Technology Trends: A Review of Technologies and Policies

Study on Technology Trends DTI

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Contents

List of Tables

List of Figures

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Abbreviations & Acronyms

AIS	Automotive Investment Scheme
AMP	Advanced Manufacturing Partnership
BEE	Black Economic Empowerment
BRICs	Biotechnology Regional Innovation Centres
CAD	Computer Aided Design
CMT	Cut, make and trim
CoE	Centre of Excellence
COMPETES	Creating opportunities to meaningfully promote excellence in technology, education and science
CSIR	Council for Scientific and Industrial Research
CTCIP	The Clothing and Textile Competitiveness Improvement Programme
DACST	Department of Arts Culture, Science and Technology
DFI	Duty-Free Importation
DST	Department of Science and Technology
dti	Department of Trade and Industry
ENIAC	Electronic Numerical Integrator And Computer (Nano-electronics technologies platform)
EPC	Excellent Performance Certification
ETRC	European Technology Research Council
FCH	Hydrogen and Fuel Cells
FP	Framework Programmes
GDP	Gross Domestic Product
GMES	Global Monitoring for Environment and Security
GRIs	Government-funded Research Institutes
GS	Good Software
HEI	Higher Education Institution
ICT	Information and Communications Technologies
IEEE	Institute of Electrical and Electronics Engineers
IMD	International Institute for Management Development
IMI	Innovative Medicines Initiative
JTI	Joint Technology Initiatives
KET	Key Enabling Technologies
KISTEP	Korea Institute of Science and Technology Evaluation and Planning
KZN	Kwa-Zulu Natal
MCT	Ministry of Science and Technology
MDC	Multimedia Development Corporation
MEP	Manufacturing Extension Partnership
MEXT	Ministry of Education, Science and Technology
MIGHT	Malaysian Industry-Government Group for High Technology
MIP	Manufacturing Investment Programme
MKE	Ministry of Knowledge Economy

MOSTI	Ministry of Science, Technology and Innovation
MSC	Multimedia Super Corridor
MVA	Manufacturing Value Added
NEDO	New Energy and Industrial Technology Development Organisation
NEP	New Excellent Product
NET	New Excellent Technology
NIC	Nanotechnology Innovation Centre
NIST	National Institute of Standards and Technology
NRF	National Research Foundation
NSTC	National Science and Technology Council
OECD	Organisation for Economic Co-operation and Development
PACEST	Presidential Advisory Council on Education, Science and Technology
PACTI	Action Plan on Science, Technology and Innovation for National Development (Brazil)
PCAST	President's Council of Advisors on Science and Technology
PCGG	Presidential Committee on Green Growth
PI	Production Incentive
PITCE	Industrial, Technological, Foreign Trade Policy (Brazil)
R&D	Research and Development
RFID	Radio Frequency Identification
S&T	Science and Technology
SETIs	Science, Engineering and Technology Institutions
SIP	Strategic Industrial Projects
SIW	Sectoral Innovation Watch
SME	Small Medium Enterprise
SMME	Small, Medium and Micro-Enterprises
SPII	Support Programme for Industrial Innovation
ST&I	Science, Technology and Innovation
STP	Seda Technology Programme
STP	Software Technology Parks
THRIP	Technology and Human Resources for Industry Programme
TIA	Technology Innovation Agency
TIFAC	Technology Information, Forecasting and Assessment Council
TIP	Technology Innovation Programme
TSB	Technology Strategy Board
UK	United Kingdom
UNIDO	United Nations Industrial Development Organisation
USA	United States of America
USPTO	United States Patents and Trademark Office
WPI	World Premier International Research Centres Initiative

Executive Summary

This investigation has been initiated by **the dti,** in order to identify technology trends both locally and abroad and develop supporting actions for the country's industries. The report set the objective "to identify global technology trends, which will influence the competitiveness and future development of South African industries, with specific focus on identifying areas for innovation so as to reduce industrial dependency on foreign technology, whilst ensuring that appropriate programmes are offered to promote innovation and technology" (terms of reference of **the dti** study on technology trends).

More specifically the terms of reference set the following objectives:

- Identify international trends related to technology development.
- Identify, on a global basis and across industrial sectors, the existing and emerging technologies that are driving success in the marketplace.
- Identify technology and sectors being supported by governments in other countries.
- Identify international innovation and technology support strategies and practices which have and are leading to sector development.
- Identify cross cutting technologies that could impact more than one sector within the manufacturing industry.
- Identify the impact of introducing such technologies on industrial development as well as the general impact on socio-economic environmental conditions.
- Identify possible technology areas for further development in South Africa.
- Formulate specific recommendation for government intervention, based on the above assessment and also considering the government's current strategies and interventions.

The report is based on an extensive national and international literature review; the development of a number of technology related indicators; patent and bibliometric analysis of South Africa and a number of other countries; review of the available technology incentives locally; and a survey of national stakeholders. The literature review is covering trends in technology development; country rankings according to technological and manufacturing performance; best practices in technology support; and identified research/technology priorities. The countries/regions emphasised are USA, Japan, European Union, United Kingdom, Brazil, India, Korea and Malaysia.

The findings of the investigation according to the set objectives are as follows:

There are four broad international trends that shape the development of technology currently. These are:

- Technology Convergence: It is recognised internationally that the world is undergoing a global technology revolution that is integrating developments in biotechnology, nanotechnology, materials technology and information technology at an accelerating pace with profound effects on society
- ICT/Digitisation is recognised as the most important technology area currently and in the foreseeable future and it permeates all facets of society.
- Emphasis on High Technology Industries; Governments internationally support the development of high technology industries on the conviction that knowledge- and technology-intensive economies create well-paying jobs, contribute high-value output and ensure economic competitiveness.
- Recognition of Importance of Transnational Corporations which account for more than 60% of all R&D in world and for 2/3 of world trade.

These trends are fuelled by a number of emerging technologies which have the potential to enable new inventions and the creation of new industries. Currently the identified enabling technologies are:

- Advanced materials.
- Advanced manufacturing systems.
- Micro and nano-electronics.
- Nanotechnology.
- Industrial biotechnology.
- Photonics.

The international review identifies 40 emerging technologies and their level of maturity. They are grouped as: nanotechnologies; knowledge based multifunctional materials; new production processes; information society technologies (IST); life-sciences, genomics and biotechnology for health and sustainable development, global change and ecosystem. These technologies have the potential to affect a multitude of sectors and the report identifies these cross cutting technologies with the most potential in terms of sectoral impact. Furthermore, it is argued that these technologies have potential for high market growth and capabilities of solving social problems ranging from health and rural development to defence and economic growth.

All countries investigated identify and support cross cutting technologies. These are: ICT; renewable energy; advanced materials and nanotechnology; advanced manufacturing technologies; aerospace technologies and biotechnology. Countries support technologically various sectors depending on their economic plans but all of them support strategic sectors such as ICT, aerospace, and green energy. The report lists cross cutting technologies and the sectors that are expected to affect (table 4). For example, 3d printing and personal fabrication is expected to affect electronics, energy, pharmaceuticals, aerospace, agro-processing and textiles.

The countries utilise a number of common approaches in order to support technologically their industries. These are: monitoring and coordination; institutionalization of priorities; support for research and development expenditures; support through innovation support programs, fiscal incentives and cluster initiatives; strengthening the science base for knowledge intensive technologies and using a multitude of incentives.

A number of indicators related to South Africa and selected countries point out that South Africa has an underdeveloped high technology, high value industry. The value added indicators, imports-exports, patents and R&D expenditure make that point. Similarly the country's publication profile shows that the research system is not geared to support the high technology industry. Critical disciplines like engineering, material sciences, computer sciences and molecular biology are underemphasized in the country. The patent analysis identifies the technologies in which South Africa has a leading position internationally. South Africa is ranked third in the world in Chemistry: Fisher-Tropsch Process or Purification or Recovery of Products; 12th in Chemistry of Hydrocarbon Compounds and also in Specialized Metallurgical Processes. Furthermore, South Africa appears to have few innovation programmes in comparison with the other countries.

A survey of relevant stakeholders (chapter 3) identifies a variety of technologies of importance for the various sectors. The stakeholders' opinions converged in identifying as being of high importance the following technologies:

- Advanced manufacturing technology;
- Modelling and simulation for improving products, perfecting processes, reducing design-to-manufacturing cycle time and reducing product realization costs; and
- Intelligent sensor network and ubiquitous computing.

