is coated on a flexible roll of film that's a few feet wide and could go a mile in length, using a roll-to-roll process.	http://electronicdesign.com/displays/silver-nanowires-infuse-flexibility-consumer-electronics-design
28	Magnetic levitation	Nanotechnology	2021-2035	A process by which a magnet moving over a piece of m etal causes electriccurrents to flow in the metal that, in turn, produce forces that push themagnet upwar. If th e force is large enough, the moving magnet can float (be levitated)	ASM ESET study, 2017
29	Nanomaterials	Nanotechnology	2021-2035	A material having particles or constituents of nanoscale dimensions, or one that is produced by nanotechnology.	ASM ESET study, 2017
30	Nano-based drug delivery system	Nanotechnology	2021-2035	Nanoparticles are taken up by cells more efficiently than larger micromolecules and therefore, could be used as effective transport and delivery systems.	ASM ESET study, 2017
31	Pressure and motion sensor	Nanotechnology	2015-2020	A motion sensor is an instrument that detects moving objects which often integrated as a component of system that automatically performs a task or alerts a user of motion in an area.	ASM ESET study, 2017
32	Metamaterial	Nanotechnology	2021-2035	Metamaterials are artificially structured materials used to control and manipulate light, sound, and many other physical phenomena	https://metamaterials.duke.edu/definition
33	Smartdust sensor networks	Digital technology, Nanotechnology	2021-2035	"Smart Dust" is an emerging technology made up from tiny, wireless sensors or "motes." Smart dust consists of sensing, computing, wireless communication capabilities and autonomous power supply within volume of only few millimetres and that too at low cost.	https://www.ijarse.com/images/fullpdf/1382192102_SMART_DUST_AN_EMERGING_TECHNOLOGY.pdf
34	Printing and flexible electronics	Digital technology, Nanotechnology	2021-2035	Nanomaterials offer tunability in terms of performance, solution processability and processing temperature requirements, which makes them very attractive as building blocks for flexible electronic systems.	ASM ESET study, 2017
35	Cognitive neurosciences & neuroimaging of active brain parts	Digital technology, Neurotechnology	2015-2020	Cognitive neuroscience is the branch that looks at how the brain works to inform and constrain theories about cognition while neuroimaging is the tool referring to any means of visualizing the brain; the great advantage of neuroimaging is that it lets us look inside the skulls of living people.	http://sitn.hms.harvard.edu/flash/2012/cognitive-neuroscience/
36	Nanosensors	Nanotechnology	2015-2020	Nanosensors are chemical or mechanical sensors that can be used to detect the presence of chemical species and nanoparticles, or monitor physical parameters such as temperature, on the nanoscale.	http://www.nature.com/subjects/nanosensors
37	Battery-free wireless communications	Digital technology	2021-2035	This new wireless communication system provides connectivity between computers out of what is essentially thin air. It takes us a step closer to an Internet of Things reality as it lets devices talk to each other without relying on batteries or wires for power. Instead, it taps into already existing ambient Wi-Fi, TV or cellular signals to exchange information	http://www.computerworld.com/article/2474512/emerging-technology/researchers-create-battery-free-wireless-communication--out-of-thin-air-.html
38	NanosensorsIoT	Digital technology, Nanotechnology	2015-2020	The Internet of Things (IoT), built from inexpensive microsensors and microprocessors paired with tiny power supplies and wireless antenna.	http://blogs.lexisnexis.co.uk/futureoflaw/2016/12/emerging-technologies-and-the-law-nano-sensors-and-the-internet-of-nano-things/

NO.	LIST OF EMERGING TECHNOLOGIES	TECHNOLOGY AREA	TIMELINE	DEFINITION	REFERENCE
39	3D printing	Digital technology, Nanotechnology	2015-2020	3D printing is a process for making three-dimensional solid objects from digital models	State and outlook 2015, The European Environment Agency
40	Holographic data storage	Digital technology	2021-2035	Holographic storage is capable of recording and reading millions of bits in parallel, enabling data transfer rates greater than those attained by traditional optical storage.	ASM ESET study, 2017
41	Inter-continental robotic surgery	Digital technology	2021-2035	Telesurgery" on patients anywhere in the world. Doctors used a combination of computers, telecommunications, videoconferencing and advanced surgical robots to guide surgery that was actually being carried out thousands of miles away.	ASM ESET study, 2017
42	Community grids	Digital technology	2015-2020	A group of interconnected loads and distributed energy resources with clearly defined electrical boundaries that act as a single controllable entity with respect to the grid.	http://cityminded.org/community-microgrids-envisioning-grid-future-11998#
43	Image recognition algorithm	Digital technology	2015-2020	An image recognition algorithm (a.k.a an image classifier) takes an image (or a patch of an image) as input and outputs what the image contains.	http://www.learnopencv.com/image-recognition-and-object-detection-part1/
44	Visual speech recognition	Digital technology	2015-2020	A typical VSR system consists of three major stages: detecting/localizing human faces, lips localization and lip reading. The accuracy of a VSR system is heavily dependent on accurate lip localisation as well as the robustness of the extracted features.	http://www.intechopen.com/books/speech-and-language-technologies/visual-speech-recognition
45	Machine readable data (metadata)	Digital technology	2015-2020	Data (or metadata) which is in a format that can be understood by a computer	ASM ESET study, 2017
46	Radio Frequency Identification	Digital technology	2015-2020	Use of radio waves to automatically identify people or objects.	ASM ESET study, 2017
47	Demand responsive domestic appliances	Digital technology	2021-2035	Changes in electric usage by demand-side resources from their normal consumption patterns in response to changes in the price of electricity over time, or to incentive payments designed to induce lower electricity use at times of high wholesale market prices or when system reliability is jeopardized.	https://www.ferc.gov/industries/electric/indus-act/demand-response/dem-res-adv-metering.asp
48	Regenerative brain parts	Biotechnology, Neurotechnology	2021-2035	Neuroregeneration refers to the regrowth or repair of nervous tissues, cells or cell products. Such mechanisms may include generation of new neurons, glia, axons, myelin, or synapses.	https://en.wikipedia.org/wiki/Neuroregeneration
49	Cloud computing	Digital technology	2015-2020	Usage of various services, such as software development platforms, servers, storage, over the Internet are often referred to as the'Cloud'.	Advisory report on Cyber Security, ASM 2017
50	Predictive algorithm	Digital technology	2015-2020	Predictive analytics encompasses a variety of statistical techniques from predictive modeling, machine learning, and data mining that analyze current and historical facts to make predictions about future or otherwise unknown event.	ASM ESET study, 2017
51	Geographical information system	Digital technology	2015-2020	A computer system for capturing, storing, checking, and displaying data related to positions on Earth's surface.	http://www.nationalgeographic.org/encyclopedia/geographic-information-system-gis/
52	Robotics	Digital technology	2021-2035	Robotics as an integrated system of control interacting with the physical world	http://www.electronicsteacher.com/robotics/what-is-robotics.php
53	Equipment telematics	Digital technology	2021-2035	Use radio frequency identification to track machines, and even to learn how to better use equipment for greater efficiency	15 Emerging Agriculture Technologies That Will Change The World, Business Insider 2014

