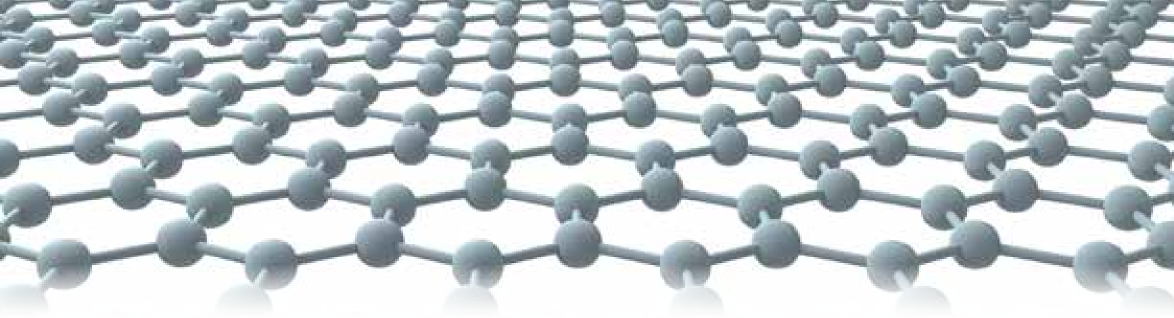
NATIONAL GRAPHENE ACTION PLAN 2020

NANOMALAYSIA

AGENSI INOVASI MALAYSIA



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Foreword

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Graphene, a carbon-based nanomaterial dubbed a "wonder material" by the scientific community, presents a unique opportunity for Malaysia to develop its capabilities as an innovation economy as articulated in the New Economic Model (2010) and the Economic Transformation Programme (2010). Graphene's superior physical properties and potential have triggered tremendous interest in the global scientific and business community, and several leading nations are investing heavily in associated R&D to carve out spheres of competency. Now, Malaysia is also exploring the right opportunities for its domestic industries by identifying which Graphene-enabled applications can catalyse growth regionally.

This National Graphene Action Plan 2020 is the result of an extensive collaboration between the Malaysian government, private sector companies, domestic and international research institutes, and academia to assess how Malaysia can benefit from the potential of Graphene. An explicit goal of the study was to determine Malaysia's near-term action plan when innovating with Graphene. It was not developed to preclude applications besides the five prioritised. The study also reviewed how government would promote and support this effort in a way that is aligned with Malaysia's broader goals of creating a better quality economic environment with more high-value jobs and higher incomes for all Malaysians.

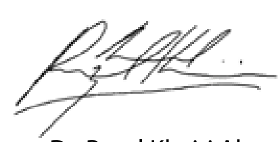
This work builds on Graphene research conducted within Malaysia and worldwide, and interviews with Graphene experts, industry leaders, researchers and academics. The research effort helped us map out all possible application areas and better understand how and where Malaysia could credibly differentiate itself from other markets by 2020. The recommendations arising from this study are not aimed to preclude local innovators from developing high-value Graphene-based technologies not included in the study. To focus on prospects for

Malaysia, the study was an inclusive effort that involved more than 50 entities from the Malaysian government, academia and industry, and over 200 individual stakeholders. A steering committee, which included representatives from multilateral government agencies and private entities involved in nanotechnology, was convened three times during the course of the study to provide guidance, and validate and endorse the emerging action plan. This was done to ensure that the views of the many stakeholders that would be involved in making this opportunity a reality for Malaysia were fully understood and reflected in Malaysia's approach to Graphene. The National Nanotechnology Policy, Study and Action Plan identified Graphene as one of the key nanomaterials to add value to four high-growth sectors: electronic devices & systems, energy & environment, food & agriculture, and healthcare, wellness & medicine.

The action plan outlined in this report is based on an in-depth analysis of the potential for Malaysia through innovation with Graphene, and the steps required to capture that value. Malaysia has the opportunity to become one of the early leaders in adopting Graphene. Undoubtedly, first movers will face challenges, particularly with sourcing the kind of expertise and support required to take products from development to commercialisation. For Malaysia to maximise Graphene's potential, key success factors identified include: having a focused action plan heavily based on existing resources and funding; adopting a portfolio approach to innovation by relying on specific downstream application areas where Malaysia already has strengths; and acting quickly to ensure Malaysia's industries innovate ahead of others to remain competitive globally. This report also outlines the government's role in helping companies identify the required stakeholders and facilitate the ensuing interactions to ensure successful product development.

We wish to acknowledge the support and contributions of all collaborating government agencies, academic and research institutions and private sector partners.

Mark Rozario



Dr. Rezal Khairi Ahmad

Executive Summary

Malaysia's aspiration to become a high-income nation by 2020 with improved jobs and better outputs is driving the country's shift away from "business as usual," and towards more innovative and high value add products. Within this context, and in accordance with National policies and guidelines, Graphene, an emerging, highly versatile carbon-based nanomaterial, presents a unique opportunity for Malaysia to develop a high value economic ecosystem within its industries. Isolated only in 2004, Graphene's superior physical properties such as electrical/ thermal conductivity, high strength and high optical transparency, combined with its manufacturability have raised tremendous possibilities for its application across several functions and make it highly interesting for several applications and industries. Currently, Graphene is still early in its development cycle, affording Malaysian companies time to develop their own applications instead of relying on international intellectual property and licenses.

Considering the potential, several leading countries are investing heavily in associated R&D. Approaches to Graphene research range from an expansive R&D focus (e.g., U.S. and the EU) to more focused approaches aimed at enhancing specific downstream applications with Graphene (e.g., South Korea). Faced with the need to push forward a multitude of development priorities, Malaysia must be targeted in its efforts to capture Graphene's potential, both in terms of "how to compete" and "where to compete". This National Graphene Action Plan 2020 lays out a set of priority applications that will be beneficial to the country as a whole and what the government will do to support these efforts.

Globally, much of the Graphene-related commercial innovation to date has been upstream, with producers developing techniques to manufacture Graphene at scale. There has also been some development in downstream sectors, as companies like Samsung, Bayer MaterialScience, BASF and Siemens explore product enhancement with Graphene in lithium-ion battery anodes and flexible displays, and specialty plastic and rubber composites. However the speed of development has been uneven, offering Malaysian industries willing to invest in innovation an opportunity to capture the value at stake. Since any innovation action plan has to be tailored to the needs and ambitions of local industry, Malaysia will focus its Graphene action plan initially on larger domestic industries (e.g., rubber) and areas already being targeted by the government for innovation such as energy storage for electric vehicles and conductive inks.

In addition to benefiting from the physical properties of Graphene, Malaysian downstream application providers may also capture the benefits of a modest input cost advantage for the domestic production of Graphene. One commonly used Graphene manufacturing technique, the chemical vapour deposition (CVD) production method, requires methane as an input, which can be sourced economically from local biomass. While Graphene is available commercially from various producers around the world, downstream players may be able to enjoy some cost advantage from local Graphene supply. In addition, co-locating with a local producer for joint product development has the added benefit of speeding up the R&D lifecycle.

Agensi Inovasi Malaysia has successfully developed the National Graphene Action Plan 2020 in which the strategy clearly identified paths, opportunities and high potential applications for Malaysian companies to leverage. Moving forward, NanoMalaysia Berhad (NanoMalaysia) has been appointed as the Lead Agency toexecute the National Graphene Action Plan 2020, aligned with their mandate to nurture nanotechnology development and its commercialization. At this juncture, timing is the key determinant in making sure Malaysian companies has the first mover advantage to enable them to move up the value chain and gaining access to the global market.

To conduct a comprehensive analysis, a wide variety of application areas for Graphene were considered. These applications were assessed for technological feasibility by 2020, total size of the opportunity globally and relevance to Malaysia. Based on these criteria, five applications were selected as initial priority focus areas for Malaysia: lithium-ion battery anodes and ultracapacitors, rubber additives, nanofluids (drilling fluids and lubricants), conductive inks, and plastic additives. Together, these applications have the potential to contribute to achieving additional gross national income impact of more than RM 20 billion and to help create 9,000 new jobs for these industries in Malaysia by 2020.

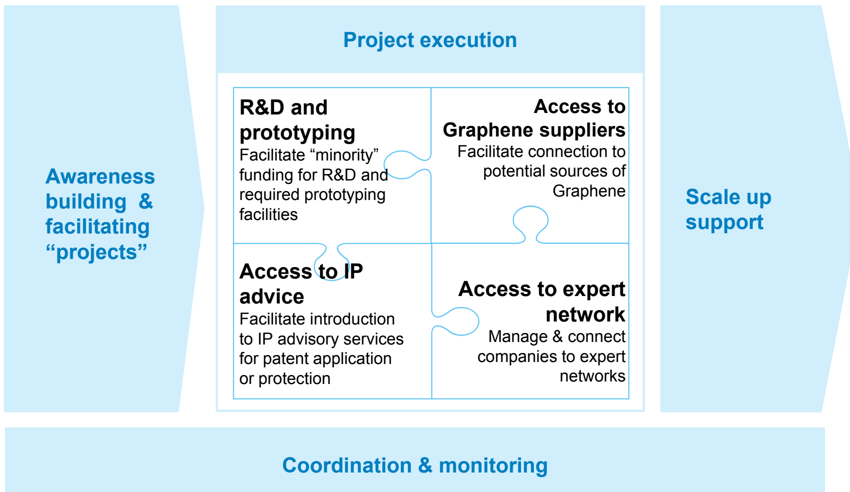
The opportunity for each of these applications in Malaysia is significant. Graphene-enhanced lithium-ion batteries can support the domestic production of electric and hybrid vehicles where battery performance is one of the main challenges in producing cost-effective and reliable vehicles. As a rubber additive, Graphene increases the strength, electrical / thermal conductivity and impermeability of rubber, offering Malaysia's rubber industry a significant advantage in manufacturing gloves, tyres or condoms, and to explore new rubber applications. Graphene-enabled conductive inks provide a cost advantage (input and manufacturing) to radio frequency identification (RFID) applications, and eventually might be applicable to photovoltaics and printed circuits. Graphene's chemical and thermal properties improve the performance of drilling fluids, while its physical properties make it an excellent lubricant, both in wet and dry applications. When used as an additive in plastics, Graphene acts as a reinforcement filler that improves the strength of the host plastic material and allows for reduction in the amount of plastic used.