The report advances the following recommendations:

- **dti should consider developing programmes supporting the development of high technology, high value added industries.** A possible approach toward this objective is the development of "science parks" or "corridors". The parks should offer adequate incentives to attract and support the prioritized industries according to international good practise. Such incentives may include world class competitive IT infrastructure at internationally competitive cost; uninterrupted electricity at internationally competitive cost; the provision of sector specific R&D and innovation funding; the provision of tax holidays (on application) to international companies with expertise in technologies of national interest; etc. Suggested parks that can be considered are: Innovation Hub for ICT and creative industries; Automotive Supplier Park for automotive and transport; Centurion for Aerospace Village for aerospace; Stellenbosch Techno-park for agro-processing; NMMU-CSIR and Cape Apparel and Textile Cluster for textiles and Onderstepoort for pharmaceuticals/animal health.
- **dti should develop sector based programmes supporting technology adoption and innovation according to international good practise.** Industry participation should be a prerequisite in these efforts. A possible mechanism for the development of sector based support can be the creation of THRIP type programmes (triple helix approach). The cross cutting technologies impacting a multitude of sectors may by prioritized as being cost effective. The most important are nanotechnologies for industry (affecting 8 sectors); smart bio-mimetic materials (7 sectors); smart interactive textiles (7 sectors) intelligent sensors networks (7 sectors); 3D printing and personal fabrication (6 sectors); industrial biotechnology (6 sectors). As in THRIP it is the industrial participant who identifies and co-funds the project the approach is particularly suited for **the dti**. This recommendation is supported by international best practice and the finding that South Africa has a limited number of technology supporting instruments in comparison to the rest of the world.
- **The dti in consultation with DST should develop and support the "South African Advanced Manufacturing Initiative".** Even though small efforts exist locally (emphasising mainly aerospace technologies) the field is recognised internationally and locally as of critical importance for the future of a variety of industries and sectors. The programme will work on a cofounding partnership basis. The dti should solicit relevant proposals from consortia of private and public organisations for the development of technology area with high potential payoff in employment and output. The industrial partners should be prepared to co-invest with the government.

Government should further support the development of shared labs, pilot plants, technology infrastructure and creation of clusters. Where necessary, government should offer modest-sized planning grants to support the preparation of such proposals.

- . **The dti should consider, together with DST, the establishment of supporting instruments enlarging the parts of the science base in the disciplines of interest to the dti and industry.** Our analysis provides evidence that the science base underemphasizes technologies supporting high technology industries, engineering and similar. The objective should be to double the available expertise in engineering and priority science fields within ten years. Such fields are engineering, materials science, computer science, chemistry, and molecular biology. In this context **the dti should aim to get directly involved in the financial support and the management of the science base.**
- **The dti in collaboration with the relevant sectors should consider the establishment of "Innovation and Knowledge Centres"** according to the UK model. The Centers will aim to bridge the innovation chasm from research to commercialization. Their focus will be to technology areas where South Africa has substantive strengths (e.g. catalysis, immunology products and similar) and it will support mainly process technology development in pilot lines, prototyping and demonstrators, accelerating commercialization. In the same context the newly institutionalised Incubation Support Program of dti could be expanded (financially) and support also development of demonstrators and prototypes.
- **The dti should establish committee for emerging technology identification and support.** South Africa does not have an emerging technologies identification/prioritization mechanism. This creates delays in the establishment of relevant supporting programs; delays in technology transfer; lack of state of the art information in industry (particularly in the technology intensive industries) and similar. The Emerging Technologies Committee of the Chamber of Commerce in the USA can be utilised as an example.

1. Introduction

The world is in the midst of a technological revolution. Advances ranging from the field of information and biotechnology to materials science and communications are occurring at an accelerating pace bringing about radical changes in all dimensions of life.

Increasingly, such applications entail the integration of multiple technologies. New approaches to harnessing solar energy, for example, are using plastics, biological materials and nano-particles. The latest water purification systems use nanoscale membranes together with biologically activated and catalytic materials. The reputable journal Nature reported recently (20 June 2012) that the Nobel winning material graphene is able to desalinate water by manipulating the size of the pores and others.

These integrated developments, from multiple scientific disciplines, transform or have the potential to change the face of work and industry, establish new economic and political powers on the global scene and even affect the quality of human life. Although technologies may have widespread implications, not all countries will necessarily be able to acquire them – much less put them widely to use – to the benefit of their industries and societies. Industrial development is particularly dependent on technology and the former is the recognized as the key to economic growth and development.

A recent report[1] by the Department of Economic and Social Affairs of the United Nations Secretariat on Industrial Development (UNIDO) for the twenty-first century articulates the primacy of industrial development in economic development. The report states: "Industrial development is not the only possible route to a developed country standard of living, but it is a well-proven one. It is for this reason that industrial development remains a high policy priority of governments in the developing world. While less vital to maintaining high incomes in developed countries, industry remains an important source of well-paying jobs, especially for those workers with less than a college education."

Countries are undertaking monitoring and assessment exercises in order to inform their policies and to gain economic advantage over their competitors. Such activities are usually reported under the title of

[1] United Nations (2007) "*Industrial Development for the 21st Century: Sustainable Development Perspectives.*" Department of Economic and Social Affairs

science and technology foresight; science and technology roadmaps and similar. Most industrialized countries undertook such exercises during the last twenty years fueled by a number of factors such as:

1. Technology is increasingly recognized to play the key role underpinning continued economic growth and prosperity, by creating greater levels of productivity, and creating new products and services;
2. The cost of performing the R&D required to create new technologies is increasing, which among other means that most single companies can no longer afford to develop new technologies on their own;
3. New technologies increasingly result from multidisciplinary research. This requires the formation of new networks and strategic alliances to allow companies to engage in the social process of innovation; and
4. Governments have a diminishing budget for science and technology. This is the result of many factors, including the increasing costs of performing R&D, the increased competition in national budgets from other priorities (e.g. welfare and health spending) and others.

In this context **the dti** in South Africa has initiated this investigation in order for the Innovation and Technology Unit to support the Industrial Policy Action Plan (IPAP). The objective of the effort is to identify technology trends locally and abroad and propose supporting actions for the country's industries.

The investigation is particularly timely as South Africa's industrial performance appears to be in a declining path, both according to UNIDO and IMD (appendix 3). UNIDO identified that the country's ranking declined from 45th in 2005 to 49th during 2009 while IMD identified that the country's ranking declined from 44th during 2010 to 52nd during 2011. It should be noted that IMD ranked even lower (58th) the country's technological infrastructure.

The structure of the report is as follows: the Chapter "Technologies and Policies: the International Experience" summarises the findings of a large European Commission multi-sectoral study that was recently completed. The investigation with state of the art recommendations analyses the factors and institutions impacting innovation performance and the structural background of innovation potential and important technologies in nine selected sectors i.e. food/drink, machinery/equipment, textile, chemicals, ICT, space and aeronautics, automotive — and three horizontal topics: biotechnology, eco-innovation, and "gazelles" (fast growing SME's). The study has far reaching consequences for innovation policy as it argues that individual sectors require particular innovation policies and that the approach of one fits all is ineffective. Simialrly the chapter elaborates on the relevant experiences of eight regions/countries which cover the most important regions in the world. The regions covered include the USA, Japan, European Union; United Kingdom; Brazil; India, Korea and Malaysia. For each country their sectoral priorities and relevant technologies are identified together with the policy approaches utilized. The Chapter ends with concluding remarks.

The following chapter "Technology Identification Survey" reports the findings of the effort to canvass the opinions of local experts. The chapter "Overview of Innovation and Technology Support in South Africa" describes the incentives offered to industry by government in South Africa. It follows the chapter "Indicators: South Africa and Selected Countries". A number of indicators are developed and reported including value added in various manufacturing sectors in South Africa and abroad; and patent analysis; bibliometric indicators. The final chapter "Findings and Recommendations" discusses the findings of the report and provides relevant recommendations. The report is supported by a number of appendices in volume 2.