NO.	LIST OF EMERGING TECHNOLOGIES	TECHNOLOGY AREA	TIMELINE	DEFINITION	REFERENCE
54	Cryptography	Digital technology	2015-2020	The art of writing or solving codes	Advisory report on Cyber Security, ASM 2017
55	Multiple biometric recognition	Digital technology	2015-2020	Multi-Biometrics is an authentication technology using different biometric technologies such as fingerprints, facial features, and vein patterns in the identification and verification process. The use of Multi-Biometrics takes advantages of the capabilities of each biometric technology while overcoming the limitations of a single technology.	http://www.nec.com/en/global/solutions/biometrics/technologies/multi_biometrics.html
56	Translation engine	Digital technology	2015-2020	Translation engine" is a common name for a "transformation engine" that converts documents from one document definition to another through "transformation maps.	http://www.filetransferglossary.com/translation-engine/
57	Big data analytics	Digital technology	2015-2020	Big data analytics is the process of examining large data sets to uncover hidden patterns, unknown correlations, market trends, customer preferences and other useful business information.	http://searchbusinessanalytics.techtarget.com/definition/big-data-analytics
58	Augmented reality	Digital technology	2015-2020	A concept of adding information and imagery to your existing environment that can give you full-color "apps" within a supplemental, glance able screen; eg: glasses that provide notifications and visual systems that can make your science fiction movie dreams a reality.	ASM ESET study
59	Cyber security	Digital technology	2015-2020	Preventative methods used to protect information from being stolen, compromised or attached in the cyber world	Advisory report on Cyber Security, ASM 2017
60	Artificial intelligence	Digital technology, Neurotechnology	2021-2035	A branch of computer science that imitates and automates intelligence behaviour of human and nature into a computing environment.	Advisory report on Cyber Security, ASM 2017
61	Blockchain	Digital technology	2021-2035	Distributed electronic ledger that uses software algorithms to record and confirm transactions with reliability and anonymity. The record of events is shared between many parties and information once entered cannot be altered, as the downstream chain reinforces upstream transactions.	http://www.pwc.com/gx/en/issues/technology/tech-breakthroughs-megatrend.html
62	Ultra-Fast, High-Resolution and High-Throughput Portable Machines	Digital technology, Nanotechnology	2036-2050	Portable machines that can capture a lot of information from patients at high resolution and in a short time.	ASM ESET study, 2017
63	Internet of Things (IoT)-Huge (big) data analytics and networking	Nanotechnology, Digital technology	2036-2050	A computing concept that describes the idea of everyday physical objects being connected to the Internet and being able to identify themselves to other devices.	Advisory report on Cyber Security, ASM 2017
64	Mobile payment system	Digital technology	2015-2020	Technologies being used for mobile payments include Near Field Communication (NFC), Bluetooth, WiFi, and RFI, a short-range transmission system.	http://searchmobilecomputing.techtarget.com/definition/m-payment
65	Information communication and network	Digital technology	2015-2020	The technology processes, stores and transfers information allows everyone across the world to collaborate and provide access to unprecedented amounts of data and information	State and outlook 2015, The European Environment Agency
66	Unmanned aerial vehicle	Digital technology	2015-2020	An aircraft that carries no human pilot or passengers. Sometimes called "drones" — can be fully or partially autonomous but are more often controlled remotely by a human pilot	http://www.rand.org/topics/unmanned-aerial-vehicles.html
67	Voice recognition	Digital technology	2015-2020	Technology that enables a machine or computer program to receive and interpret dictation or to understand and carry out spoken commands.	ASM ESET study, 2017
68	Virtual reality	Digital technology	2015-2020	Computer-generated simulation of a three-dimensional image or a complete environment, within a defined and contained space (unlike AR), that viewers can	http://www.pwc.com/gx/en/issues/technology/tech-breakthroughs-

NO.	LIST OF EMERGING TECHNOLOGIES	TECHNOLOGY AREA	TIMELINE	DEFINITION	REFERENCE
				interact with in realistic ways. VR is intended to be an immersive experience and typically requires equipment, most commonly a helmet/headset.	megatrend.html
69	Mood sensing algorithm	Digital technology, Neurotechnology	2015-2020	Mood sensing can enable users to digitally communicate closer to the way they would in real life. For mood sharing, an automatic mood sensor will not only improve the usability but also more importantly, lower the social barrier for a user to share their mood: we do not directly tell others our mood very often, but we do not try to conceal our mood very often either.	http://mashable.com/2013/07/01/microsoft-mood-technology/#0GBu_xifRZqD
70	Brain fingerprinting	Digital technology, Neurotechnology	2015-2020	Brain fingerprinting detects concealed information stored in the brain by measuring brainwaves.	https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3311838/
71	Basic brain computer interfaces for gaming	Digital technology, Neurotechnology	2015-2020	A direct communication pathway between the brain and an external device. BCIs are often directed at assisting, augmenting, or repairing human cognitive or sensory-motor functions	ASM ESET study, 2017
72	Next generation brain to computer interfaces	Digital technology, Neurotechnology	2021-2035	A direct communication pathway between an enhanced or wired brain and an external device for researching, mapping, assisting, augmenting, or repairing human cognitive or sensory-motor functions.	ASM ESET study, 2017
73	Wireless bidirectional brain interface (sensing/stimulation)	Digital technology, Neurotechnology	2021-2035	Wireless integration of mechanism between recording and the relaying of information from and to the brain for the development of brain-computer interfaces	http://ieeexplore.ieee.org/document/5334562/
74	Mindreading technology for security purpose	Digital technology, Neurotechnology	2036-2050	Interpretation of human thought or cognition by brain activity without depending on speech or action.	https://en.wikipedia.org/wiki/Mind_reading_computers
75	Brainwave technology	Digital technology, Neurotechnology	2036-2050	Brainwave technology is an emergent technology, part of the still largely uncharted frontier of brain-computer interfaces and communication.	ASM ESET study, 2017
76	Nanotubes for synthetic neurons and neural implants	Nanotechnology, Neurotechnology	2036-2050	Nanotechnology is of particular interest to neuroscience because molecular and signal processing occurs at the micron scale of neurons, which have distinct nanoscale compartments, including synapses, axons and dendrites.	https://www.ncbi.nlm.nih.gov/pmc/articles/PMC2596192/pdf/nihms-80331.pdf
77	Deep learning neural networks with artificial intelligence	Digital technology, Neurotechnology	2021-2035	A branch of machine learning that uses artificial neural networks that are composed of many processing layers	ASM ESET study, 2017
78	Intention decoding algorithms	Digital technology, Neurotechnology	2021-2035	By scanning blobs of brain activity, scientists may be able to decode people's thoughts, their dreams and even their intentions	Closed Loop Neuroscience, Academic Press 2016
79	Emotion tracking	Neurotechnology	2015-2020	A computer program to recognize human emotions based on facial cues or physiological responses	ASM ESET study, 2017
80	DNA based data storage	Biotechnology, Digital technology	2015-2020	A DNA storage system consists of a DNA synthesizer that encodes the data to be stored in DNA, a storage container with compartments that store pools of DNA that map to a volume, and a DNA sequencer that reads DNA sequences and converts them back into digital data.	https://homes.cs.washington.edu/~luisceze/publications/dnastorage-asplos16.pdf
81	Precision agriculture	Biotechnology, Digital technology	2015-2020	A farming management concept based on observing, measuring and responding to inter and intra-field variability in crops.	https://en.wikipedia.org/wiki/Precision_agriculture
82	Marker assisted breeding (for livestock and plants)	Biotechnology	2015-2020	An indirect selection process where a trait of interest is selected based on a marker (morphological, biochemical or DNA/RNA variation) linked to a trait of interest (e.g. productivity, disease resistance, abiotic stress tolerance, and quality), rather than on the trait itself. This process is used	https://en.wikipedia.org/wiki/Marker-assisted_selection

NO.	LIST OF EMERGING TECHNOLOGIES	TECHNOLOGY AREA	TIMELINE	DEFINITION	REFERENCE
				in plant and animal breeding.	
83	Natural product derived therapeutics	Biotechnology	2021-2035	Using products that are generally derived from living material--human, animal, or microorganism in order to prevent or cure diseases in humans.	ASM ESET study, 2017
84	Stem cell	Biotechnology	2021-2035	A stem cell is a generic cell that can make exact copies of itself indefinitely. A stem cell has the ability to make specialized cells for various tissues in the body, such as heart muscle, brain tissue, and liver tissue.	http://umm.edu/health/medical/ency/articles/stem-cell-research
85	Regenerative medicine	Biotechnology	2021-2035	Regenerative medicine is a broad field that includes tissue engineering but also incorporates research on self-healing – where the body uses its own systems, sometimes with help foreign biological material to recreate cells and rebuild tissues and organs	https://www.nibib.nih.gov/science-education/science-topics/tissue-engineering-and-regenerative-medicine
86	Molecular markers for identification of important traits	Biotechnology	2021-2035	Molecular markers have been looked upon as a tool for a large number of applications ranging from localization of a gene to improvement of species by marker assisted selection. They have also become extremely popular for phylogenetic analysis adding new dimensions to the evolutionary theories in plant and animal research.	https://www.omicsonline.org/open-access/molecular-markers-an-excellent-tool-for-genetic-analysis-2155-9929-1000233.php?aid=54474
87	Biomarkers for diseases	Biotechnology	2015-2020	Biomarkers for measuring the progress of disease, evaluating the most effective therapeutic regimes for a particular cancer type, and establishing long-term susceptibility to cancer or its recurrence. The parameter can be chemical, physical or biological. In molecular terms biomarker is "the subset of markers that might be discovered using genomics, proteomics technologies or imaging technologies	https://en.wikipedia.org/wiki/Biomarker_(medicine)
88	Genomic profiling	Biotechnology	2015-2020	A laboratory method that is used to learn about all the genes in a person or in a specific cell type, and the way those genes interacts with each other and with the environment.	https://www.cancer.gov/publications/dictionaries/cancer-terms?cdrid=561401
89	Natural product derived supplements	Biotechnology	2015-2020	Using natural compounds to cure and to relieve the patients and for the development of supplements	ASM ESET study, 2017
90	Biopharming	Biotechnology	2021-2035	Biopharming is a very new approach and uses genetically engineered techniques to induce crops such as corn, tomatoes and tobacco or animals to produce high concentrations of high value pharmaceuticals	http://www.pir-resourcing.com/news/biopharming-future-powerful-new-approach
91	Nutrigenomics	Biotechnology	2021-2035	The study of how foods affect our genes and how individual genetic differences can affect the way we respond to nutrients (and other naturally occurring compounds) in the foods we eat.	http://nutrigenomics.ucdavis.edu/?page=information
92	Gene editing	Biotechnology	2021-2035	Gene editing (or genome editing) is the insertion, deletion or replacement of DNA at a specific site in the genome of an organism or cell	https://www.horizondiscovery.com/gene-editing
93	Enzyme technology	Biotechnology, Green technology	2015-2020	The technology that studies how to analyze, design, engineer, and then produce enzymes for commercial use	http://www.orcexperts.com/experts.asp?strQuery=enzyme+technology
94	Biomimicry	Biotechnology	2015-2020	Biomimicry is an approach to innovation that seeks sustainable solutions to human challenges by emulating nature's time-tested patterns and strategies	https://biomimicry.org/what-is-biomimicry/
95	Nanoencapsulation	Biotechnology, Nanotechnology	2015-2020	The entrapping of active ingredients in nanometer-sized capsules	Encyclopaedia of Nanotechnology, 2012