This report does not address the feasibility of Graphene applications and opportunities beyond 2020, reflecting the view that while development of post-2020 applications is ongoing, there is a lot of inherent uncertainty around the "winning" applications.

Each of these selected application areas was further analysed to evaluate potential market size and to identify the best areas for Malaysian players to compete. In setting an execution action plan, Malaysia is committed to assisting its local companies and industries to successfully innovate with Graphene (Exhibit 1). The government will play a number of roles within the mandate of the National Graphene Action Plan 2020 to initiate the development of a Graphene ecosystem.

EXHIBIT 1

Government to play a critical role in establishing and maintaining Graphene project development activities



The first will be to build awareness about Graphene, its versatility and potential applications to Malaysian industry. In addition to the publication of this report, the government will lead an extended outreach effort to continue generating awareness and call companies to action.

Second, during execution, the government will also play a role in encouraging companies to invest in late-stage Graphene-related R&D as well as early commercialisation. This includes facilitating access to Graphene suppliers, domain experts, and prototyping facilities (e.g., facilities and infrastructure offered by SIRIM and Technology Park Malaysia); navigating the IP landscape; and providing access to any available funding support.

Finally, once a company with the help of its partners has prototyped a product and is ready to commercialise, it can leverage existing programmes to scale up its operations as required including incentives available from the Malaysian Investment Development Authority (MIDA) and others.

In parallel, given the potentially large number of parties involved in this action plan from both the public and private sector, the government will play an active monitoring and coordination role to ensure progress. Two areas will be monitored closely: the progress of Graphene-related projects (especially when public funds are used for R&D), and the quality of partners – both Graphene suppliers and domain experts, to ensure Malaysian companies are able to access the highest quality partners within each category.

Eventually, once there is active downstream participation, the government will seek to attract a cluster of Graphene producers. Moreover, the scope of targeted applications can also be extended to other industries where Graphene is expected to play a revolutionary role in the coming years. This complete ecosystem will then drive further collaboration and innovation.

Today, the government is taking big strides in laying the foundation for this ecosystem:

1) appointing a lead agency that will facilitate and monitor execution through awareness building and convening players to create "projects"; 2) expanding the scope of existing funding sources to include Graphene; and 3) building and vetting a network of Graphene experts and maintaining a list of available Graphene suppliers. In parallel, companies interested in pursuing Graphene can, on their own, explore opportunities by assessing existing and desired research capabilities, and leveraging government resources for experts, prototyping facilities, and funding to begin proof-of-concept experimentation.

Introduction

Graphene, a recently discovered carbon-based material with superior physical properties and application versatility, has tremendous potential to disrupt several industries. Many governments, (e.g., the U.S., EU, UK, South Korea and Singapore) have started to significantly invest in Graphene R&D and commercialise relevant applications. Without purposeful investment in Graphene innovation, there is a risk that Malaysia will be left behind with possibly significant adverse impact on key sectors. However, it is still early in the development cycle, allowing Malaysian companies to develop their own intellectual property and applications instead of relying on international licenses.

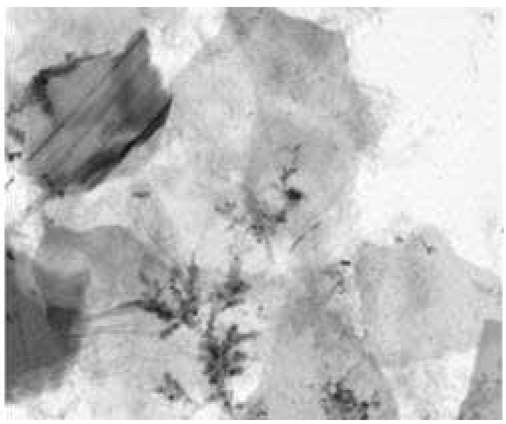
The National Graphene Action Plan 2020 lays the foundation for Malaysia to catalyse several of its existing and emerging industries to increase global competitiveness. The initial action plan lays out the scope for the five most promising downstream applications in the Malaysian context, and the implications on their relevant supply chains, to incorporate Graphene between now and 2020. Once robust commercial downstream industry begins to develop, Malaysia can consider broad scale production of Graphene, given its potential competitive advantage in having lower access costs to methane, a key input factor for the chemical vapour deposition method of extracting Graphene. Over time, and with the development of a Graphene ecosystem, additional applications will be added.

Broadly, innovation with Graphene in Malaysia will focus on commercialisation instead of expansive research. This entails helping Malaysian companies develop and capture the initial IP and knowledge, and the development of higher quality products for both exports and internal consumption. This report also lays out where in the value chain Graphene can be incorporated for the five priority applications, and identifies the emerging business opportunities within each application.

Local stakeholders in Malaysia have expressed interest in exploring Graphene. They include potential Graphene producers, end-users and academics. Graphene R&D activity is already underway in areas such as rubber products, drilling fluids, conductive inks and high-voltage devices. Significantly, under the guidance of the National Nanotechnology Directorate's Graphene Consortium, there is ongoing work on Graphene-based electronic devices and systems as well as pristine and large area Graphene synthesis. Based on interviews conducted as part of the industry engagement portion of this action plan development, the expectation of private companies is that they will be part of a Graphene ecosystem of end users, experts, and eventually, producers.

Successful implementation of Graphene enabled applications will depend upon collaboration between companies, Graphene suppliers, experts, and enabling government bodies. This action plan describes the key facilitation role that will be played by the Malaysian government to help companies, first by promoting and raising awareness, and later in bringing together the relevant partners and overseeing their joint path to success.

Graphene

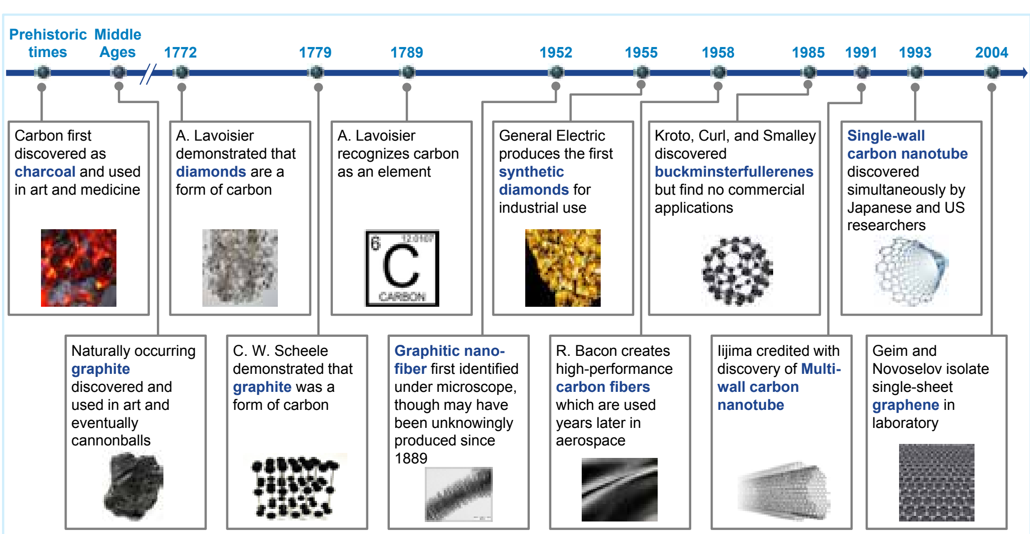


Characteristics

Graphene is widely considered as one of the most promising materials discovered in the past decade. Several superior properties have already been proven, and new properties and applications are continually being discovered. Isolated only in 2004 (Exhibit 2), Graphene is a nano-carbon material and has similar beneficial properties as carbon nanotubes (CNTs) but promises to be easier to manufacture and integrate with base materials.

EXHIBIT 2

Timeline of elemental carbon allotrope discoveries



SOURCE: Kirk-Othmer Encyclopedia of Chemical Technology, Frostburg University, CARBON

From the early days of research, Graphene's distinctive properties have been evident, offering tremendous potential across a number of different applications. A combination of its properties as shown in Exhibit 3 can enable new applications and enhance existing ones.

What is Graphene?

Graphene is a one atomic-layer thick honeycomb sheet of carbon atoms. These layers can be stacked together, up to 20 thick, and still be considered Graphene. A thicker stack would be considered Graphite. It is chemically identical to graphite and similar to unrolled carbon nanotubes.

The atomic structure of Graphene is illustrated to the right.