2. Technologies and Policies: International Experience

This chapter elaborates on the findings of the Sectoral Innovation Watch project of the EU and elaborates on experiences related to technology/innovation policy (technology/sector identifications and modus operandi) in eight regions/countries, which cover the most important regions in the world. The regions discussed include the USA, Japan, European Union; United Kingdom; Brazil; India, Korea and Malaysia. For each country the sectoral priorities and relevant technologies are identified together with the support approaches utilized. Emphasis is placed on recent policy related activities affecting industrial establishments. The chapter ends with concluding remarks.

The European Commission (Directorate General Enterprise and Industry) supported the development of the three year Sectoral Innovation Watch (SIW) SYSTEMATIC project.[2] The objective of the effort was to analyze the factors and institutions impacting innovation performance and the structural background of innovation potential in the nine selected sectors. The investigated sectors were food/drink,

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2 Europe Innova (2008) "*Sectoral Innovation Watch: Synthesis Report.*" European Commission Directorate General Enterprise and Industry, Brussels

machinery/equipment, textile, chemicals, ICT, space and aeronautics, automotive — and three horizontal topics: biotechnology, eco-innovation, and "gazelles" (fast growing SME's).

The motivation for the project stated that even though conditions and approaches to innovation differ from sector to sector, most policy instruments in the EU and internationally are of horizontal nature (i.e. support all sectors). Hence, the project aimed to identify those differences and relevant policy instruments.

Some of the findings are as follows:

- Sectors differ considerably in their modes of innovation. In some sectors firms that produce technology, i.e. firms that carry out R&D either continuously or intermittently, are more prevalent. Such sectors are the ICT sector, the automotive industry or the chemical industry. The total share of innovators in these sectors is also above average, as is their economic performance. In turn technology users, i.e. firms that use, adapt and modify existing technologies, are in sectors such as food, textiles or the energy industry. These firms are more likely to look beyond technological opportunities and the total number of innovators among them is low.
- Knowledge acquisition from external sources is of particular importance in sectors with large shares of technology users, whereas R&D activities are important in sectors where firms that are technology producers prevail.
- Technology users may be highly innovative in terms of the turnover they generate through the introduction of new products. In this case innovation is driven by the acquisition of external knowledge. Formal cooperation agreements, licenses, commissioned research, or informal exchanges with suppliers or competitors, act as (weak) substitutes for in-house R&D. In addition, innovation expenditures related to personnel training and activities related to market introduction of innovation are all crucial factors for the firm's innovative success. Yet, the results also show that across all types of firms, R&D investment remains the most important factor for innovation success.
- There is a broad spectrum of specific national sector responses to national policies that have an effect on innovation performance. These results suggest adjusting the national and regional innovation policy mix to accommodate factors specific to sectors. For example, for the energy sector, the ICT industries and the aerospace industry public R&D subsidies have a positive effect,

whereas R&D spending by the government seems to crowd out R&D investment in the textile and chemical sectors. The variables involving free market access seem to have a positive effect in the energy and food sectors, while they have a detrimental effect on ICT and aerospace companies.

- There is an inverted U-shape relationship between competition and R&D across countries and sectors. This means that firms have little incentive to invest in R&D if they are not stimulated by competition, whereby too much competition discourages investments into R&D activities, as the likelihood of diminishing returns on their efforts increases. However, the effect of competition on innovation declines when a country lags behind other more advanced countries. This means that in less advanced countries more competition could actually harm R&D spending. This implies that more competition might not initially be good for less advanced countries. However, as they pass productivity thresholds competition would become a more important factor in stimulating innovation. This means that in less advanced countries competition policies should not be too rigid, and temporarily allow less competition among fewer companies.
- There is a multitude of policy instruments used in Europe for the benefits of industry (Table 1). SMMEs attract the largest number of instruments by target and innovation the largest number by type.
- The three top challenges facing all industries are related to human capital, the support of knowledge creation, diffusion and technology transfer and financial constraints.

Table 1: Policy measures per sector and share of targets and types (Number of cases: 1157)

Sector	ICT	Aero-nautics	Bio-tech	Chem-icals	Auto-motive	Food	Ga-zelles	Machi-nery	Eco-inno	Energy	Tex-tile	Total number
What are the measures												
All industry sectors	36	24	30	37	40	28	41	41	49	36	47	433
Particular industries	25	44	38	49	38	44	19	38	32	38	34	416
Large companies	36	59	45	43	45	34	17	46	38	45	42	466
SMEs	57	67	59	59	61	61	85	59	61	45	65	710
Research organisations	39	56	64	49	46	39	26	39	49	42	30	502
Individuals	21	13	22	20	18	27	20	20	30	35	15	258
Other	25	21	18	14	10	11	8	23	18	16	12	181
What are the types of measures												
Cluster initiative	23	24	32	21	24	22	16	13	29	7	14	241
Technology platform	26	24	16	24	18	14	14	17	31	25	14	235

Innovation Programme	45	35	45	43	56	43	45	48	49	35	47	520
Regulation	9	11	6	9	3	10	6	3	9	13	3	85
Competition regulation	1	3	2	0	1	6	0	0	1	5	2	22
Quality regulation	2	8	3	6	4	13	1	4	5	7	9	64
Fiscal initiative	16	24	26	21	30	23	38	24	31	35	20	302
Other	24	25	18	23	21	17	25	28	15	15	20	237
Number of measures	121	63	125	111	120	109	105	71	110	110	107	1157

Among the information provided was the identification of technologies of importance for the various sectors. A summary of the findings for the various sectors appears in appendix 4.

The recent experiences related to technology/innovation policy of the selected countries follow:

2.1 USA

Technology is recognised for its contribution to economic growth and productivity increases and hence, government attention has been focused on how to augment private-sector technological development. It is widely accepted that technological progress is responsible for up to one-half the growth of the US economy and is one principal driving force in long-term growth and increases in living standards.

The development of an industrial policy is a debated issue in the USA. Advocates argue that such an effort could ameliorate much of the uncertainty with which the private sector perceives future government actions and that consideration and delineation of national objectives could encourage industry to engage in more long-term planning with regard to R&D and to make decisions as to the best allocation of resources. They provide examples of successes such as the ARPANET, the predecessor of Internet; the stealth aircraft, the GPS, the M-16 assault rifle and night vision goggles. Furthermore, it is argued that industrial policy has established the foundations for new industries like optical networking, supercomputers and design tools for computer chips.

Opponents however, express doubts as to its efficacy, to fear of adverse effects on the market system, to political beliefs about government intervention in the economic system and to the current emphasis on short-term returns in both the political and economic arenas.

As a result while many past activities focused primarily on research the Clinton administration increased federal coordination and augmented direct government spending for technological development. The Clinton initiatives shifted the emphasis toward *development* of new products, processes and services by the private sector for the commercial marketplace.

The Bush administration was more supportive of indirect strategies such as tax incentives, intellectual property protection, and antitrust laws to promote technology advancement, increased government support for basic research and decreased direct federal funding for private sector technology activities. In the 2006 State of the Union Address, the then President Bush announced the "American Competitiveness Initiative" to facilitate innovation and provide "the nation's children a firm grounding in math and science". To achieve these goals, the President called for doubling over the next 10 years the amount of federal funding for basic research, particularly in the National Science Foundation, the Office of Science in the Department of Energy and in the core programmes of the National Institute of Standards and Technology, Department of Commerce.

Current federal efforts are aimed at:

1. Encouraging industry to spend more on R&D;
2. Assisting small high-technology businesses;
3. Promoting joint research activities between companies;
4. Fostering cooperative work between industry and universities;
5. Facilitating the transfer of technology from the federal laboratories to the private sector; and
6. Providing incentives for quality improvements.

More recently the President's Council of Advisors on Science and Technology (PCAST)[3] in its report on advanced manufacturing concluded that "what America needs to regain its leadership in manufacturing is not an industrial policy, in which government invests in particular companies or sectors, but rather a coherent innovation policy in which government not only supports sustained investment in basic research to promote scientific discoveries, but also co-invests in precompetitive applied research to accelerate the maturation and manufacturing-readiness of emerging technologies."[4]

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3 The report was brought to our attention by Dr. Walsh M of the National Institute of Standards and Technology. It was also mentioned that only "occasionally some technology development will receive more attention in response to a well-defined need". Nanotechnology, bio-manufacturing, and robotics were technologies that were mentioned.