Emerging Science, Engineering and Technology (ESET) Study

The Academy of Sciences of Malaysia (ASM) is a statutory body under the purview of Ministry of Science, Technology and Innovation (MOSTI) Malaysia.

ASM is currently undertaking a foresight study on identifying Emerging Science, Engineering and Technology (ESET) for Malaysia towards year 2050. The main objectives of this study are to envision how emerging science and technology will shape scenarios of Malaysia by year 2050 and to be prepared with a strategic plan towards the envisioned 2050 future.

The study's deliverable will be in the form of an ESET Foresight Report for Malaysia towards 2050. Five areas identified in ESET are Biotechnology, Digital Technology, Green Technology, Nanotechnology and Neurotechnology, which are based on studies by Dr. Richard Watson and his colleagues at Imperial College London.

Therefore, to move forward, ASM would like to acquire your feedback via this survey. ASM looks forward to your support towards the success of this study.

* Required

Technology Prioritisation Survey

The purpose of this survey is to develop a decision making tool, which to be incorporated into the ESET Foresight Report. In view of limited resources in Malaysia, emerging technologies will need to be prioritised based on their Attractiveness and Feasibility criteria.

Members of the ASM ESET Working Groups have been engaged to identify the lists of Attractiveness and Feasibility criteria.

This survey will take around 15-20 minutes to be completed.

1. **Name** *

   ____

2. **Organization** *

   ____

Skip to question 3.

5 areas of ESET

3. **Choose one area of ESET that you like to rate** *

   Mark only one oval.

   - ◯ Biotechnology *Skip to question 4.*
   - ◯ Digital Technology *Skip to question 5.*
   - ◯ Green Technology *Skip to question 6.*
   - ◯ Nanotechnology *Skip to question 7.*
   - ◯ Neurotechnology *Skip to question 8.*

Biotechnology

The following is a list of emerging technologies within Biotechnology area that have been identified to impact future scenario of Malaysia towards 2050.

4. **Select one emerging technology to rate** *

Mark only one oval.

- ◯ Algal biophotovoltaics
- ◯ Algal biosequestration
- ◯ Biofuels/ renewable energy
- ◯ Biomarkers for diseases
- ◯ Biomimicry
- ◯ Biopharming ('Pharming' humanised animals/plants for medicines)
- ◯ Bioremediation & phytoremediation – naturally occurring
- ◯ DNA based data storage
- ◯ Enzyme technology
- ◯ Genetic editing technologies
- ◯ Genetic profiling
- ◯ Integrated bio-refinery in palm oil mill
- ◯ Marker assisted breeding for livestock and plants
- ◯ Molecular markers for identification of important traits of livestock and crops
- ◯ Natural product derived supplements
- ◯ Natural product derived therapeutics
- ◯ Novel antimicrobial products
- ◯ Nutrigenomics
- ◯ Precision agriculture
- ◯ Protein engineering
- ◯ Regenerative medicine
- ◯ Robots in farming
- ◯ Stem cell

Skip to question 9.

Digital Technology

The following is a list of emerging technologies within Digital Technology area that have been identified to impact future scenario of Malaysia towards 2050.

5. **Select one emerging technology to rate** *

Mark only one oval.

- ◯ Artificial intelligence (AI)
- ◯ Augmented reality (AR)
- ◯ Basic brain computer interfaces for gaming
- ◯ Battery-free wireless communications
- ◯ Big data analytics
- ◯ Blockchain
- ◯ Cloud computing
- ◯ Community grids
- ◯ Cryptography
- ◯ Deep learning neural network with artificial intelligence
- ◯ Demand responsive domestic appliances
- ◯ Equipment telematics
- ◯ Holographic data storage
- ◯ Image recognition algorithm
- ◯ Intention decoding algorithms
- ◯ IoT big data analytics and networking
- ◯ Machine readable data
- ◯ Mobile payment system
- ◯ Mood sensing algorithm
- ◯ Multiple biometric recognition
- ◯ Nano sensors IoT
- ◯ Next generation brain to computer interfaces
- ◯ Optical computing
- ◯ Predictive algorithm
- ◯ Quantum computer for crypto-cracking
- ◯ Radio Frequency Identification (RFID)
- ◯ Robotics
- ◯ Unmanned aerial vehicle (UAV)
- ◯ Virtual reality (VR)
- ◯ Visual speech recognition
- ◯ Voice recognition
- ◯ Wireless bidirectional brain interface (sensing/stimulation)

Skip to question 9.

Green Technology

The following is a list of emerging technologies within Green Technology area that have been identified to impact future scenario of Malaysia towards 2050.

6. **Select one emerging technology to rate** *

Mark only one oval.

- ⬭ Algal biophotovoltaics
- ⬭ Algal biosequestration
- ⬭ Biofuels
- ⬭ Biomimicry inspired wave and tidal energy
- ⬭ Naturally occuring bioremediation & phytoremediation
- ⬭ Carbon storage in building material
- ⬭ CO2 to carbon nanotubes conversion
- ⬭ Enzyme technology
- ⬭ Fuel cell
- ⬭ Integrated bio-refinery in palm oil mill
- ⬭ Integrated co-processing technology
- ⬭ Membrane technology
- ⬭ Micro-hydro systems using rainwater in high rise building
- ⬭ Ocean thermal energy conversion
- ⬭ Photovoltaic cell
- ⬭ Rainwater harvesting
- ⬭ Smart energy monitoring and network
- ⬭ Smart grid distribution of renewable energy
- ⬭ Solar grey water disinfection
- ⬭ Thorium reactor
- ⬭ Ultra capacitor vehicles
- ⬭ Wastewater nutrient recovery
- ⬭ Wave disc engines

Skip to question 9.

Nanotechnology

The following is a list of emerging technologies within Nanotechnology area that have been identified to impact future scenario of Malaysia towards 2050.

7. **Select one emerging technology to rate** *

Mark only one oval.

- ◯ 100 atoms per bit data density
- ◯ 3D printing
- ◯ Carbon storage in building material
- ◯ CO2 to carbon nanotubes conversion
- ◯ Fuel cell
- ◯ Magnetic levitation
- ◯ Metamaterial
- ◯ Nano based touchscreen windscreen
- ◯ Nano based drug delivery system
- ◯ Nano based oncotherapy
- ◯ Nanoelectromagnetic communication
- ◯ Nano energy generator
- ◯ Nano material
- ◯ Nano robots
- ◯ Nano sensors IoT
- ◯ Nanotubes for synthetic neurons and neural
- ◯ Photovoltaic cell
- ◯ Printed and flexible electronics

Skip to question 9.

Neurotechnology

The following is a list of emerging technologies within Neurotechnology area that have been identified to impact future scenario of Malaysia towards 2050.

8. **Select one emerging technology to rate** *

Mark only one oval.

- ( ) Artificial intelligence (AI)
- ( ) Brain fingerprinting
- ( ) Brain wave technology
- ( ) Deep learning neural networks with artificial intelligence
- ( ) Electrical neurostimulation
- ( ) Emotion tracking
- ( ) Neural network image recognition
- ( ) Neuroimaging of active brain areas
- ( ) Neuroprosthetics
- ( ) Next generation brain to computer interfaces
- ( ) Nootropic drugs for medical and recreational use
- ( ) Regenerative brain parts
- ( ) Restoration/regeneration of spinal cord
- ( ) Reverse engineering of the brain
- ( ) Wireless bidirectional brain interface (sensing/stimulation)

Skip to question 9.