At time of printing, the International Organization for Standardization was still determining a “standard” definition for Graphene.

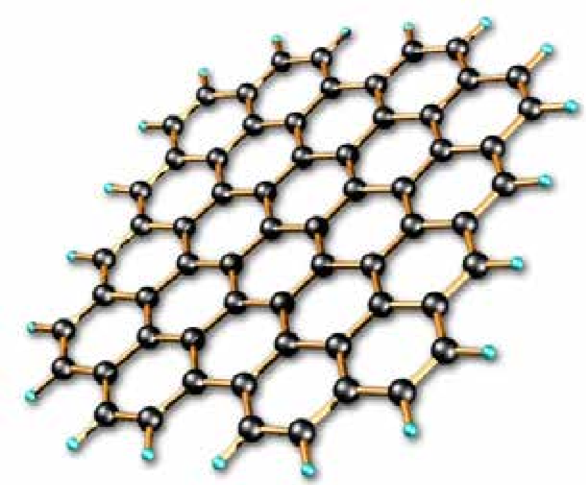
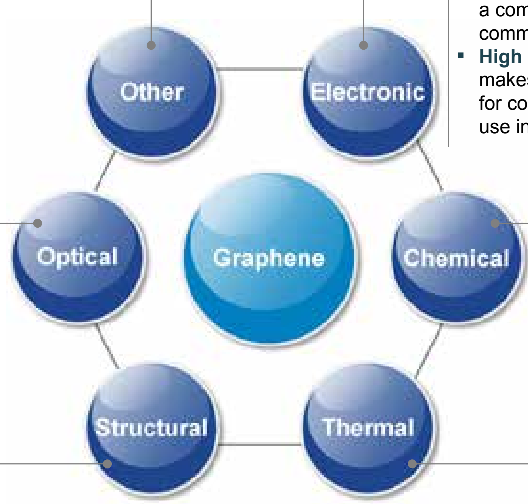


EXHIBIT 3

Graphene possesses a unique combination of properties



Other

- Super **permeability to water** could enable new types of filters
- Antibacterial properties hold promise for medical uses

Electronic

- **High electron mobility** makes it a competitor to Silicon that is commonly used in computing
- **High Electrical conductivity** makes it a potential replacement for copper wires on chips and for use in conductive inks

Optical

- **Superior optical transparency** enables its use in transparent conducting electrodes

Chemical

- **Graphene with rough edges** enables higher strength rubber and plastics
- **High surface area to volume ratio** makes it suitable as a catalyst and as a sensor

Structural

- **High strength** (300 times that of steel), **high rigidity** (Tensile strength of 1 Tpa), and stretch capabilities enable a variety of applications including composite matrices and flexible displays

Thermal

- Excellent **thermal conductivity** could enable high performance heat sinks

For instance, Graphene's properties enable innovation in the following applications:

- Graphene is an excellent thermal conductor, with 5-10 times the heat conductivity of copper. Heat sinks and thermal interface materials used to cool down electronic components could utilise Graphene to achieve improved heat dissipation and thereby achieve higher performance computing and extend the life of electronic products;

- Graphene's high surface area-to-volume ratio and abundant availability of bonding sites make it suitable for applications such as lithium-ion batteries, sensors, plastics additives and rubber additives. This property makes Graphene easier to integrate with the base material (compared with preceding technologies such as carbon nanotubes), and to transfer beneficial properties such as strength enhancement, conductivity and impermeability. Graphene's abundant bonding sites can also allow for reduction of required material in the manufacturing of a given product;

- A single Graphene layer is highly optically transparent making it suitable for the manufacturing of touch screen sensors and flexible displays. While competing technologies have been explored for the past few decades Graphene has the potential to be a higher performance, lower cost alternative.

Graphene is available in flakes and sheets (see Exhibit 4). In the form of flakes (sometimes referred as "platelets"), Graphene is used primarily as an additive while Graphene sheets can be used for applications such as flexible displays. Quality is determined by a number of factors including chemical purity, physical structure, and electronic properties. While Graphene can be made with fewer impurities, not every application requires the highest grade in order to benefit from Graphene's properties.

EXHIBIT 4

Graphene is commonly available in two forms

Credits: MIT Technology Review

Credits: Graphene Supermarket

Production

As shown in Exhibit 5 below, there are two main production methods for Graphene: chemical exfoliation (CE) and chemical vapour deposition (CVD). It is important to distinguish between the methods since the varieties in quality and economics of production are tied to the demands of specific applications. The lower cost CE method can produce various types of low-to-medium quality Graphene flakes while the CVD method can produce both flakes and sheets of medium-high quality.

EXHIBIT 5

Chemical vapor deposition and chemical exfoliation are the dominant methods of Graphene production

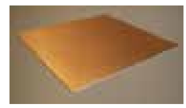
Chemical Exfoliation

Block of Graphite

Flake Graphene

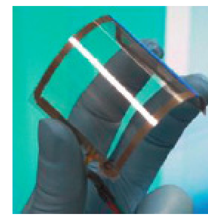
Ultrasonic Bath

Chemical Vapor Deposition



Sample substrate

CVD Apparatus



Sheet Graphene

SOURCE: Nature, University of Manchester

The chemical exfoliation method, a "top-down" approach, derives Graphene from Graphite. In this process, a block of Graphite is submerged in an acid "bath", and flakes of Graphene are peeled off using ultrasonification. Although there are currently no producers in Malaysia using this method, the technology is available on the market with individual upstream players customising their processes for different applications. Since Graphite is the main input, nations with abundant supplies of Graphite have a natural cost advantage.

The CVD method, a "bottom-up" approach, uses methane (which could be derived from biomass) as a feedstock to produce Graphene. The feedstock is passed over a catalyst at high temperatures which results in Graphene forming on the surface of the catalyst. On completion of this process, the system is cooled and the catalyst is removed to separate the Graphene.

A costing analysis of the CVD method was performed to better understand the cost-contribution of methane to the total cost of production, considering factors such as utility, labour, capital expenses, and cost of feedstock. It appears that there is a modest cost-benefit to CVD production in Malaysia because of factor cost advantages with methane and electricity.

Other potential advantages of local production are reduced shipping time (and cost) and made-to-specifications customisation, however these only make sense if there is high volume consumption of Graphene into applications. Aside from savings in raw material input costs, innovation in the system design and production methods can be a bigger driver of cost.

Malaysia's focus within a global context

A number of countries have launched initiatives related to Graphene, further building up global momentum behind research and development. Many of these efforts are in the early R&D stages, focused on fundamental research rather than commercialising products. While big efforts in the U.S. and the EU focus on R&D across a variety of applications, some countries such as South Korea have adopted a more narrow approach, targeting main efforts to a limited number of applications. Other countries like China are also investing substantially, as indicated by the considerable number of patent filings and journal publications (Exhibit 6).

EXHIBIT 6

Many governments globally are making significant investments into developing Graphene hubs

National commitments to Graphene research

	EU	USA	Japan	China	S. Korea	Singapore[1]
	$1.3B over 10 years	$50M+/year	Undisclosed National Funding	Undisclosed National Funding	~$300M over 10 years (potential)	$32M
# of patent applications	170	1500	500	1160	800	20

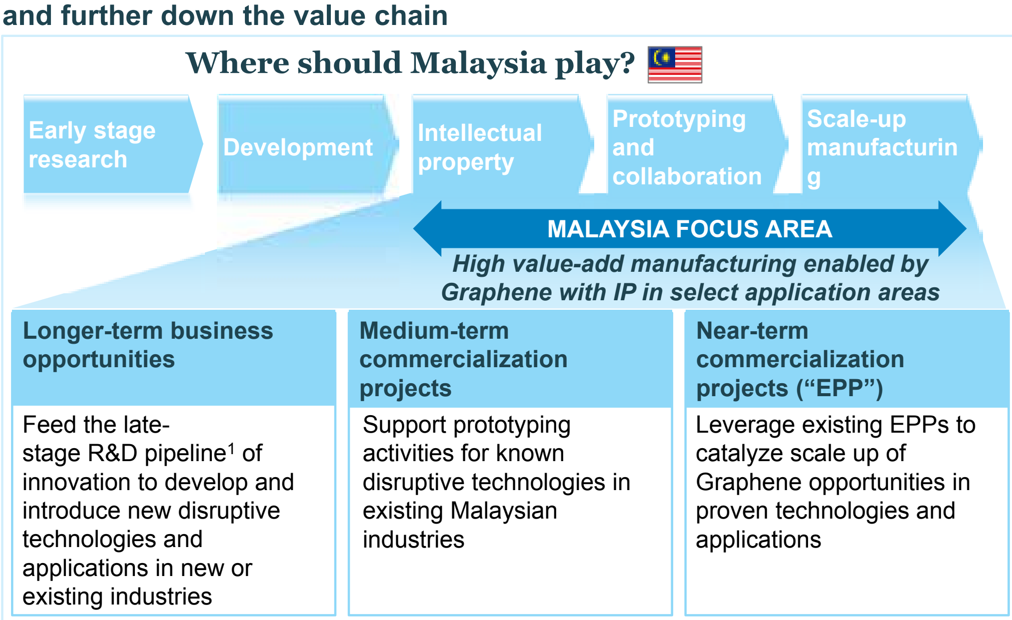
1 Disclosed direct spend on Graphene, for prototyping and rapid development, additional funding channels available, but are not Graphene specific

SOURCE: Press releases, European Commission, USAF, US NSF/DOE, Expert interviews

Similar to these early adopters, Malaysia has to decide whether and how much to invest in its Graphene capabilities. Based on Malaysia's scale and its aspirations to become a developed nation by 2020, the Malaysian government will adopt a downstream-focused approach, with the aim of fostering concrete commercial benefits across key industries. Therefore, this action plan seeks to actively involve and benefit Malaysian industry throughout the value chain. As a first step, it focuses on a few priority applications, which carry the highest potential for economic and employment benefits to Malaysia. Over the longer term, Malaysia must also keep sustainable and long-term benefits of high value applications under its radar.