3 Office of Science and Technology Policy, Executive Office of the President (2011), *President's Council of Advisors on Science and Technology Releases Report on Advanced Manufacturing* available at http://www.whitehouse.gov/sites/default/files/microsites/ostp/adv_man_press_release_final.pdf

Advanced manufacturing involves the manufacture of conventional or novel products through processes that depend on the coordination of information, automation, computation, software, sensing, and networking, and/or make use of cutting edge materials and emerging scientific capabilities.

In response to the report, President Obama announced the creation of an Advanced Manufacturing Partnership, to be spearheaded by leaders from top engineering universities and several major US manufacturers. The President also directed the National Economic Council and the Office of Science and Technology Policy to work closely with the new Partnership to implement a number of the PCAST report's recommendations, including that the Federal government:

- Invest in shared infrastructure facilities, including Federal and university laboratories, which could be easily accessed by small and medium-sized firms and would facilitate significant productivity gains by allowing those companies to rapidly prototype, customize, test and produce new products;
- Support the development of advanced manufacturing processes that cut across multiple industry sectors and could be used by an array of companies to dramatically reduce product development time and increase entrepreneurs' ability to design and transition their inventions into products made in the United States; and
- Participate in partnerships with industry and academia that identify and invest in broadly-applicable, precompetitive, emerging technologies — such as nano-manufacturing flexible electronics, information technology-enabled manufacturing, and advanced materials — that have the potential to transform the manufacturing sector.

The *American Recovery and Reinvestment Act of 2009* committed over $100 billion to support groundbreaking innovation with investments in energy, basic research, education and training, advanced vehicle technology, innovative programmes, health IT and health research, high speed rail, smart grid, and information technology. Figure 1 shows the allocation of funds to various objectives.

The building blocks of American innovation[5] are as follows:

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[5] NEC (2009) *"A Strategy for American Innovation: Driving Towards Sustainable Growth and Quality Jobs."* National Economic Council
http://www.whitehouse.gov/administration/eop/nec/StrategyforAmericanInnovation/

A. Unleash a Clean Energy Revolution

B. Support Advanced Vehicle Technologies

C. Drive Innovations in Health Care Technology

D. Harness Science and Technology to address the “Grand Challenges” of the 21st Century

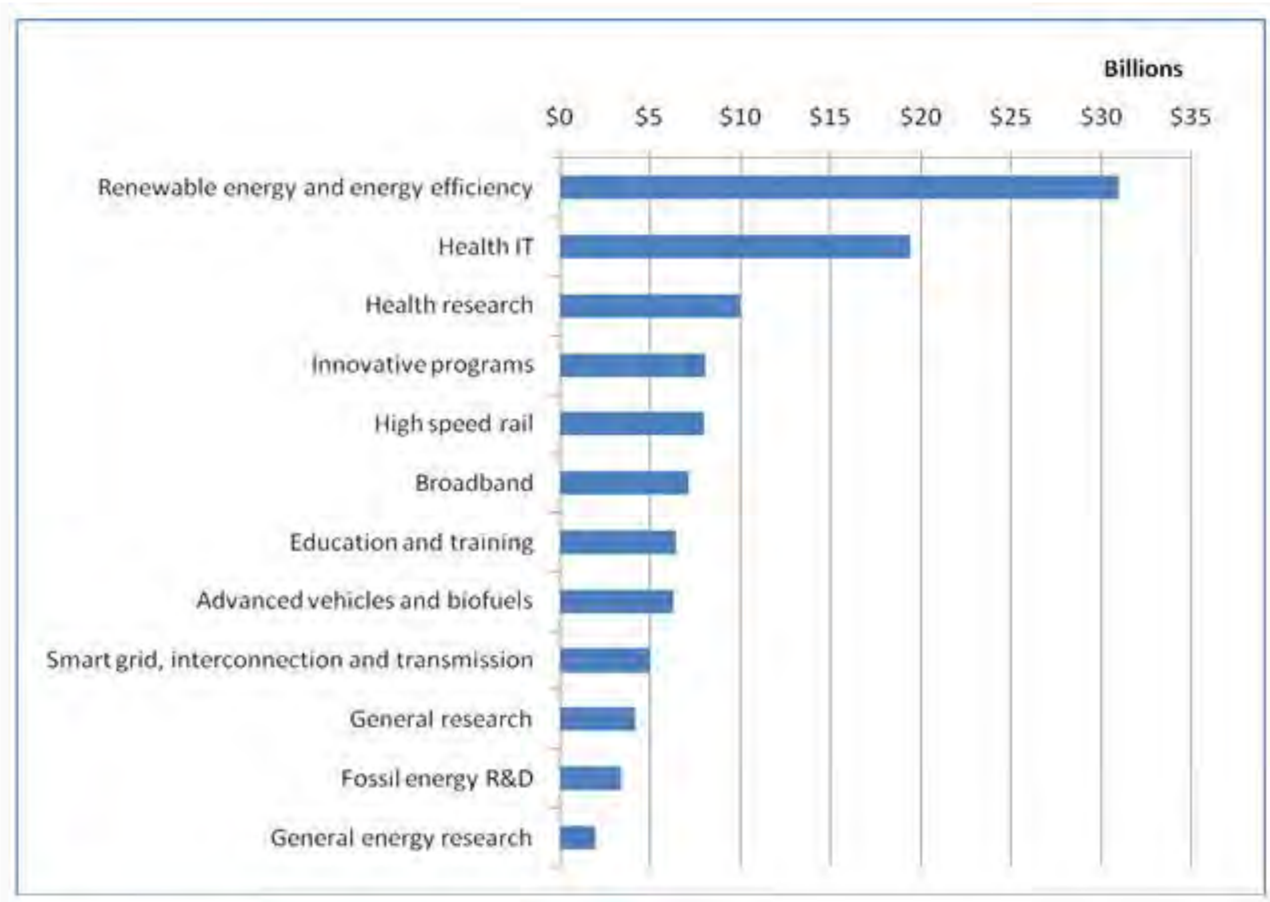

Figure 1: Innovation Funding in the Recovery Act

Funding in the USA is allocated to the various agencies such as NSF, NIH and NIST earmarked for particular programmes. A relative recent programme is the Technology Innovation Programme (TIP). TIP is similar to Advanced Technology Programme in the sense that it aims to promote high-risk R&D. In the TIP initiative, a joint venture may involve two separately owned for-profit companies but may also be comprised of one small or medium-sized firm and a university (or other non-profit research organisation). During 2009, nine awards were announced for new research projects to develop advanced sensing technologies that would enable timely and detailed monitoring and inspection of the structural health of bridges, roadways and water systems that comprise a significant component of the country's public infrastructure.

Another programme focusing on technology transfer is that of regional centres. It assists small manufacturing companies to use knowledge and technologies developed under the auspices of the National Institute of Standards and Technology and other federal agencies. The initial programme was expanded to create the Manufacturing Extension Partnership (MEP) in order to meet new and growing needs of the relevant community. There are now centres in 50 States and Puerto Rico.

The America COMPETES Act of 2007 directed the Secretary of Commerce and established an Office of Innovation and Entrepreneurship to foster innovation and the commercialization of new technologies, products, processes, and services with the goal of promoting productivity and economic growth in the United States. Furthermore, the COMPETES Act required a study on the competitive and innovative capacity of the United States. The Economic and Statistics Administration in the Department of Commerce completed the report.

The report[6] was released on January 6, 2012 by the Secretary of Commerce, John Bryson at the Centre for American Progress in Washington DC. It recommends increased federal support in basic research, the redoing of the American education system and the reallocation of wireless spectrum. It also details the importance of the manufacturing sector to the American economy and the how improvements in research and development, education and information infrastructure can lead to employment and a greater competitive edge.

The report outlines a series of steps the Obama administration has taken to support American manufacturing, including rescuing the US auto industry, the recent creation of the White House Office of Manufacturing Policy and formation of the Advanced Manufacturing Partnership (AMP), as well as initiatives such as the Materials Genome Initiative and the National Digital Engineering and Manufacturing Consortium.

It should be emphasized that while above are outlined the more recent initiatives and priorities, the USA supports comprehensive all research areas. For example, USA has the largest nanotechnology

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6 US Department of Commerce (2012) "*The Competitiveness and Innovative Capacity of the United States*." available at http://www.commerce.gov/americacompetes

programme in the world managed by a committee in the Office of Science and Technology Policy in the White House.