Prioritisation rating

9. **Attractiveness Criteria**

In your opinion, what is the impact of your selected emerging technology to Malaysia in terms of the following criteria ?

Mark only one oval per row.

	Very High Impact	High Impact	Moderate Impact	Low Impact	No Impact
Global innovation index	( )	( )	( )	( )	( )
Efficiency of public service delivery	( )	( )	( )	( )	( )
National readiness to natural disaster and climate change	( )	( )	( )	( )	( )
GDP	( )	( )	( )	( )	( )
Employment rate	( )	( )	( )	( )	( )
National healthcare	( )	( )	( )	( )	( )
Safety and security of water-energy-food	( )	( )	( )	( )	( )
Safety and national security	( )	( )	( )	( )	( )
Environment and resource sustainability	( )	( )	( )	( )	( )

10. **Feasibility Criteria**

How would you rate your selected technology in terms of the following criteria currently in Malaysia ?

Mark only one oval per row.

	Very Good	Good	Fair	Poor	Very Poor
Human resource capacity	◯	◯	◯	◯	◯
Infrastructure and R&D capabilities	◯	◯	◯	◯	◯
Academia-government-industry-community network	◯	◯	◯	◯	◯
Synchronization between market needs and outcome from RD&C	◯	◯	◯	◯	◯
Funding availability from government	◯	◯	◯	◯	◯
Funding availability from private sector	◯	◯	◯	◯	◯
Awareness and knowledge of existing national policies and initiatives by researchers and entrepreneurs	◯	◯	◯	◯	◯
Policies & initiatives supporting technology development, commercialization and industry uptake	◯	◯	◯	◯	◯
Technology risk, ethical, cultural and regulatory concern	◯	◯	◯	◯	◯
Public awareness on the technology and on-going research	◯	◯	◯	◯	◯

11. **In your opinion, what is the current status of your selected technology?**

Mark only one oval.