EXHIBIT 7

The Government of Malaysia has chosen to focus on a few applications, and further down the value chain



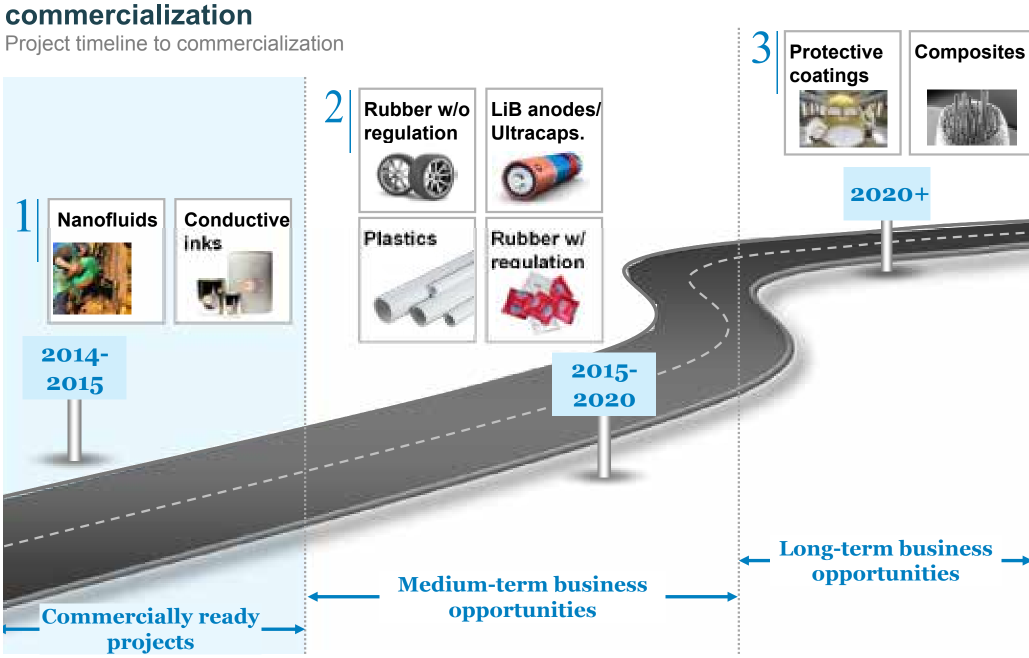
1 Requires investment in university research grants to facilitate longer term R&D, similar to other countries (commercialization window beyond 2020)

Both the applications selected for Malaysia's initial focus as well as subsequent uptake can be divided into the three horizons presented in Exhibit 7 above.

EXHIBIT 8

Identified applications are at varying stages of R&D maturity and time to commercialization

Project timeline to commercialization



This report does not address the feasibility of Graphene applications and opportunities beyond 2020, reflecting the view that while development of post-2020 applications is ongoing, there is a lot of inherent uncertainty around the "winning" applications.

Based on best practices from innovating nations and numerous interviews with companies and academics in Malaysia, there is a clear role for government to play in fostering the development of a Graphene ecosystem in Malaysia. The government's role in facilitating Graphene adoption is discussed in detail in "The Role of Government to Capture the Opportunity" section.

Graphene applications relevant for Malaysia

Downstream Industry Focus

Despite its recent discovery 10 years ago, Graphene has been widely researched and available with market prices based on form and quality. Graphene producers are primarily focused on innovating and scaling up production processes to reduce manufacturing costs and to increase the quality of Graphene produced. To date, there has been selected uptake in downstream use of Graphene, primarily in structural materials such as those used for tennis rackets, despite the broad and promising research published. The reason is that Graphene is a relatively new material; incorporating Graphene into various materials is not straightforward and requires in-depth knowledge of the materials' characteristics and specific behaviours in the context of particular applications. In addition there is also the need for comprehensive prototyping and testing as with any new material. Malaysia is well positioned to be at the forefront of this by making a jump start on the commercialisation and scale up.

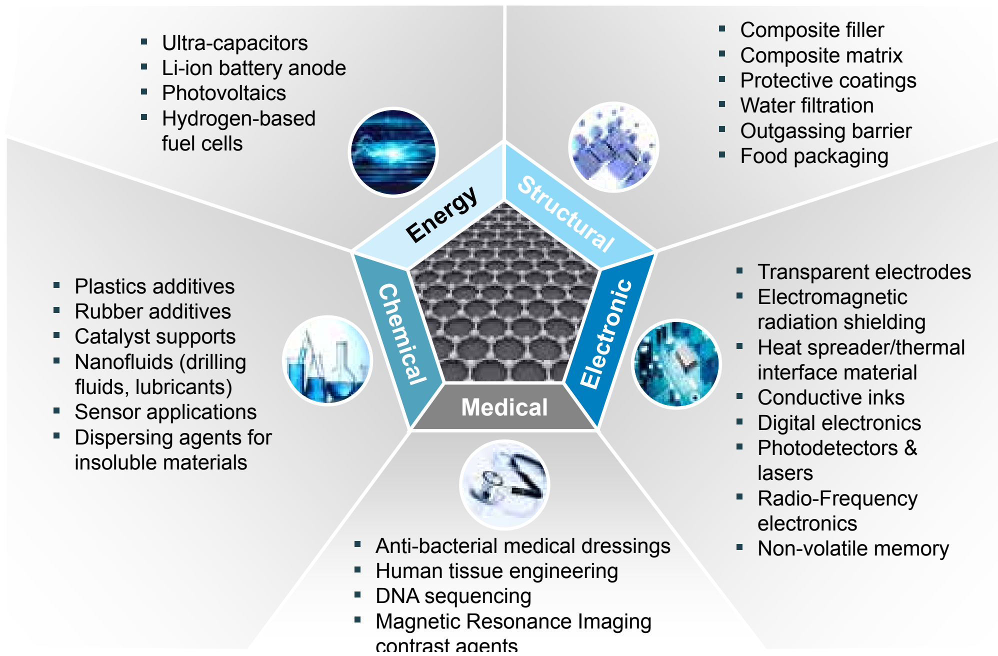
The objective of the National Graphene Action Plan 2020 is to identify commercially viable opportunities for Malaysia with the potential to add value to existing applications and industries, and to spur investment and lift gross national income (GNI). If leveraged to its full potential, Graphene could generate substantial upside for Malaysia through commercialisation of Graphene-enhanced products. An estimated GNI impact of RM 20 billion by 2020 could be at stake. If executed correctly, the downstream players investing in Graphene R&D and developing proprietary products will capture this opportunity.

Any innovation action plan has to be focused and tailored to the needs and ambitions of local industries to ensure economic benefits. To this end, this action plan focuses on Graphene-related applications whose commercialisation can have tangible impact to the Malaysian economy by 2020 and beyond. This principle will guide the action plan towards an initial set of focus applications for Malaysia.

In order to conduct a comprehensive analysis, a wide array of application areas of Graphene were considered – 28 in total, across five broad categories of physical properties where Graphene offers a substantial benefit – energy, electronics, structural, chemical and medical. These 28 applications can be seen in Exhibit 9 below.

EXHIBIT 9

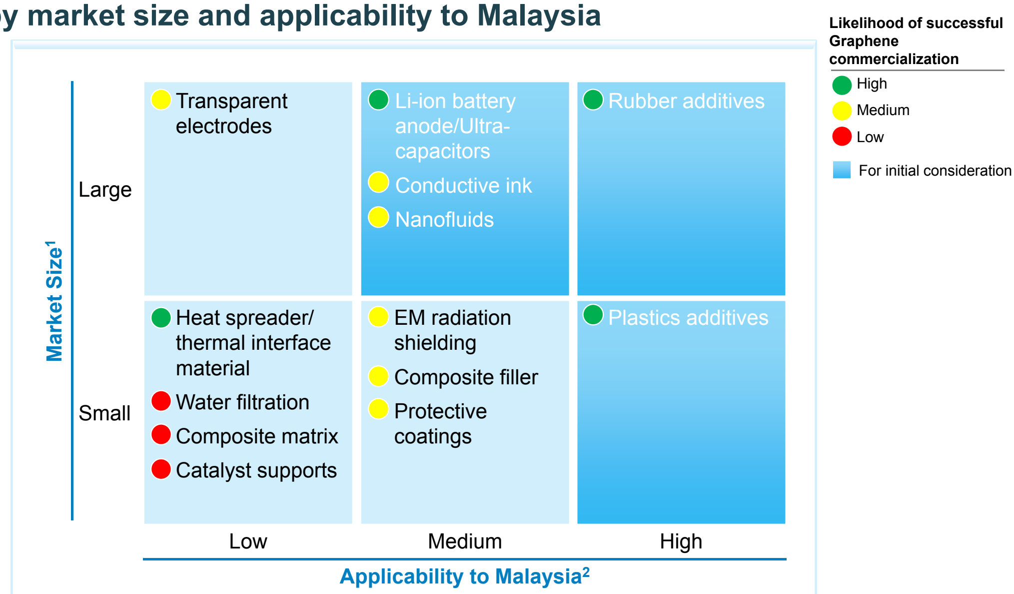
Total universe of Graphene applications evaluated for technical feasibility



For applications deemed technologically feasible by 2020, further analysis was conducted including a detailed assessment of market potential, maturity of Graphene integration in the application, and applicability to Malaysia (e.g., Malaysia's priority sectors, its relative regional competitive advantage in these sectors, GDP contribution and the extent of existing economic activity in Malaysia along each application's value chain).