2.2 Japan

Japan suffered from economic stagnation for more than 10 years and they have institutionalized a number of policies in order to expand the economy in general and the manufacturing sector in particular. It should be emphasized that manufacturing has been a key element of Japan's economy since the beginning of the post–World War II period. Manufacturing exports from Japan equalled US$510.7 billion in 2006, which accounted for 80 %of the country's total goods and services exports.

An important characteristic of the Japanese efforts is that all activities are well coordinated and thought out. For example "The government's science and technology strategic roadmap and its manufacturing competitive strategy are inextricably linked, well coordinated and organised, consistent in focus and policy direction, and very well funded".

A recent US Department of Commerce[7] report identified that five themes illustrate the current state of Japan's efforts to enhance its competitiveness and advance its economy:

1. "Japan is engaged in a cohesive "innovation program" at all levels—academia, government, and industry (Innovation 2025).
2. Japan's science and technology and its manufacturing competitiveness strategic roadmaps are inextricably linked and well funded.
3. Japan's key to global competitiveness will be to develop its human resources.
4. Japanese industry is moving forward with an aggressive competitiveness strategy without direct government support or intervention.
5. Japanese leaders are thinking about how to advance the country's strategic and commercial relationship with that of the United States."

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[7] US Department of Commerce (2009) "*Japan's Manufacturing Competitiveness Strategy: Challenges for Japan, Opportunities for the United States.*" US Department of Commerce, International Trade Administration Springfield, VA 22161

The "Innovation 25" project was launched in 2006 to develop a strategic policy roadmap for the next two decades. Innovation is considered as the driving force for the competitiveness of Japan. The established policies to achieve innovation include:

1. Using global environmental issues as an engine for economic growth and international contributions;
2. Doubling investments for education;
3. Reforming universities;
4. Increasing investments in science and technology;
5. Reviewing regulations and social systems with the aim of promoting innovation; and
6. Establishing mechanisms within the government to drive Japan as an innovation oriented nation.

In this context, the government of Japan funds "world class research institutes" and "centres of excellence". The establishment of "world class research institutes" was initiated during 2007. Japan's Ministry of Education, Science, and Technology (MEXT) is supporting the "World Premier International Research Centres Initiative" (WPI), which aims to maintain five world-class research institutes with US$4 million to US$7 million of funding for each institute per year for 10–15 years. MEXT also initiated the 21st Century Centre of Excellence (COE) programme, creating 274 centres between 2002 and 2004 with funding of about US$1.1 million per year for five years for each project, totalling US$1.5 billion. The programme is designed to "cultivate a competitive academic environment among Japanese universities by giving targeted support to the creation of world standard research and education bases." The budget for 2007 was approximately US$186.6 million for on-going grants, and the New Global COE programme starting in 2007 had a budget of US$133.5 million. The Global COE programme is focusing on improving human capital in a global context.

The second theme is the link between the Japanese government's science and technology (S&T) strategic roadmap and the country's manufacturing competitiveness strategy. Japan has a S&T strategy that is the driving force across all sectors. Now in the third phase, the Science Basic Plan[8] focuses on research and development (R&D) and new manufacturing processes. The plan is focused around eight priority areas:

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[8] Government of Japan, (2006) "Science & Technology Basic Plan," available at *ww8.cao.go.jp/cstp/english/basic/3rd-Basic-Plan-rev.pdf*

- Life sciences;
- Information and communication technology;
- Environmental sciences;
- Nanotechnology and materials;
- Energy;
- Manufacturing technology;
- Infrastructure; and
- Frontiers (outer space and oceans).

Japan aims to increase its manufacturing competiveness by harnessing the investments in R&D through aggressive commercialization programmes and by strengthening collaborations and partnerships among academia, industry, and government. This concept is known as the "Innovation Highway Concept—Public–Private Sector Collaboration." Development focus areas Include:

- Rare metal substitution;
- Newly designed airplanes and rockets;
- Next generation robots;
- Nanotechnology basic research;
- Effective Internet search systems;
- Advanced medical technologies; and
- Next generation fuel batteries. [9]

These focus areas and strategies are directly linked to the Science Basic Plan.

The third theme, states that the key for innovation will be to develop human resources and people. In this context, Japan aims to create new all-English universities, such as the one in Okinawa, in order to foster the kind of international collaboration that will be key to realizing this goal. The doctoral programme in materials science and engineering at the University of Tsukuba admits approximately one-half of its students from abroad and seminars are conducted in English.

[9] METI (2006) "*White Paper on Manufacturing Competitiveness"* Ministry of Economics, Trade, and Industry, Japan

It should be mentioned that the government has established the New Energy and Industrial Technology Development Organisation (NEDO) in order to improve basic research in special fields of interest to industry. The areas of research that NEDO supports are often related to cutting-edge technology and scientific research, which are risky projects that industry or universities alone could not afford to examine. NEDO is currently supporting 18 programmes stemming from eight priority areas (electronics and information technology; machinery systems technology; aircraft and space technology; nanotechnology and materials technology; biotechnology and medical technology; chemical substance management; fuel cell and hydrogen technologies; and new energy, energy conservation and environment technologies). It appears that the future policy in Japan will be to continue to outsource "modular," or more simple products (e.g., refrigerators, TVs, rice cookers etc), and to retain manufacturing products requiring a sophisticated level of coordination, engineering design, and technology (e.g., robotics, scientific instruments, autos, machine tools).

Japan has been the leading country in the world in the identification of future technologies since 1970. Foresight activities have been institutionalized in the National Institute of Science and Technology Policy — an organisation affiliated with MEXT (Ministry of Education, Culture, Sports, Science and Technology). The most recent effort is "the 9th Delphi Survey 2010".[10]

The aim of the survey was to define "what we should do from now onward" to attain future goals and resolve the global and national challenges. The effort involved 12 panels which identified 94 areas and 832 topics. The 12 focus areas of the panels appear in Table 2.

Table 2: Foresight: Focus of panels

Panel	Viewpoint (defined by each panel)	Number of areas
1	Utilisation of electronics, communication and nanotechnology in a ubiquitous society	6
2	Information technology including media and contents	12

10 NISTEP (2010) "*The 9th Science and Technology Foresight -Contribution of Science and Technology to Future Society - The 9th Delphi Survey*" Science and Technology Foresight Centre National Institute of Science and Technology Policy; Tokyo

3	Biotechnology and nanotechnology to contribute to humankind	8
4	Medical technology to contribute to healthy lifestyles of the nation's people using IT, etc.	5
5	Understanding of dynamics of space, earth, life, and science and technology which expand the region of human activity	7
6	Promotion of diverse energy technology innovations	13
7	Necessary resources, including water, food, minerals	7
8	Technologies for protecting environment and forming sustainable society	10
9	Fundamental technologies, including substances, materials, nanosystems, processing, measurement, etc.	5
10	Manufacturing technologies which totally support development of industry, society and science and technology	8
11	Strengthening of management led/required by advancement of science and technology	8
12	Infrastructure technologies supporting daily life base and industrial base	5
TOTAL		94

The areas identified from panel 10: *Manufacturing technologies* which totally support development of industry, society, and science and technology are as follows:

A. Large volume production for small variety of products.
B. Adaptive production for various items with variable quantity.
C. On-demand production.
D. Other production schemes.
E. Globalization, value-adding and market creation.
F. Energy, resources and environment.
G. Unpopularity of science and engineering, human resource problem, the declining birth rate and aging population.
H. Safety and security.

The top topics identified by the survey in each area appear below (the figure after each topic indicates the percentage of votes received by the topic).

A: <u>Large volume production for small variety of products</u>

Product and material manufacturing technology for safe, clean and energy-efficient mass production using knowledge of the mechanism of nature and organisms 79%

A failure tracking system that embeds an IC chip in each part of the manufactured product to identify its history information including the manufacturer, materials, parts, changes in function and characteristics, users, etc) 65%.

B: Adaptive production for various items with variable quantity

Ultra-large storage memory of 1PB (peta byte) or more capacity, including atomic memory, molecular memory, and self-organising memory, that is beyond the concept of the conventional semiconductor device (i.e. flash memory) 77%.

Nano- and micro-sized plasma technology for high temperature and high density, whose controllability is better than large-scale thermal fusion reactors such as the ITER 73%

C: On-demand production

Product and device technology for extra-long-term use (including recycling) based on comprehensive and long-term continuous recording and storage of information related to the history of products, including the initial design, the reliability evaluation and the maintenance records 75%.