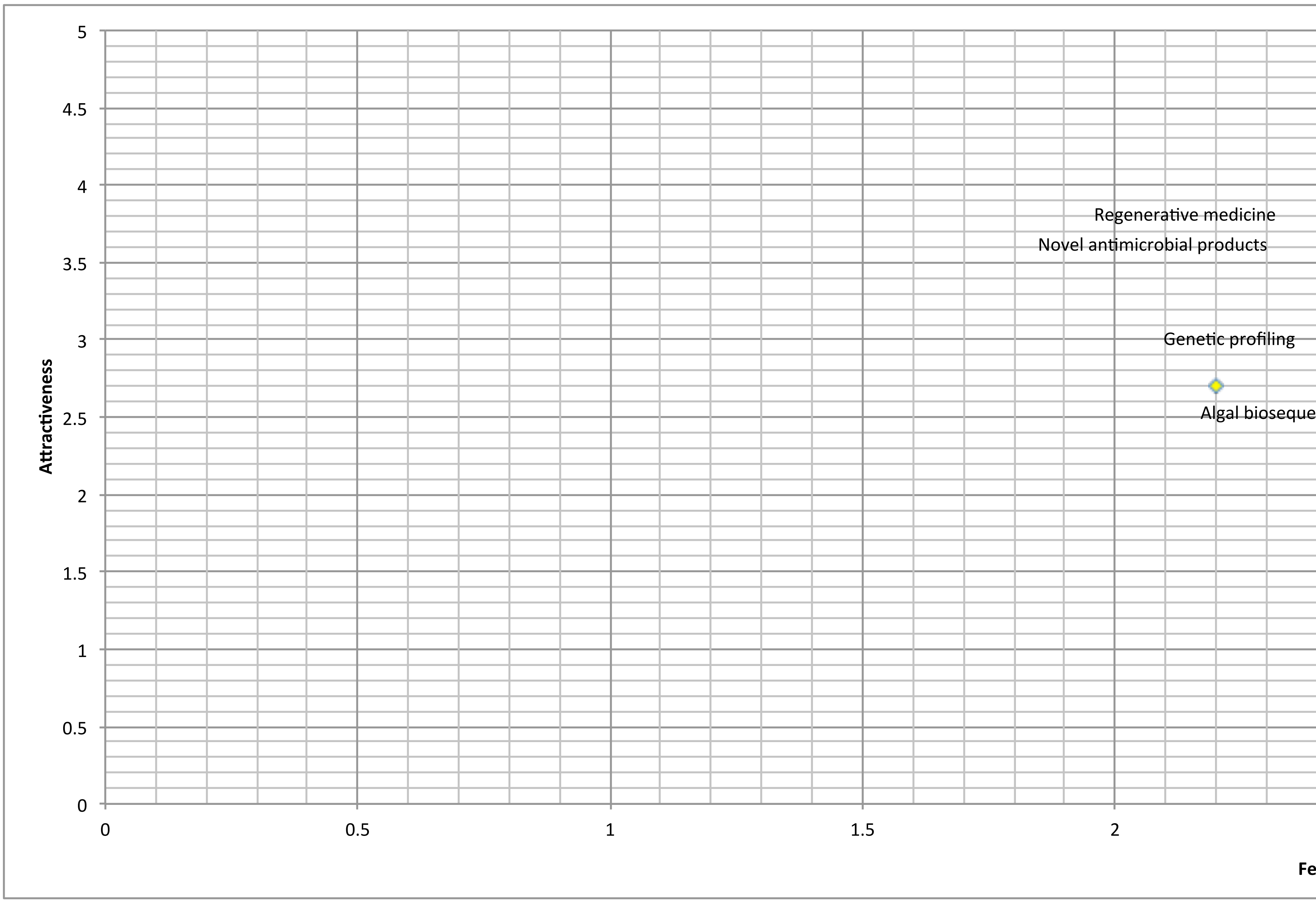
◯ Concept/theory

◯ R&D

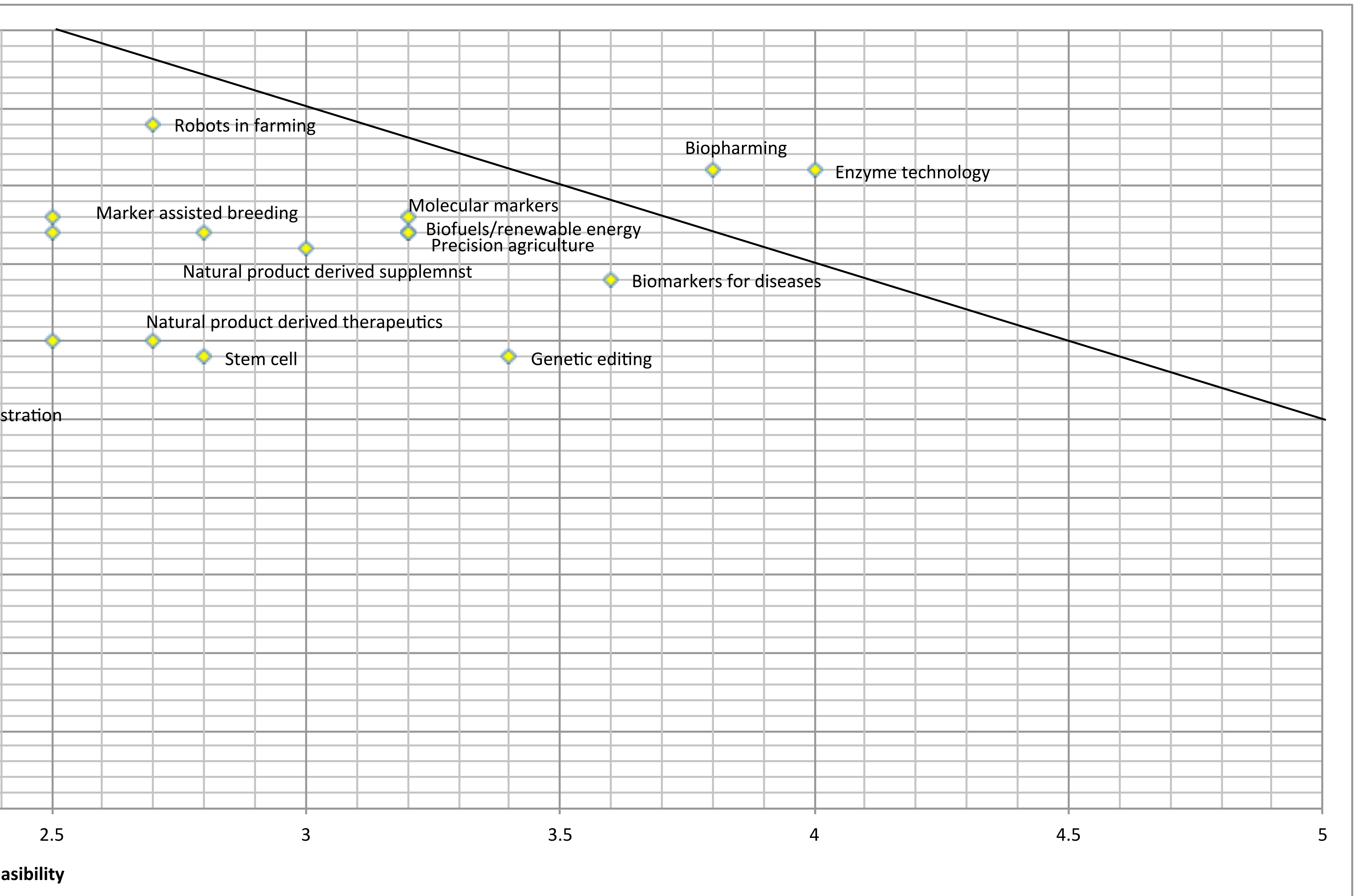
◯ Prototype

◯ Commercialization

ATTRACTIVENESS-FEASIBILITY MATRIX FOR
BIOTECHNOLOGY AREA



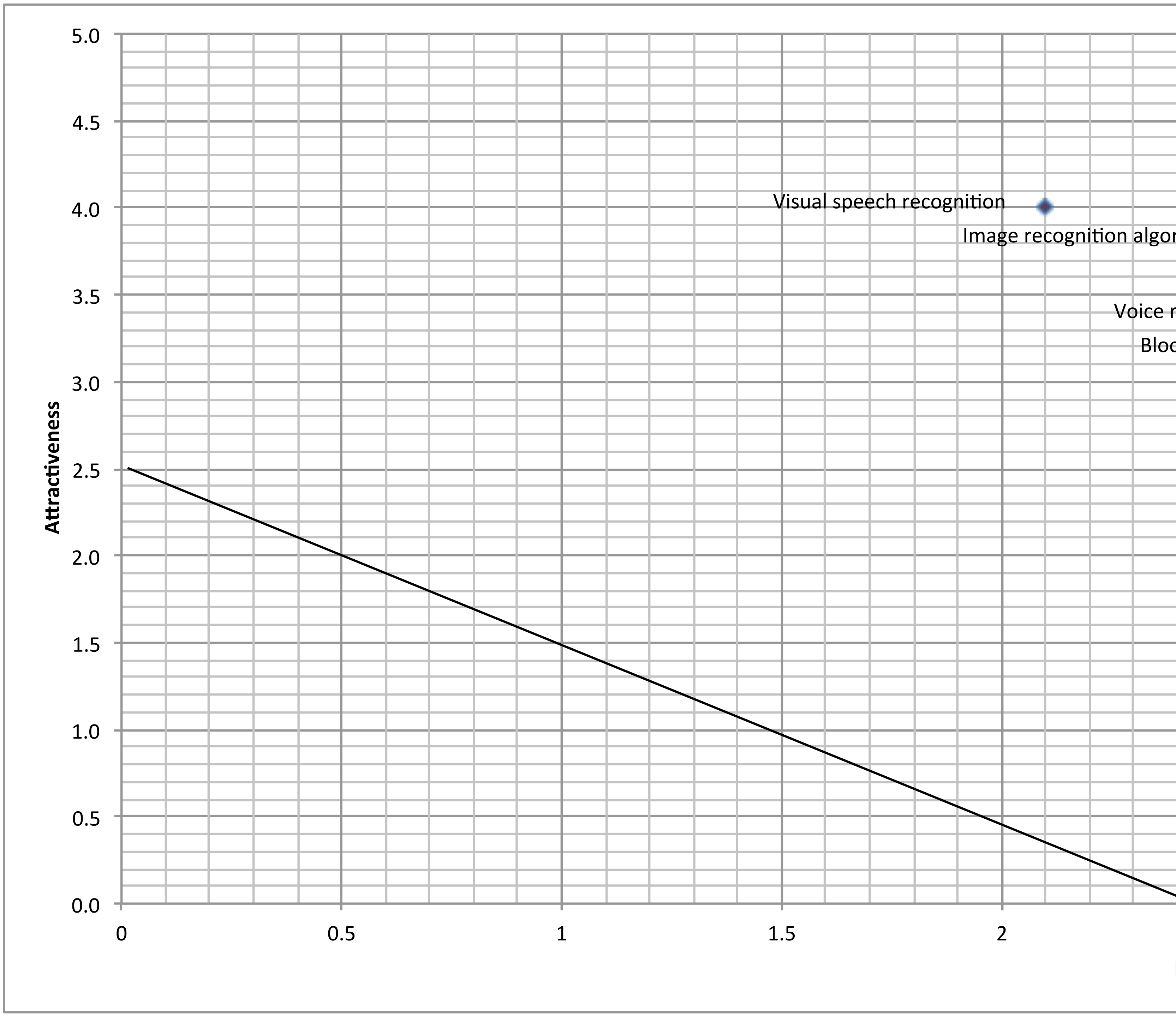
Note: The points in the graph correspond to individual technologies. Emerging technologies in the upper right corner are strong candidates for 'prioritised technologies', the emerging technologies in the lower left corner correspond to less attractive technologies with low feasibility in the considered environment (national economy, industry).



Robots in farming
Biopharming
Enzyme technology
Molecular markers
Marker assisted breeding
Biofuels/renewable energy
Precision agriculture
Natural product derived supplemnst
Biomarkers for diseases
Natural product derived therapeutics
Stem cell
Genetic editing
stration
2.5
3
3.5
4
4.5
5
asibility