EXHIBIT 10

Five applications were selected based on mapping by market size and applicability to Malaysia



1 Market size is high if addressed Graphene market size is ~$1B or higher
2 Applicability to MY is based on current downstream players, upcoming policies, and focus `of neighboring countries

Based on the outcome of this analysis, subsequently validated through discussions with industry, government and academia, five specific application areas were selected as the initial priority focus areas for Malaysia (Exhibit 10). The five application areas are: lithium-ion battery anodes and ultracapacitors, conductive inks, rubber additives, plastics additives, and nanofluids (drilling fluids and lubricants). Each of the selected application areas was further analysed to evaluate where in its global value chain would decisions regarding Graphene's adoption likely be driven, and how, as a result, should Malaysian industry participants capture Graphene-related opportunities.

In terms of Graphene integration, each of these applications will require varying types and qualities of Graphene as an additive. No single form of Graphene will address all applications, both from a functional and an economic perspective.

Enabling domestic production of Electric Vehicles and Hybrids by 2020

Graphene offers a compelling value proposition for enhancing lithium-ion batteries as well as ultracapacitors. In lithium-ion batteries, Graphene anodes could potentially enable up to 10[1] times more energy storage and 10 times faster recharging capability[2] with the exact same dimensions as conventional anodes. In ultracapacitors, Graphene could be used to enhance the electrodes, enabling a larger storage capacity. The two can be bundled to produce longer-lasting, fast recharging energy storage devices.

Producing Graphene-enhanced lithium-ion batteries could create a significant opportunity to support the production of electric and hybrid vehicles in Malaysia.

1 X. Zhao et al, pp. 1078-84, vol. 1 (2011), Advanced Energy Materials

2 In 2013, a U.S. based Graphene producer, XG sciences, launched a new generation Si-Graphene anode material for lithium ion batteries with four times the capacity of conventional anodes.

Energy storage devices

A lithium-ion battery is a rechargeable battery comprised of a graphite anode, a metal oxide cathode and an electrolyte containing a lithium salt. The anode and cathode's capability to handle and store lithium ions impacts the battery's energy capacity and charging speed.

The ultracapacitor (also referred to as supercapacitor) is a device for storing electrical energy with rapid charge times and long lifecycles. The virtue of ultra-rapid charging and delivery of high current on demand makes the supercapacitor an ideal candidate as a peak-load enhancer for hybrid vehicles.

Lithium-ion batteries are a crucial component for hybrid and electric vehicles. Battery performance (primarily the ability to hold charges for long durations and rapid recharging times) and cost are the primary challenges in producing electric vehicles that can effectively compete with conventional vehicles. Graphene could help unlock the potential market opportunity for hybrid and electric vehicles. Other lateral opportunities include the use of Graphene-enhanced lithium-ion batteries in the consumer electronics and power grid support markets.

Malaysia has a unique regional opportunity to enter and innovate in the lithium-ion battery industry. Due to insufficient demand for lithium-ion batteries in Malaysia and ASEAN, no automotive[3] lithium-ion battery or ultracapacitor producers have been established thus far; upstream suppliers of battery components like anodes are also missing. Graphene enhanced lithium-ion battery production in Malaysia is timely because (1) the technology has the potential to be truly disruptive, (2) there is opportunity to become the first at-scale battery manufacturer in ASEAN, and (3) demand-side factors suggest significant regional growth potential in the medium term.

The emergence of the new National Automotive Policy (NAP) and the resulting support of Pemandu's Electrical & Electronics EPP18 (Enabling Electric Vehicle Component Manufacturing) will provide added incentive and support for emerging Malaysian champions in the lithium-ion battery sector. First, the NAP's push for large scale domestic production; the assembly of electric vehicles and energy efficient vehicles (EEV) will create the demand needed for lithium-ion battery manufacturers to produce at scale. The potential market is even larger once the broader ASEAN market is considered (Thailand, for example, has stated electric vehicle aspirations in the mid-to long term). Second, Malaysia is home to several leading international and domestic electric vehicle car manufacturers who have a strong interest in improving battery performance and lowering costs. Co-location of battery production with the automotive manufacturer is important, as transporting the batteries is costly and hazardous.

The industry revenue potential from establishing production of Graphene-enabled automotive lithium-ion batteries aimed at the domestic market could reach RM 2.8-3.5 billion

3 There are small electronics lithium-ion battery manufacturers in Malaysia (Samsung, ABM Fujiya), with offshore R&D centres.

Government directive fostering growth of National Electric Vehicle Ecosystem

NAP2014: Policy to make Malaysia the regional automotive hub in Energy Efficient Vehicles (EEV), including fuel efficient vehicles, hybrid, electric vehicles and alternately-fuelled vehicles. The target is to have 85% of total vehicles produced in Malaysia in 2020 be EEV.

Pemandu Electrical & Electronics Entry Point Project 18: "Enabling Electric Vehicle Component Manufacturing" aims to fast-track EV adoption, targeting for 2,000 electric buses and 100,000 electric cars on the roads by 2020. A key initiative includes the establishment of a Lithium-Ion (Li-Ion) battery manufacturer in Malaysia.

by 2020. This essential component of electric and hybrid vehicles will allow the development of a larger, more competitive automotive industry.

Enhancing the competitiveness of Malaysia's rubber industry to create new products and high-value jobs

When incorporated as an additive to rubber, Graphene offers superior properties such as increased strength, excellent conductivity (electric and thermal), and better impermeability. For latex or synthetic rubber products such as gloves and condoms, Graphene's strength can be combined with the elasticity of latex to produce an enhanced material that is thinner, stronger and more impermeable. The elasticity will have to be controlled by the proportion of Graphene, additional chemical modifications, and the manufacturing process. For tyres and industrial rubber products, Graphene has been proven to be a more effective additive than carbon black, and even carbon nanotubes[4]. Graphene can impart 6-7 times more strength than carbon black, while imparting increased conductivity, impermeability, and flame resistance.

Graphene offers significant potential for the rubber industry. Today, the global rubber industry represents a RM 900 billion market, in which Malaysia is a leading global player in several product categories. The overall Malaysian rubber industry itself is worth ~RM50 billion in which rubber gloves are the largest sub-sector, followed by industrial rubber products, condoms and tyres. Graphene could allow Malaysia's downstream rubber players to develop and commercialise breakthrough types of product applications to increase their global competitiveness.

Malaysia is home to leading global manufacturers of medical gloves. In addition, Malaysia is also the world's second largest exporter of condoms, and home to the world's largest manufacturer of latex condoms. For Malaysia's leaders in global rubber glove and condom manufacturing, there is tremendous potential from being able to offer thinner, stronger, more elastic products through the integration of Graphene into rubber. Time to commercialisation of various rubber products will depend on whether the industry is regulated. Regulated products typically require a longer product testing and approval cycle.

4 Two sources used: Y.Mao et al, article 2508, (2013), Nature; T.Ramanathan et al, vol. 3 (2008), Nature

Similarly, Malaysian retread tyre manufacturers could be the first to market with stronger and more durable Graphene-enhanced retread tyres. There is demand for such products from the medium and heavy commercial vehicles segment; as well as from some foreign markets that are less price-sensitive than regional buyers, and instead are focused on higher quality retread tyres.

Finally, Malaysia is also home to a large automotive original equipment manufacturer (OEM) market, which constantly fuels the demand for stronger, longer lasting industrial auto rubber parts (e.g., engine mounts). The industrial auto rubber manufacturers are under severe pressure to provide these parts at the lowest cost to the car OEMs. Graphene's application in this industry could potentially help reduce costs and achieve the objectives of the industrial auto rubber parts manufacturers through reduction or substitution of incumbent materials and manufacturing processes.

While many Graphene rubber enhancements have been proven in research labs, the "playing field" remains wide open as no company has to-date commercialised a Graphene enhanced rubber product. From late-stage R&D and prototyping through to commercialisation, Malaysia's rubber players could very well be the first to market with an innovative, competitive portfolio of new Graphene-enhanced products.