Micro chemistry process for on-site production of drugs cosmetics and medium-activity material whose activity deteriorates quickly (including measures to relax laws) 58%.

D: Other production schemes

A mathematical modelling framework and corresponding optimisation methodology that support the embodiment process according to the scheme and scenario related to various design methodology (it is important to mainly aim the design optimization at the system level and to establish a practical framework that can optimize the design of a system including a large-scale and complicated combination of elements) 64%.

Next-generation system engineering for the "System of Systems" (the advanced system coupling various systems including hierarchy and mutual dependency in wider areas, which surpasses the target level of conventional system engineering) 60%

E: Globalisation, value-adding and market creation

Membrane processing and formation technology that can maintain biocompatibility for 10 years or more within an implanted device 84%

Measurement technology concerning cumulative exposure to nano particles, to estimate the amounts of inhalation and skin absorption when people spend time in an environment including nano particles 84%

F: Energy, resources and environment

Comprehensive and objective evaluation indices that replace CO_2 as an indicator for the environmental load of energy and resource consumption, production processes (plants) and products, and measurement techniques for such indices 91%.

A recycling production system unifying the processes of the "input of resource → design and production → use → disposition" and the "collection → separation → resource recycling" 79%

G: Unpopularity of science and engineering, human resource problem, the declining birth rate and aging population

An intelligent system and robot enabling remote control, semi-autonomous, or automation of safe, efficient and low cost outdoor work on behalf of human beings, aiming to minimize harm to humans due to natural and human-caused disasters, or during inspections in danger zones and repair work for infrastructure that are deteriorated or damaged by a natural disaster 60%

H: Safety and security

An automatic content monitoring system (including adult verification system) aiming to enable minors to use the Internet safely 74%.

Virtual plant-operation support system that visualizes the inside condition of a reactor and the future deteriorated condition of the plant 65%.

2.3 European Commission

The Framework Programmes (FP) are the European Union’s main instrument for funding research. These multi-annual programmes have been implemented since 1984. The current Framework Programme, FP7, runs until the end of 2013. In FP7, the Commission keeps as a main instrument the transnational collaborative projects and networks which typically involve public research and industry. However, it also established a number of new efforts to increase the relevance of FP7 for industry. In particular the Commission set up long-term public-private partnerships, called “Joint Technology Initiatives” (JTI) in areas where existing schemes are inadequate in view of the scope of research and the scale of material and human resources required.

The JTI are managed by dedicated structures which are independent legal entities. JTIs have a dedicated budget and staff and provide a framework for the public and private players to work and take decisions together. They organise calls for proposals, oversee selection procedures and put in place contractual arrangements for projects set up to implement the JTI research agenda. Hence, they allow funds from different sources to be jointly managed and they are responsible for the related communication and dissemination activities.

The identification criteria for JTIs are as follows:

- Inability of existing instruments to achieve the objective;
- Scale of the impact on industrial competitiveness and growth;
- Added value of European-level intervention;
- Degree and clarity of definition of the objective and deliverables to be pursued;
- Strength of the financial and resource commitment from industry;
- Importance of the contribution to broader policy objectives including benefit to society; and
- Capacity to attract additional national support and leverage current and future industry funding.

In the above context the EU has set up the following six initiatives:

1. Innovative Medicines Initiative (IMI).
2. Embedded Computing Systems (ARTEMIS).
3. Aeronautics and Air Transport (Clean Sky).
4. Nano-electronics Technologies 2020 (ENIAC).
5. Hydrogen and Fuel Cells Initiative (FCH).
6. Global Monitoring for Environment and Security (GMES).

During 2009 the Commission identified a set of key enabling technologies (KET) that could strengthen the EU's industrial and innovation capacity to address the societal challenges ahead and proposed a set of measures to improve the related framework conditions. As such, the document COM (2009)[11] forms part of the development of EU industrial policy and of the preparation for the new European plans for innovation. The identified technologies are:

- Nanotechnology;
- Micro-nano-electronics;

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[11] COM (2009) "*Preparing for our future: Developing a common strategy for key enabling technologies in the EU*." European Commission, Brussels.

- Advanced materials;
- Photonics;
- Industrial biotechnology; and
- Advanced manufacturing systems.

The Commission identified that "KETs are knowledge and capital-intensive technologies associated with high R&D intensity, rapid and integrated innovation cycles, high capital expenditure and highly-skilled employment. Their influence is pervasive, enabling process, product and service innovation throughout the economy. They are of systemic relevance, multidisciplinary and trans-sectorial, cutting across many technology areas with a trend towards convergence, technology integration and the potential to induce structural change".

The commission further identified the global market potentials of the identified technologies (Table 3).

Table 3: Global market potential for key enabling technologies

	Current market size (~2006/08) bn USD	Expected size in 2015 (~2012/15) bn USD	Expected compound annual growth rate (%)
Nanotechnology	12	27	16
Micro and nanoelectronics	250	300	13
Industrial biotechnology	90	125	6
Photonics	230	480	8
Advanced materials	100	150	6
Advanced manufacturing systems	150	200	5
Total	832	1282	

The Communication set up a high level expert group tasked with developing a shared longer term strategy and action plan on the identified of key enabling technologies. The group presented its final report to the Commission on the 28 June 2011.[12]

The report identified three pillars that aim to assist in bridging the "valley of death" in Europe. These are:

- A pillar focused on technological research;
- A product demonstration pillar focused on product development; and

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12 EU (2011) *"High Level Expert Group on Key Enabling Technologies."* available at http://ec.europa.eu/enterprise/sectors/ict/files/kets/hlg_report_final_en.pdf

- A production pillar focused on world-class, advanced manufacturing.

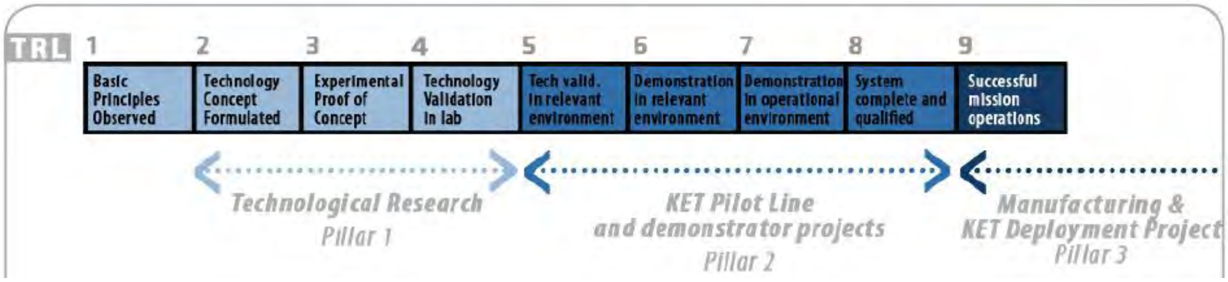

Figure 2: Technology readiness Levels Scale

Figure 2 outlines in detail the different research and deployment steps, which support the innovation and industrialization process of technologies to transform ideas to the market. Level 1 concerns basic research, levels 2 - 4 describe the activities of technological research (pillar 1), and levels 5 - 8, product development (i.e. process technology development in pilot lines, prototyping, and demonstrators actions - pillar 2).

The recommendation is that future programmes should fully and simultaneously support all these activities up to and including level 8 along with the supporting infrastructures (technological platforms and pilot lines along with first-in-kind equipment and facilities).

Additional recommendations of importance are related to institutionalization of the effort. These are:

- “The EU should create a European Technology Research Council (ETRC) to promote individual excellence in technologically focused engineering research and innovation and establish the appropriate framework conditions in order to support key enabling technologies skills capacity building at national and regional level.”
- “The European Commission should establish a European KETs Observatory Monitoring Mechanism tasked with the mission of performing analysis and a “key enabling technologies Consultative Body” comprised of stakeholders across the entire innovation chain to advise and monitor the progress in Europe of the high level group KET recommendations towards the development and deployment of KETs for a competitive Europe this should include all relevant data regarding policies and strategies evolution outside EU.”

2.4 United Kingdom

The UK is one of the European countries paying emphasis in foresight and technological innovation. The Government Office for Science exists to support the Government Chief Scientific Adviser. The office undertakes regular foresight exercises. Foresight's strength lies in its ability to influence and inform policy, through evidence-based, peer reviewed strategic insights. The Office has appointed currently a Lead Expert Group in order to undertake a n investigation about the "Future of Manufacturing"[13].