ATTRACTIVENESS-FEASIBILITY MATRIX FOR

DIGITAL AREA



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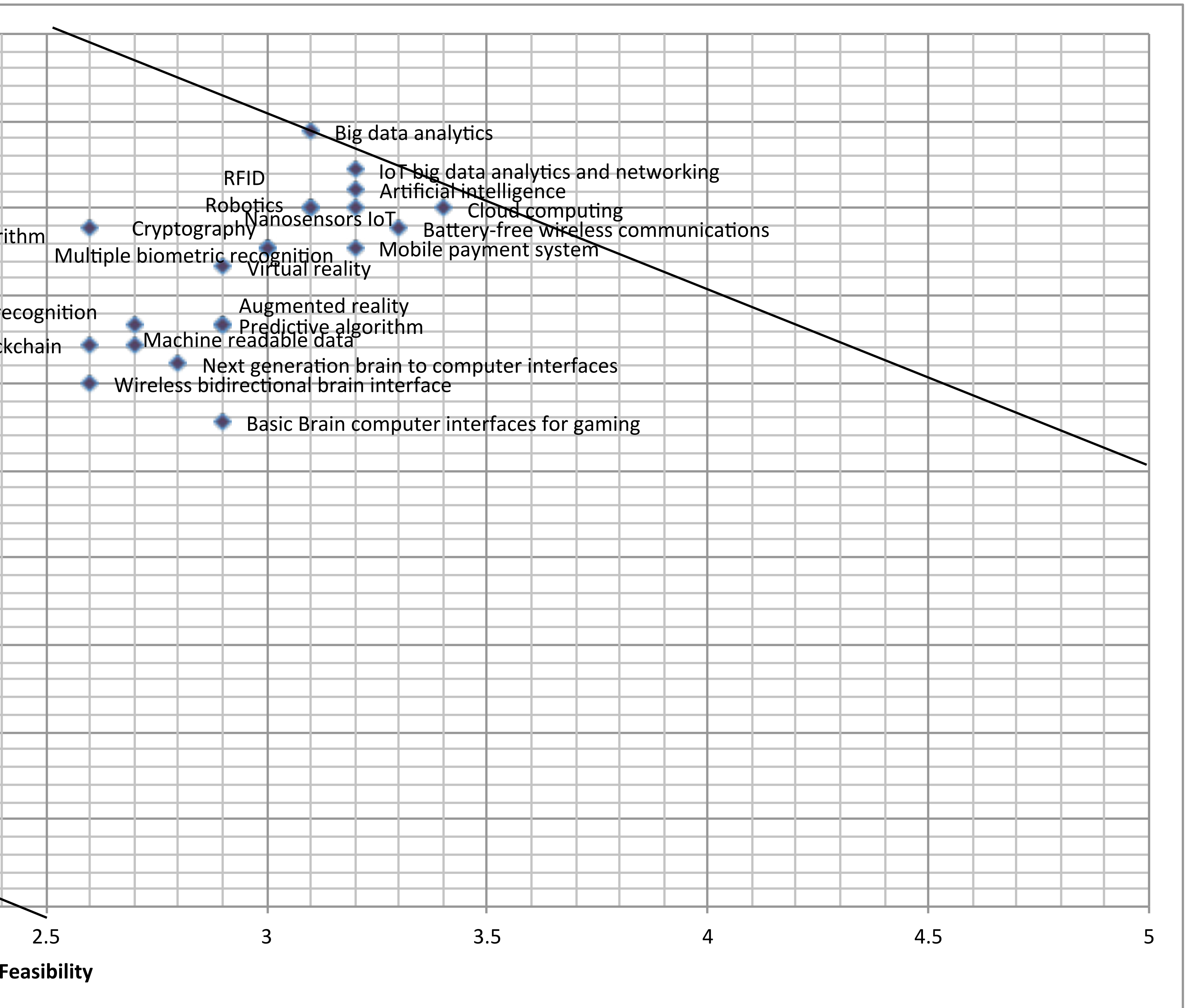
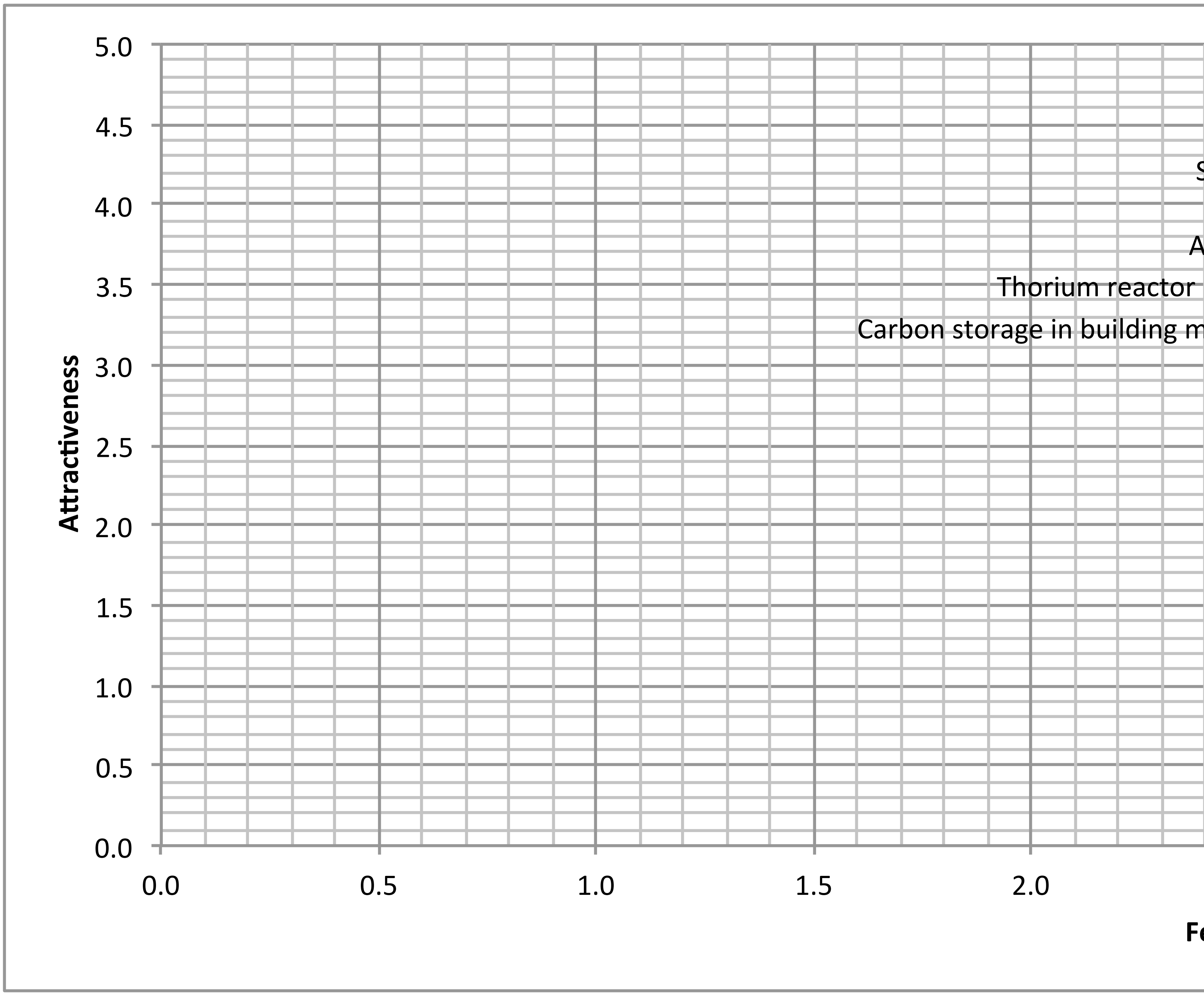


Big data analytics
IoT big data analytics and networking
Artificial intelligence
RFID
Robotics
Nanosensors IoT
Cloud computing
Battery-free wireless communications
rithm
Cryptography
Multiple biometric recognition
Mobile payment system
Virtual reality
Augmented reality
recognition
Predictive algorithm
kchain
Machine readable data
Next generation brain to computer interfaces
Wireless bidirectional brain interface
Basic Brain computer interfaces for gaming
2.5
3
3.5
4
4.5
5
Feasibility