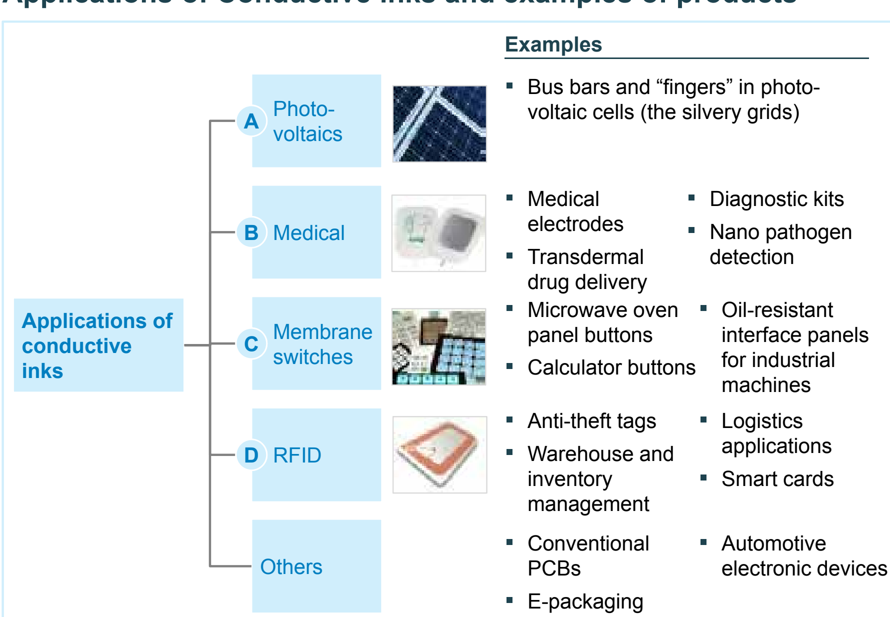
By 2020, Malaysia's rubber producers could be generating RM 13 billion in sales of rubber products enhanced with Graphene, with potentially a third of that market coming from premium or entirely new product categories.

Stimulating growth and innovation in emerging industries with conductive inks

Conductive inks are a significant cost component for many applications, such as photovoltaic cells, medical devices, membrane switches, and RFID chips (Exhibit 11). Conductive inks can replace printed wiring, especially beneficial for small circuitry that needs low cost methods.

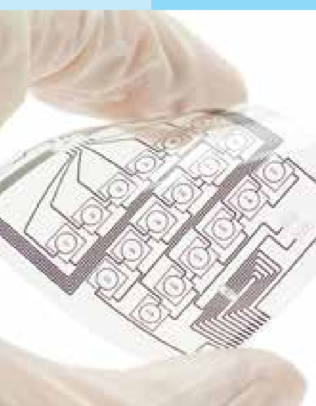
EXHIBIT 11

Applications of Conductive inks and examples of products



SOURCE: Lux Research, Inc.

Graphene's high electron mobility and resulting high electrical conductivity creates a unique opportunity to replace silver-based conductive inks, with a lower-cost, higher-performing Graphene-based ink. Graphene-based inks hold a compelling value proposition for the industry:



Conductive Inks in Use

Conductive inks are inks that can be printed directly on a substrate through a regular printing process (e.g., silk screen). These circuits can also be printed on flexible surfaces (e.g., plastics). The inks are usually applied onto the substrate and heated slightly to evaporate the solvent and sinter (melt) the conductive particles together.

- Lower input costs since Graphene is cheaper than silver while offering comparable performance
- Lower operating costs of utilising Graphene-enabled conductive inks due to the ability to produce highly customised circuits (with reduced changeover costs), and reduced processing temperatures resulting in lower manufacturing costs
- Higher degree of applicability as the lower processing temperature of Graphene will allow circuits to be printed on heat-sensitive substrate materials (e.g., plastics)
- Better performance in the long run as theoretically, when the technology matures, Graphene will be able to perform better than silver-based inks

EXHIBIT 12

Potential benefits of Graphene conductive inks for Malaysian companies

	Graphene opportunity		
	Lower material costs	Lower CAPEX costs	Other benefits
RFID	✓	✓	▪ Graphene can be printed on heat-sensitive material – new markets of labels, retail packaging ▪ Low-cost RFID can see applications in retail stores – large market opportunity
Membrane Switches	✓[1]	✓	▪ Graphene inks are more flexible and resistant to oxidation – creates more durable products
Photovoltaic Cells	✓	✓[2]	▪ Graphene inks are more durable/flexible than silver inks
Medical Devices	✓	✓	▪ Inkjet printed Graphene enables very fine circuitry—reducing the form factor of products
	▪ Graphene inks are much cheaper than silver inks	▪ Inkjet printing does not require large scale machinery to be cost effective	

Adoption assumptions based on Market forecasts and expert interviews.
1 Graphene inks may not have a large cost advantage over copper used in membrane switches
2 Photovoltaic cells do not require inkjet printing, and are usually produced in large quantities to justify high CAPEX processes
Sources: IDTechEx; Lux Research, Inc; Expert interviews

Based on these advantages, Graphene-enabled conductive inks have the potential to catalyse the growth of several new industries in Malaysia, several of which are Entry Point Project[5] priorities (e.g., RFID, photovoltaic cells) in Malaysia's Economic Transformation Programme. Given that the value chain for each of these industries are not entirely Malaysia-based (e.g., RFID chips are imported to Malaysia), this new technology can allow incumbent and upcoming industry players capture more of the industry value chain by moving upstream or creating competitive advantages in existing markets.

For RFIDs, Graphene conductive inks can be used to produce much cheaper tags, by inkjet printing of the RFID antennae. Today, due to the high costs of RFID systems (and current investments in traditional barcode systems), there is insufficient demand in Malaysia, creating a barrier to developing a home grown RFID industry. As a result, Malaysian RFID system integrators choose to import chips manufactured in Taiwan and China and only assemble locally. A main lever to increasing domestic demand to justify economically viable, at-scale manufacturing of chips is developing more affordable RFID systems, and positioning these as an attractive alternative to incumbent technologies (e.g. bar codes) for asset management or valuable inventory management. Aside from cost benefits stemming from Graphene technology, other advantages of domestic chip production include lower transportation costs and reduced exposure to currency fluctuations. In the medium term, as more cost-effective manufacturing processes get developed, and the adoption and subsequent use of RFID takes hold, there will be an opportunity for Malaysia to attract or grow its own chip manufacturer, and focus on a broader Asia Pacific market for RFID (estimated at RM 6 billion by 2015[6]).

Similar to RFID, Malaysia is home to large solar (photovoltaic) panel and module assemblers. These assemblers rely primarily on photovoltaic cells produced offshore. Local producers, new to the market and small in size, are still developing core product offerings. Graphene will be valuable to local solar cell producers as it enables lower manufacturing costs. Graphene conductive inks could be used to replace the silver-based mesh currently covering individual cells. By leveraging this opportunity, Malaysian domestic cell producers or assemblers can get ahead of the innovation curve and spur scaleable and competitive domestic production.

It is important to note that Graphene conductive inks are already in the market, simplifying the adoption for users of these inks. In fact, Graphene inks are already in some commercial

5 Entry point projects are developed as part of the Economic Transformation Programme, which was formulated as part of Malaysia's National Transformation Programme. Further details are available at etp.pemandu.gov.my

6 Frost & Sullivan, "Asia Pacific RFID Market", 2010

products and small quantities can be purchased for immediate testing (e.g., Vorbeck Inc). Because of the small number of incumbent players producing conductive inks globally, there is still opportunity for Malaysia (which at present does not participate in the global market) to develop production capability of Graphene enabled variations. Because conductive ink technology is still novel, ink producers will become "natural promoters", educating their buyers (electronics manufacturers) about the cost effectiveness of the inks, to encourage faster adoption across multiple potential applications.

While the projected market size of Graphene-enabled conductive inks within Malaysia is relatively small at RM 1.1 billion by 2020, these conductive inks can drive the emergence and growth of solar cell and RFID manufacturing[7]. Both of these areas have been recognised as priority areas in the development of the Electric & Electronics (E&E) sector in Malaysia.

Enhancing the competitiveness of nanofluids producers

As an additive, Graphene can be functionalised to enhance the performance of oilfield chemicals by increasing their lubricity and thermal conductivity, while making them more effective. The two main categories of oilfield chemicals considered for Graphene application are drilling fluids and lubricants. Since Graphene is added at the nano-scale, the addition makes the fluids in question "nanofluids".

Drilling Fluids:

Drilling fluids are used to aid the drilling of wellbores to facilitate the extraction of oil or gas. Drilling fluids typically represent about 20 percent of total drilling costs, and are a crucial input to successfully reaching the energy source (oil or gas) in the smallest amount of time and expense. To drilling fluid providers, Graphene-enhanced drilling fluids are an innovative way to address the challenges faced by oil drillers, such as wellbore stability and fluid loss during drilling.

In this environment, Graphene-enhanced[8] drilling fluids present two main benefits for oil and gas drillers. First, they address complicated drilling environments, reducing inherent drilling risk and accelerating time to completion by increasing wellbore stability, reducing fluid loss, and lubricating the drill head while conducting heat away. These are achieved through a combination of chemical and thermal conductivity properties. Second, Graphene additives are cost-effective relative to additives currently used, as they are needed in lower concentrations, which translates into lower input costs. Finally, the fact that Graphene additives are at nano-scale translates into a lower replacement rate as the Graphene is not filtered out, and therefore does not need to be replaced with each filtering cycle.

How do Drilling Fluids Work?

Drilling fluids enable the drilling process by suspending cuttings, controlling pressure, stabilizing exposed rock, providing buoyancy, and cooling and lubricating. Drilling fluids are water-, oil- or synthetic-based, and contain additives.