The Technology Strategy Board is the UK's national innovation agency. The vision of the Technology Strategy Board is for the UK to be a global leader in innovation and a magnet for innovative businesses. Since 2008 when they sprang out of the Department of Trade and Industry, together with their partners and industry they have invested over £2bn in UK innovation and they brought more than 110 universities to engage in business innovation projects. TSB budget is around £1bn for the period 2011-12 to 2014-15. Their approach to accelerating the pace of innovation over the 2011-2015 period is captured in the strategy document, "Concept to Commercialisation",[14] published in May 2011.

The strategy identifies focus in the following five areas:

- Accelerating the journey between concept and commercialization;
- Connecting the innovation landscape;
- Turning government action into business opportunity;
- Investing in priority areas based on potential; and
- Continuously improving our capability.

TSB is following four criteria in order to identify the areas where to invest:

1. "How big is the market
2. What is our capability?
3. Is the timing right?
4. Why should government support this?

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13 Personal communication Dr Paul McCaffrey: Project Leader, Future of Manufacturing Project, Foresight, UK Government Office for Science.

14 TSB (2011) "*Concept to Commercialization: A strategy for Business Innovation 2011-15.*" Technology Strategy Board, available at http://www.innovateuk.org/_assets/0511/technology_strategy_board_concept_to_commercialisation.pdf

TSB is establishing "Technology and Innovation Centres". The initiative builds on the 2010 review by Hermann Hauser, "The Role of Technology and Innovation Centres in the UK"[15], which made a strong case for such centres, and their potential was also highlighted in Sir James Dyson's report, "Ingenious Britain: Making the UK the leading high tech exporter in Europe".[16]

During 2011, the Technology Strategy Board decided to establish six to eight world leading centres, with the first two being in high value manufacturing and cell therapy. The investment aims to bridge the gap between the research base and businesses, helping to commercialize the outputs of the UK's universities and research institutes. TSB is also establishing "Innovation and Knowledge Centres" in order to accelerate and promote business exploitation of emerging research and technology fields. TSB has established the following centres:

- Centre for Secure Information Technologies at Queens University Belfast;
- Regenerative Therapies and Devices at the University of Leeds;
- The Sustainable Product Engineering Centre for Innovative Functional Industrial Coatings at Swansea University; and
- Smart Infrastructure and Construction at the University of Cambridge.

Emerging technologies are defined as those that are still emerging from the science base, that are at an early, pre-commercial stage and that have the potential to enable innovations that will disrupt the marketplace. The digital camera and PET medical imaging systems are examples of such innovations.

TSB is responsible for the identification of enabling technologies for industry and the development of programmes for their support.

Emerging technologies are defined as those that:

- "Enable something to be done that was previously not possible or was possible only in theory;
- Lead to new products and services;
- May be adopted by existing industries or may result in new industries; and
- May arise from:

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15 Hauser H. (2010). "*The Role of Technology and Innovation Centres in the UK.*" available at www.bis.gov.uk

16 Dyson J. (2010). "*Ingenious Britain: Making the UK the leading high tech exporter in Europe.*" available at www.conservatives.com.

- A major scientific breakthrough like radar or the transistor
- The integration of several technologies like the 5.25 inch disk drive or
- A single advance that enables a much bigger innovation, such as switching circuits for mobile phones."[17]

Currently the enabling technologies identified by TSB are:

- Advanced materials;
- ICT;
- Electronics, photonics and electrical systems; and
- Biosciences.

TSB identified two important competencies in the UK – high value manufacturing and digital services. High value manufacturing includes aerospace, automotive, chemicals, pharmaceuticals and foods.

TSB also supports particular sectors identified to have potentials in the UK. The creative industries have identified as such a sector and TSB supports technology developments in areas such as electronics, pervasive computing, modelling and visualization. Creative industries include:

- Content industries - computer games developers and publishers, video, film, TV, radio, music, publishing and rich media;
- Product and fashion design;
- Architecture and interior design;
- Broadcast, broadband and telecommunications service providers;
- Culture, visitor attraction, events and tourism; and
- Advertising, design services and marketing.

The Government Chief Scientific Adviser and the HM Treasury have an interest in future technologies and commission relevant investigations. A recent investigation is the "Technology and Innovation

[17] TSB (2010) "*Emerging Technologies and Industries Strategy 2010-2013."* Swindon http://www.innovateuk.org/_assets/pdf/corporate-publications/tsb%20emerging%20technologies%20%20industries%20strategy%20%202010%20-%202013.pdf

Futures" (TIF) project. The brief was "to identify potentially important technologies for the UK in the next 5-15 years – with particular regard to the economic benefits they could generate".[18]

Three major transformative trends were identified:

- A 21st-century manufacturing revolution: manufacturing-on-demand based on 3D printing and a move to product *plus* service commercial models.
- Smart infrastructure: will include a smart electric grid, increased use of sensor networks and 'cannibalisation' of existing infrastructure for other uses.
- A second internet revolution: the emergence of a 'web of data' adding structure and meaning to the data and text of the web.

The report further identified the following technologies and the sectors that will be affected. For some technologies, the forecasts of market size for the middle of the 2020s are huge: up to $100bn for nanomaterials, over $200bn to build a European smart grid, £150-£350bn global market for industrial biotechnology and a £100-£150bn market for plastic electronics.

The identified important technologies affecting the manufacturing industry and the industries to be affected appear in Table 4:

Table 4: Important technologies and sectors to be affected

Technology	Industries to be affected	
3D Printing and personal fabrication	Electronics	Aerospace
	Energy (solar cells)	Food
	Pharmaceuticals	Clothing
Nanomaterials, Nano-tubes and graphene	Electronics	Instruments
	Energy (incl. green technologies)	Transport (automotive)
	Aerospace	Pharmaceuticals (medical imaging)
	Chemicals (sensors)	Textiles
Intelligent Polymers	Electronics	Energy
	Health	Textiles (smart interactive)

[18] Government Office for Science (2010). *"Technology and Innovation Futures: UK Growth Opportunities for the 2020s."* Foresight Horizon Scanning Centre, Government Office for Science, http://www.bis.gov.uk/assets/bispartners/foresight/docs/general-publications/10-1252-technology-and-innovation-futures.pdf

	Transport equipment	
Active packaging (incl. sensor technology and RFID)	Food	
	Pharmaceuticals	
	Security (authenticity)	
Smart (multifunctional) and biomimetic materials	Automotive	Electronics
	Capital &Transport equipment	Green technologies
	Medical	Aerospace
	Textiles (military uniforms)	
Smart interactive textiles	Defence	Agriculture
	Medical	Fashion
	Clothing	Automotive
	Energy	
Fuels cells for industry and carbon capture technologies	Automotive	Manufacturing industry
	Electronics	Energy
Smart grid and meters for support of alternative sources of energy and enable consumer choice	Energy related industries	
Biotechnology (industrial)	Agri food	Carbon-neutral clothes/materials
	Pharmaceutical	Chemicals
	Energy (Bio-fuels)	Textiles
Lab on a chip	Pharmaceutical	Green technologies
	Chemical	Sensors
Omics (genomics, proteomics, epigenomics; bioinformatics)	Agri-food	
	Pharmaceuticals	
Synthetic biology	Pharmaceuticals	Sensors
	Chemicals	Electronics
	Agro food	Green energy
Cloud Computing for Industry	ICT	
	All manufacturing activities (e.g. inventory control, database processing etc)	
Intelligent Sensor Networks and Ubiquitous Computing	Capital and transport equipment	Pharmaceuticals
	Aerospace	Electronics
	Automotive	Green energy
	Chemicals	
New Computing Technologies (photonics, quantum, biological inspired computing)	Electronics	Sensors (medical, defence)
	Energy (photovoltaic, lighting)	Automotive

Service and Swarm robotics	Manufacturing	Energy
	Health	Creative industries (entertainment)
	Transport	Aerospace (defence)
Secure communication (Digital Security for industry) (quantum cryptography, digital watermark)	Manufacturing	
	ICT	
	Creative industries	
Modeling and Simulation for improving products, perfecting processes, reducing design-to-manufacturing cycle time, and reducing product realization costs	Aerospace	
	Automotive	
Supercomputers	Aerospace	Pharmaceuticals
	Automotive	Creative Industries

2.5 Brazil

Brazil is the economic leader of the South American countries, with a strong financial and industrial base and substantial natural resource wealth. "Brazil's primary objective is to gain and hold a position as one of the world's leading economic powers. It is recognized that this objective can only be realized in the long term by also becoming one of the world's leaders in science and technology".[19]

The Ministry of Science and Technology (MCT), created in 1985, has the mission of planning, coordinating and supervising S&T activities in priority areas in Brazil. The MCT's main funding agency for technological development and innovation is FINEP, the Brazilian Innovation Agency. Among other activities this Agency implements the National Fund for Science and Technology and 14 sectoral funds, in the following areas:

- Oil and Gas (CT-Petro);
- Energy (CT-Energy);
- Water Resources (CT-Hidro);
- Transportation (CT-Transporte);

[19] National Academies Press (2010). *"S&T Strategies of Six Countries: Implications for the United States."* Standing Committee on Technology Insight-Gauge, Evaluate and Review Committee on Global Science and Technology Strategies.