ATTRACTIVENESS-FEASIBILITY MATRIX FOR

GREEN AREA



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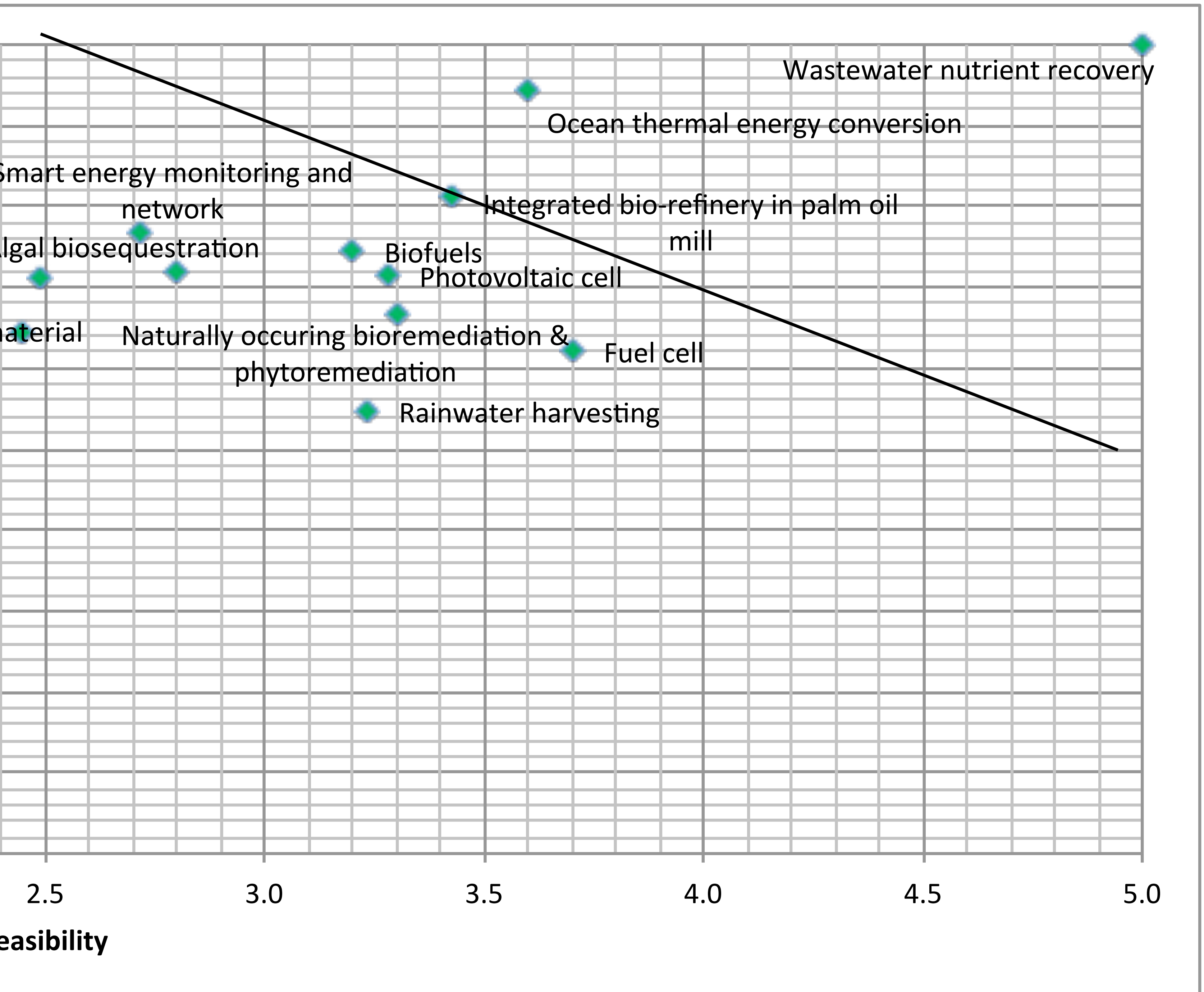
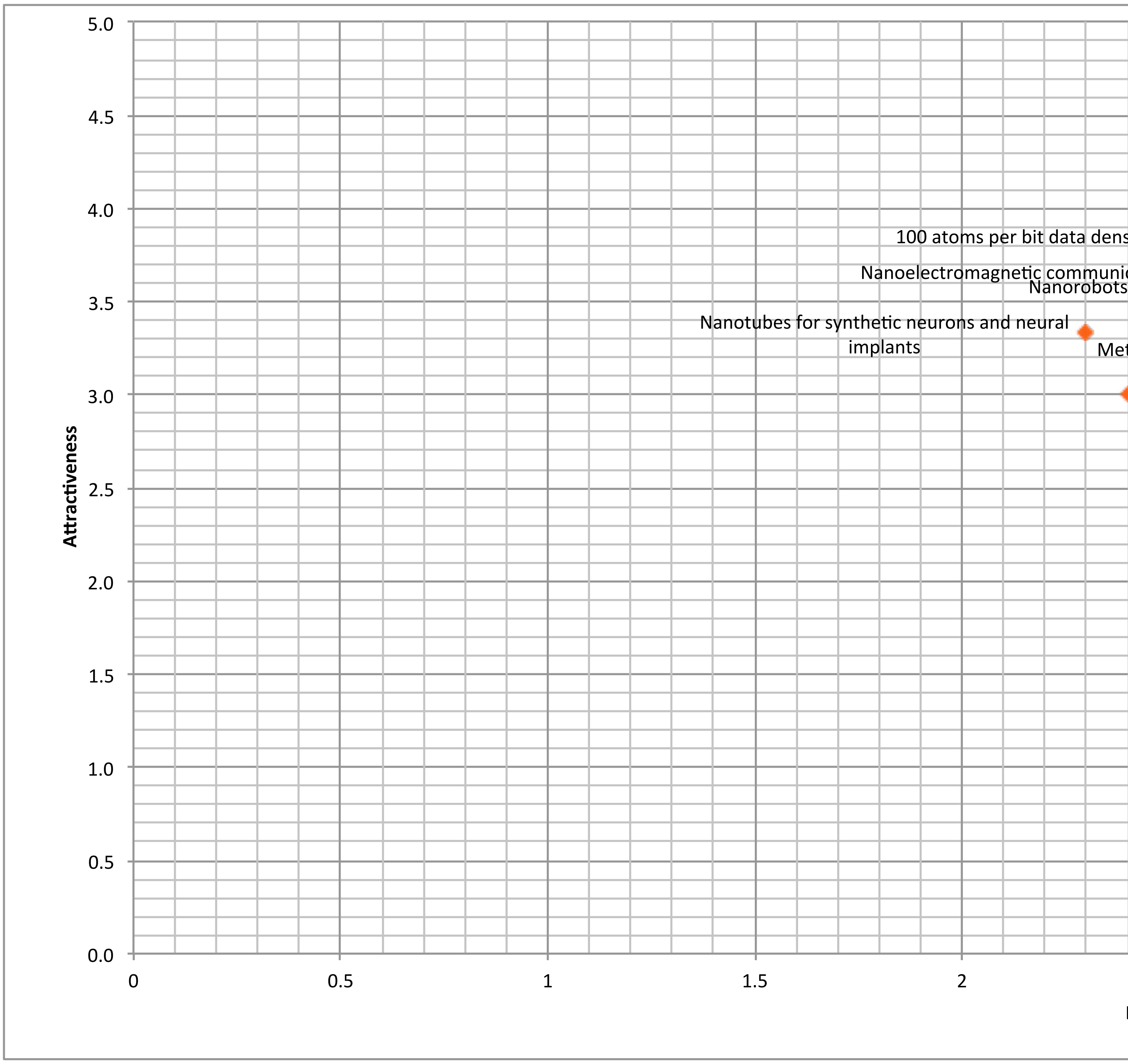


Wastewater nutrient recovery
Ocean thermal energy conversion
Smart energy monitoring and network
Integrated bio-refinery in palm oil mill
lgal biosequestration
Biofuels
Photovoltaic cell
aterial
Naturally occuring bioremediation & phytoremediation
Fuel cell
Rainwater harvesting
2.5
3.0
3.5
4.0
4.5
5.0
easibility