7 Lux Research, Inc. "Inking Money: The Prospects for Materials in Printed Electronics."

8 In-lab demonstrations conducted using mix of pulverized graphene oxide for strength and large flakes. Source: The Tour Group/ Partnership between Rice University and Schlumberger's subsidiary M-I SWACO

Developing enhanced drilling fluids is an attractive value proposition in Malaysia as it is home to a number of base fluid and drilling fluid providers. Malaysia is also centrally located in an oil-rich region where drilling conditions are becoming increasingly complex (e.g., deeper wells, offshore drilling). Considering the high player concentration within the drilling fluids market, and the prominence of large international firms, Graphene affords local players a unique opportunity for disruptive innovation and growth.

Lubricants

The lubricant industry[9], an important supplier to both the automotive and the industrial sectors, is currently facing pressures which are poised to spur innovation:

- First, lubricant makers are facing significant cost pressures. In an effort to control costs, the automotive industry is pressuring additive manufacturers to develop formulations that can do "more with less"; the lubricant marketers' ability to pass along costs to automotive and industrial manufacturers is decreasing, creating additional pressure to innovate cost-effective alternatives
- Second, the automotive players and industrial machinery fabricators are developing smaller, more complex, heavy-duty engines, to address increasing performance requirements. This trend creates strong demand for reformulated, higher-performing lubricants
- Last, environmental considerations are increasing, as automotive players globally are demanding cleaner, bio-based alternatives to current lubricants. This will put a premium on using more environmentally-friendly feedstock as inputs, over conventional base oils.

What are Lubricants?

Lubricants are finished lubricating fluids (typically oils) consisting of base stocks and additives that enhance lubricity and heat conductivity of the base fluid. There are thousands of variants depending on end use.

Graphene presents a unique opportunity for innovation in the lubricant industry because its tribological properties (relating to friction, lubrication, and wear of interacting surfaces) are superior to other commonly-used additives. Researchers have found Graphene to be useful in both wet and dry applications. In wet applications, the immediate potential is in producing a less toxic wet lubricant since the base fluid can be water-based. Potential wet applications include lubricating motion-machines with stainless ball bearings, from table fans to wind turbines, as well as micro machines. There are also opportunities to produce novel dry lubricants. Graphene as a dry lubricant can be applied to mechanical parts through a dipping process (parts are dipped in a Graphene solution and then dried) to reduce friction, increase adherence to surfaces, and eliminate the need for wasteful reapplication. Dry lubricants are applicable for emerging fields such as nano-robotics, where novel materials and application solutions have to be developed.

9 Industry trends were derived from expert interviews and research reports including Freedonia 2009 report; SRI; Ricardo, an automotive engineering consultancy

Within Malaysia, lubricant innovation could be attractive to petrochemical companies producing base oils[10], palm oil plantation owners seeking outputs for their biomass, and to automotive manufacturers seeking to reduce manufacturing costs and to promote of "green" products.

Malaysia has the potential to drive a step-change in adoption of Graphene-enhanced lubricants. First, since Graphene-enhanced lubricants have yet to be commercialised, there is room for domestic producers to innovate with Graphene. Second, the fact that Malaysia is home to several independent automotive manufacturers, and boasts a sizable manufacturing sector, means that adoption can be driven locally, with the potential for later expansion into international markets.

The overall impact from developing Graphene enhanced drilling fluids and lubricants, could lead to an increase in GNI of RM 1 – 1.2 billion and the creation of ~250 Malaysian jobs.

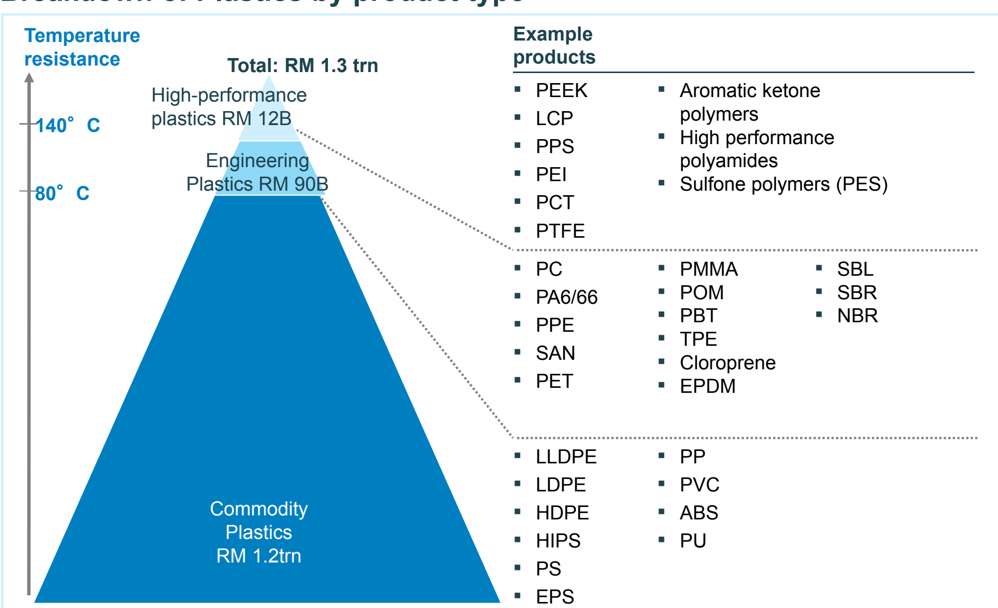
10 Globally, Malaysia is the leading domestic producer of lubricants.Petronas is ranked as the 13th largest producer with annual production of 650 million litres, and stated aspirations to become #5. Source: Lubes'n'Greases WHICH YEAR? annual survey

Capturing greater value in plastics manufacturing through development of new materials and products

Plastics are an important RM 1.3 trillion global industry dominated by commodity plastics, with smaller niche end applications in engineering and high performance plastics (HPPs). Exhibit 13 shows the categorisation of common plastics. Various compounds are blended in to enhance specific properties and make plastics usable for specific applications. These additives can be introduced either in the plastic manufacturing stage (where the plastic is in pellet form), through the integration as a masterbatch, or by individual converters (the end customers who convert plastic inputs into final products).

EXHIBIT 13

Breakdown of Plastics by product type



1 Marketing & Sales
SOURCE: SRI

Graphene's unique properties position it to be a highly value-added additive. As a reinforcement filler, Graphene can increase the mechanical rigidity and strength of its host plastic. Graphene also adds properties similar to that of other carbon additives—increased electrical and thermal conductivity, and ultraviolet light protection. Graphene will also provide cost savings to producers (compounders or converters) as a cheaper alternative to existing strength enhancing additives, and by allowing producers to use less plastic.

In the next 3-5 years, high performance and engineered plastics will be among the first commercial applications to incorporate Graphene, due to the performance enhancement potential Graphene provides. Graphene is expected to become increasingly relevant for bulk plastics in 5-10 years, once Graphene prices reduce significantly due to economies of scale achieved in production. However, niche "slices" of this broad category (producers developing high price segments with lower cost sensitivity) may become open to Graphene in the shorter term (3-5 years). Adoption rates are highly dependent on Graphene manufacturers' ability to produce on a large scale[11].

11 Based on interviews with Malaysian Graphene-enhanced masterbatch producers and experts with international Engineering/ High Performance Plastics development backgrounds

For innovative Malaysian plastics companies, enhancing current products with Graphene, or developing entirely new product lines is a compelling opportunity to increase differentiation, and product value-add. Since the majority of manufactured plastics are exported, the opportunity to capture additional markets is not capped by internal demand. Moreover, the diversity of the products which can be enhanced by plastics, including plastic resins in the midstream creates opportunities for Malaysian producers. Once this happens, upstream graphene production also becomes more viable to sustain the value chain locally.

Seizing the plastics opportunity could lead to an increase in GNI of RM 250 - 300 million and the creation of 600 and 200 Malaysian and high value jobs, respectively, by 2020.

Impact to Malaysia

By innovating in each selected application area, Malaysia stands to benefit substantially from Graphene adoption. In all, the Malaysian economy will add RM 10 billion to its GDP, with a commensurate RM 20 billion impact to GNI. In addition, about 9,000 Malaysian jobs could be created, with about 2,000-3,000 of these jobs being categorised as high-value.

These figures solely represent the near-term impact on adopting downstream players. They do not include the impact from a broader application set which could emerge in the future. For example, the size of the conductive inks industry does not capture the impact from emerging solar cell or RFID industries. Similarly, growth in each industry's respective value chain is also not captured. These side-benefits (or 'spill-over' benefits) will multiply the effect of early and deliberate Graphene innovation in Malaysia.

EXHIBIT 14

By 2020, the National Graphene Action Plan has the potential to add more than RM 20 Bn in GNI impact and help create 9,000 new Malaysian jobs

Opportunity area	Potential revenue impact to Malaysia[1] RM mn	GNI RM mn	Malaysian jobs created #
Rubber Additives	3800-4400	8000-9500	5,700
Conductive inks	950-1250	2000-2500	1,000
Nanofluids[2]	950-1250	2000-2500	250
Lithium-ion batteries	2800-3500	6500-8000	1,700
Plastic Additives	250-300	500-800	600
Total	**9,000 - 11,000**	**18,500 - 23,000**	**~ 9,000**

20-30% of these jobs expected to be high value - e.g. R&D, business development etc. **Automation to be an important driver**

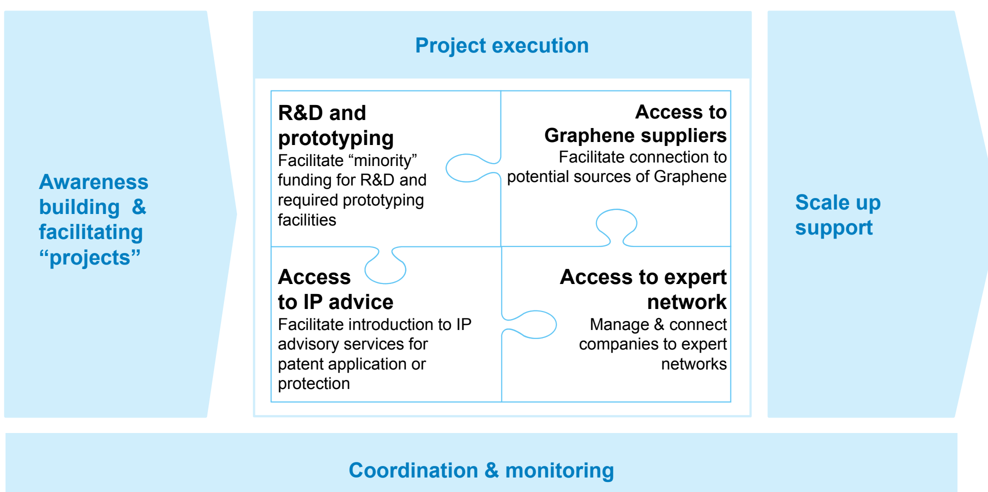
Role of Government to capture the opportunity

To realise this potential opportunity, Malaysia must move decisively and strategically ahead of its regional competitors and ensure that the right ecosystem is built to catalyse the innovation and adoption of Graphene enabled applications. Government will have a significant role to play and a lead agency will be tasked to convene and coordinate across the complex ecosystem in all application areas.

In assessing the country's Graphene action plan, significant downstream engagement across the five selected application areas was conducted. In more than 100 interactions with companies' CEOs and R&D heads, researchers and academics, specific areas of support were identified where government could play an enabling facilitating role. The resulting framework is presented in Exhibit 15 below.

EXHIBIT 15

Government to play a critical role in establishing and maintaining Graphene project development activities



1. Awareness building and facilitating projects: As Graphene is a relatively new and unknown material, most Malaysian companies are unaware of the vast potential it holds for their respective products and services. The lead agency will be responsible for conducting an extended outreach effort, and generate awareness and comprehension within industry for the potential applications of Graphene.

   There will also be a role for government to play in facilitating partnerships and collaborations across the various stakeholders in the ecosystem (e.g., between industry and academia, or between upstream and downstream producers).

2. Project Execution: As companies, partnerships or joint ventures decide to explore the vast potential of Graphene enabled applications, the role of government will shift towards assisting companies with late stage R&D and prototyping. Through downstream engagement with industry, four basic project execution support functions were identified:

a. "Minority" matching funding support for late-stage R&D and prototyping. This will include expanding existing funding platforms and identifying accessible prototyping. Prototyping equipment and facilities are available at government research agencies and in universities (Exhibit 16).

EXHIBIT 16

Government research agencies and universities in Malaysia that already have prototyping facilities NON EXHAUSTIVE

b. Facilitating access and connection to potential sources of Graphene (Exhibit 17), made to specification. Based on the government's impartiality, the provided Graphene supplier lists represent publicly available information about global producers. While the government does not endorse specific producers, all things being equal, preference for local suppliers will always be encouraged.

EXHIBIT 17

List of Graphene suppliers globally

DISCLAIMER NOTE

The enclosed list of suppliers has been compiled from publicly available resources. Provision of this list constitutes in no way an endorsement or recommendation of any of the listed suppliers. The provider has no financial or other relationship with any of the listed entities. Use of any of the listed entities is entirely at the discretion and risk of the contracting party.

Potential sources of Graphene

CONTACT DETAILS IN APPENDIX

Company	Location	Material	Year founded	Potential application areas
[illegible]	Malaysia	Highly Graphitic NanoFlores (Nanoplatelets) Sheets (Nanofilm)	2006	Drilling fluids, lubricants, plastics, rubber
[illegible]	USA	Graphene Flakes (Nano platelets)	2006	Composites, inks, energy, rubber
[illegible]	UK	Graphene Flakes (Powder, dispersion)	2010	Composites, coating, energy, fuels
[illegible]	UK	Graphene Sheets	2007	Research
[illegible]	South Korea	Graphene Sheets (CVD wafer)	2012	Touch screen panels
[illegible]	Spain	Graphene Sheets (Monolayer film)	2010	Research
[illegible]	China	Graphene Flakes (Nano platelets)	2010	Composites, energy
[illegible]	USA	Graphene Flakes (Nano platelets)	2009	Photovoltaics, sensors
[illegible]	USA	Graphene Flakes (Nano platelets)	N/A	Inks, polymer filler, energy
[illegible]	USA	Graphene Flakes, Graphene Sheets (Nano platelets)	2006	Energy storage, inks and coatings

Potential Graphene solutions-only providers

CONTACT DETAILS IN APPENDIX

Company	Location	Material	Year founded	Potential application areas
[illegible] RICE	South Korea	Graphene Flakes (Nano platelets)	2012 (Licensed patents from Rice)	Electronics, advanced optical devices
[illegible]	USA	Not specified	N/A	Electronics, energy storage, coatings, composites
[illegible]	USA	Graphene Flakes (Nano platelets)	N/A	Plastic/rubber additives
zyvex	USA	Graphene Flakes (Nano platelets)	2007	Composites

c. Introduction to IP advisory service providers to help navigate the local and global IP landscape; and assist in filing for patent application and protection. Existing platforms include PlatCom (a Joint Venture between AIM and SME corp) as well as MyIPO.

d. Supplement existing industry R&D capabilities with specialised Graphene expertise through building a network of local and global experts. In Exhibit 18 below, the framework for the development of this expert network is presented, along with the names of existing networks that can be leveraged.

EXHIBIT 18

Principles for establishing a Graphene “expert network”

NON-EXHAUSTIVE LIST

Criteria	▪ Experts to be identified **on the basis of their expertise in Graphene and/or the 5 selected domains** — Criteria include track record I research, publications and patents, experience in commercialization of technologies etc.
Sources	▪ A mix of experts to be compiled from **academic and Graphene/ nanotech industry sources** — Sources include universities, Graphene suppliers and solution providers etc.
Setup	▪ Setting up the network will involve **a focused one-time effort at the start**, followed by regular reviews on an ongoing basis
Engage-ment model	▪ A **virtual network (central website)** set up to be the cornerstone of the new ecosystem ▪ Companies should be able to easily access the network and **engage experts freely**, with Facilitator potentially facilitating these engagements

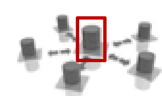
The University of Nottingham Malaysia Campus

USM

Steinbeis

NANOMALAYSIA

CREST



3. Scale-up support: At the commercialisation stage, industry will need specific government support in building up production scale facilities. The role of the lead agency will be to facilitate introductions to existing government agencies such as PEMANDU and MIDA to access available resources, tax incentives, and EPPs to support in the scale-up.

4. Coordination and monitoring: The lead agency (NanoMalaysia) will also be responsible for tracking and monitoring progress and development of the execution of the National Graphene Action Plan 2020 in each of the application areas. Specifically, the progress of projects, especially when public funds are used for R&D and scale-up, and the impact to the economy in terms of GNI, investment and job creation.

Summary

The National Graphene Action Plan 2020 aims to define how Malaysia can benefit from the considerable potential of Graphene, and set an approach and roadmap to capture this potential.

By 2020, the National Graphene Action Plan 2020 has the potential to contribute RM 10 billion of Malaysia's GDP, and more than RM 20 billion of GNI impact. In addition, about 9,000 Malaysian jobs could be created with about 2,000-3,000 categorised as high-value jobs.

The Graphene focusses initially on thriving domestic industries such as rubber products and areas being targeted for innovation by the government such as electric vehicles. Downstream applications present the greatest opportunity for Malaysia in the near-term to integrate Graphene and to explore product enhancement. These include lithium-ion battery anodes and ultracapacitors, rubber additives, nanofluids (drilling fluids and lubricants), conductive inks, and plastic additives. Still early in the development stage, Graphene's superior and proven physical properties offer tremendous potential for Malaysian industries to fundamentally change product capabilities and raise their profiles globally.

Capturing this opportunity will require concerted efforts across several stakeholder groups in the public, private and academic sectors. Malaysia is committed to assisting its companies, and the government will play an active role in initiating and promoting the development of a Graphene ecosystem. This entails building awareness about the versatility of Graphene and its potential applications, and encouraging companies to invest in R&D, prototyping and early commercialisation. In parallel, the government will facilitate access to Graphene suppliers, domain experts, and prototyping facilities; assist with navigating the IP landscape; and provide access to any available funding support.

Gradually, the adoption of Graphene can also be extended to other industries where Graphene is expected to play a transformative role in the coming years. Considering the potential, the government is taking big strides to lay the foundation for a healthy Graphene ecosystem. A lead agency will be appointed to facilitate and monitor execution. Access to funding resources will be expanded to cover Graphene related activities, and a network of Graphene experts and suppliers will be developed.

This level of investment and support reflects Malaysia's broader aspiration of becoming a high-income nation by 2020. Graphene presents a unique opportunity for Malaysia to achieve some of these economic development goals while creating an ecosystem of new producers, suppliers and downstream industry.