ATTRACTIVENESS-FEASIBILITY MATRIX FOR
NANOTECHNOLOGY AREA



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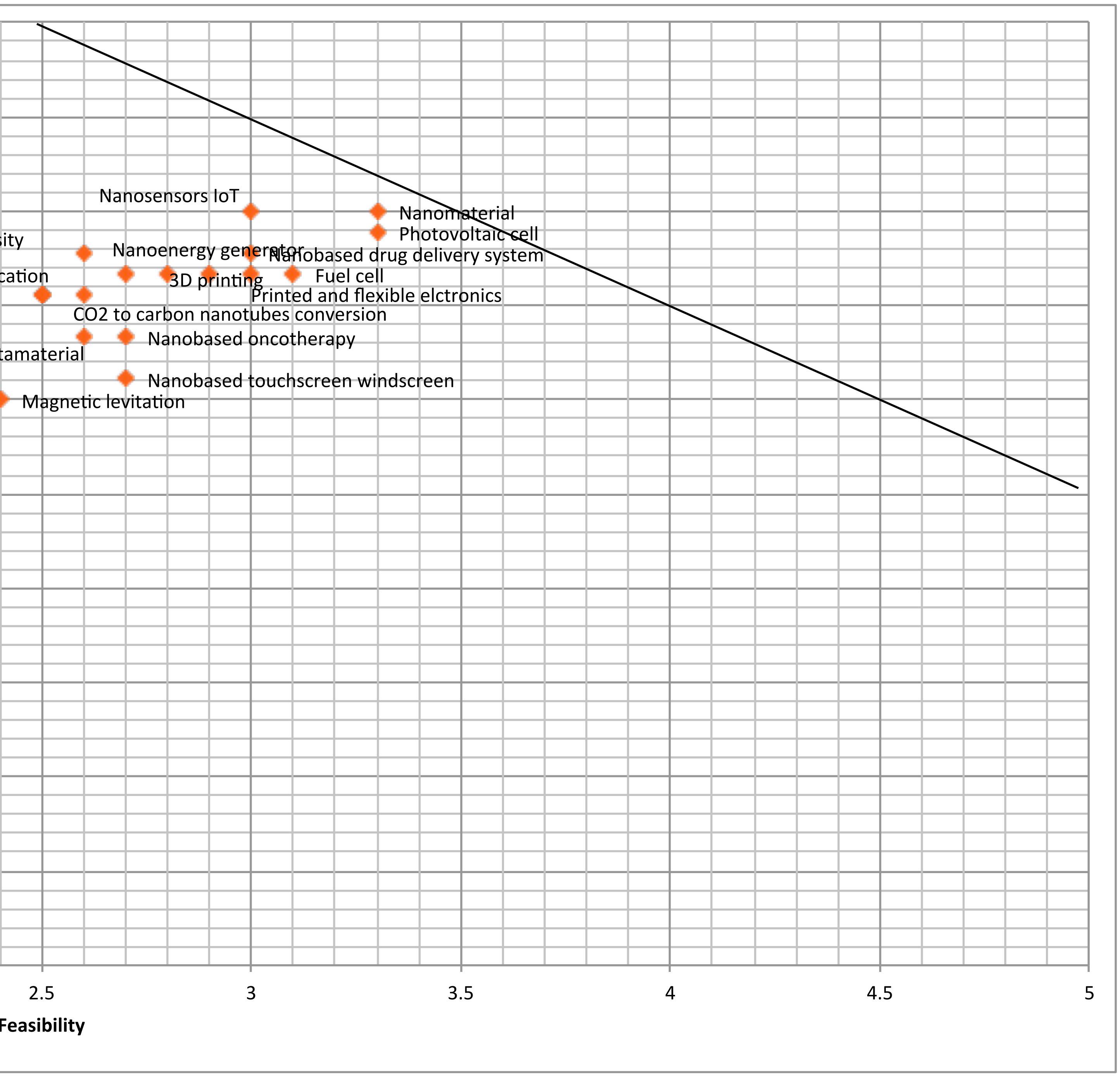
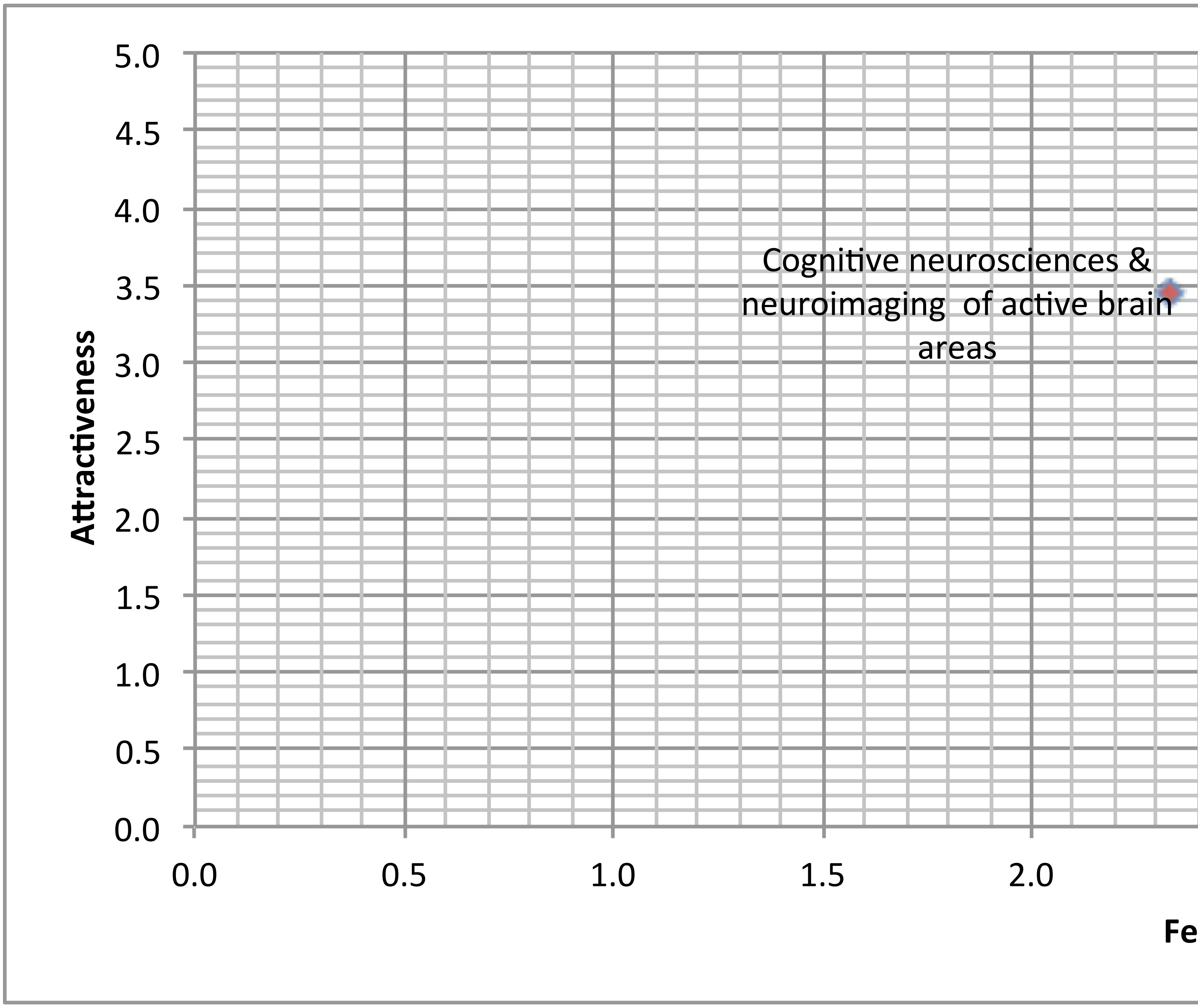


Nanosensors IoT
Nanomaterial
Photovoltaic cell
sity
Nanoenergy generator
Nanobased drug delivery system
cation
3D printing
Fuel cell
Printed and flexible elctronics
CO2 to carbon nanotubes conversion
Nanobased oncotherapy
tamaterial
Nanobased touchscreen windscreen
Magnetic levitation
2.5
3
3.5
4
4.5
5
Feasibility

ATTRACTIVENESS-FEASIBILITY MATRIX FOR
NEUROTECHNOLOGY AREA



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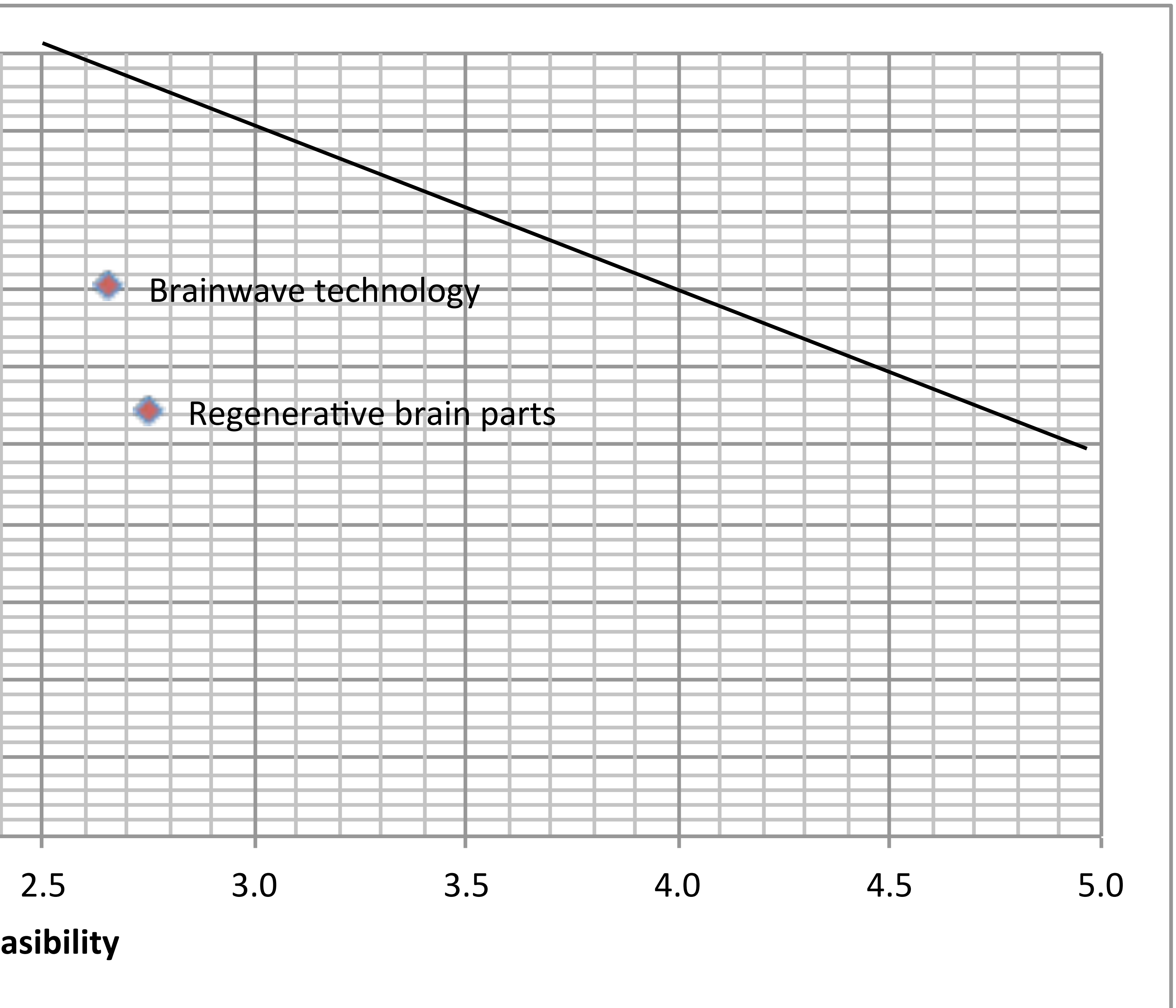
Brainwave technology
Regenerative brain parts
2.5
3.0
3.5
4.0
4.5
5.0
asibility

DIGITAL TECHNOLOGY

NANOTECHNOLOGY

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