- Mineral Resources (CT-Mineral);
- Spatial Activities (CT-Espacial);
- Information Technologies (CT –Info);
- Agribusiness (CT-Agro);
- Biotechnology (CT-Biotec);
- Health (CT-Saúde);
- Telecommunications (Funttel);
- Aeronautics Sector (CT-Aeronáutico);
- Development of R&D Activities in the Amazon Region (CT-Amazônia); and
- Marine and River Transportation and Naval Construction (CT-Aquaviário).

The science and technology sectoral funds were established at the end of the 1990s, aiming at providing more stable financial resources to science, technology, and innovation (ST&I) activities in Brazil. Their funding comes from taxes on specific activities (e.g. telecommunications, electricity, oil & gas etc).

Access to the funds may involve:

- Cooperative projects with universities and research centres (both as project leader or participants);
- Credit at favourable conditions (interest rates are subsidized by the funds); and
- Grants (although no firm would access grants before 2007).

The National Council for Science and Technology Development, CNPq, funds basic and applied research and human resources. There are also two mission agencies – CNEN in nuclear energy and AEB in space field. The main guidelines of the Science and Technology Development Plan (Plano de Desenvolvimento Científico e Tecnológico) of 2007 recommend:

- Consolidation of the National System of S&T&I;
- Creation of a favourable environment for innovation in firms;
- Strengthening of the country's innovation capability in strategic areas; and
- Promotion of the popularization and diffusion of technologies to improve life conditions of the population.

The 2007-2010 Action Plan on Science, Technology and Innovation for National Development (PACTI) addresses key S&T deficiencies, including the lack of industry investment in S&T, lack of scientists and engineers employed by industry, limited commercialization of knowledge, and limited expertise in key technology areas.

The PACTI's four priorities are (1) expansion and consolidation of the national S&T innovation enterprise, (2) promotion of technology innovation in companies, (3) R&D in strategic areas, and (4) S&T for social development. Furthermore, the PACTI targets the following strategic areas of research:

- Information and communication technologies;
- Health supplies;
- Bio-fuels;
- Electrical power, hydrogen, and renewable energy;
- Oil, gas, and coal;
- Agribusiness;
- Biodiversity and natural resources;
- The Amazon and the semi-arid region;
- Weather and climate change
- Space programme;
- Nuclear programme; and
- National defence and public safety. [20]

The Brazilian government in an effort to reduce the nation's dependence on foreign innovation has created more than 30 incentives for businesses to invest in innovation. The number of benefiting companies increased from 70 during 2006 to 500 by 2008. The incentives fall into three main categories: support for technical expertise, research grants to non profit facilities, and funding provided for commercial development in strategic areas (such as light aircraft, conventional energy sources, renewable energy, and nanotechnology). Approximately $3 billion in non reimbursable funds and tax credits has been provided over a four-year period.[21]

The government currently also runs a programme that pays half the salaries of doctoral researchers for their first three years of employment in industry. The salaries are competitive, ranging from $6 000 to $7 000 per month for half time.

The key research priorities identified in the MCT Strategic Plan are:

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[20] MCT (2007) "*Science, Technology and Innovation for National Development Action Plan 2007-2010, Summary Document"* Ministry of Science and Technology, Brazil, Available at: http://www.mct.gov.br/upd_blob/0203/203404.pdf.

[21] Erawatch (2010), *ERAWATCH Research Inventory Report For: BRAZIL*. Available at: http://cordis.europa.eu/erawatch/index.cfm?fuseaction=prog.downloadCountryReport&countryCode=BR&full=1. Last accessed 2010.

- Promoting research and innovation in the framework of the Industrial, Technological, Foreign Trade Policy (PITCE) guidelines along the four priority sectors: capital goods; software; microelectronics and pharmaceuticals;
- Creating feasibility for strategic research programmes on stem-cell research, bio-products, molecular biology, nanotechnology and energy (hydrogen, biomass and bio-fuels);
- Increasing social inclusion and development opportunities based on S&T in particular for the poorest.

Brazil has strongly encouraged the establishment of technology parks and business incubators, mostly for budding small high technology companies. Several dozens of such parks are now in existence. In the state of Sao Paulo , the state government has sponsored a technology park programme for several cities which have a strong high tech base, These cities have strong research universities, pure and applied research institutes and high technology companies, such as Embraer one of the largest aircraft manufacturers in the world. Campinas also boasts the largest number of high-tech business incubators and industrial parks (a total of eight), such as the CIATEC I and II, Softex, TechnoPark, InCamp, Polis, TechTown, Industrial Park of Campinas and others. Because of this Campinas has been dubbed the Brazilian Silicon Valley.

2.6 India

India has long history in the support of science and technology as a means to improve the national economy and the lives of its citizens. The political commitment is reflected in the Scientific Policy Resolution of 1958, the Technology Policy Statement 1983 and the 2003 Science and Technology Policy of the Government of India. These initiatives have led to the creation of a substantial S&T infrastructure covering government institutions, universities, nongovernmental organisations and industry. It should be emphasized that India has had recent successful demonstrations of indigenous capabilities such nuclear power, satellite launches and multi-use launch vehicles.

India's system for innovation is dominated by the central and state government agencies. Government is responsible for about 74% of national R&D expenditures. The industrial sector (public and private) accounts for about 30% of total expenditures. The government encourages greater participation from the industrial sector over the recent years.

Within India, there are about 400 national laboratories, 400 R&D institutions in the government sector, and about 1,300 R&D organisations in the industrial sector. More than 300 multinational companies have opened their R&D centres and laboratories in different sectors of the economy.[22] Some corporations have formed alliances with Indian institutions for joint research projects.

India's planning commission issues five-year plans since independence in 1947. Each plan contains a section on S&T. The plans discuss accomplishments and relevant issues during the previous five years and propose initiatives for the next five years. India has a stated goal of becoming a developed nation by 2020, and it aims to be one of the top 5 countries in the world in terms of GDP. The five-year plans highlight S&T as a contributor to this long-term vision. Other stated goals include the increase of R&D expenditures from 0.9% to 2% of GDP and to increase education spending from 4% to 6% of GDP. In an effort to increase educational resources, the Indian government recently presented to the Parliament the Foreign Educational Institutions Bill. The Bill allows foreign universities to establish campuses in India[23]. It is expected that the bill will spur an increase in the number of top-quality institutes in India and will offer students an alternative to travelling overseas for education.

The current plan (2007-2012) sets out a broad strategy for improving the national S&T environment by enlarging the pool of scientific manpower, encouraging risk taking on the part of scientists, supporting creativity in the education system, supporting both basic research and applied research and technology development, encouraging industry to interact with academia, and providing incentives for young people to pursue scientific careers. The plan also recommends that scientific developments in the rest of the world be monitored and surveyed in order to assist in the selection of critical technologies for prioritized investment.

The current five-year plan identifies detailed research foci and envisioned outcomes for 16 sectors with the greatest proposed national laboratory funding in the following areas, in descending order:

- Aerospace;

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22 World Bank (2007) "*Unleashing India's Innovation: Toward Sustainable and Inclusive Growth.*" Available at http://siteresources.worldbank.org/SOUTHASIAEXT/Resources/223546-1181699473021/3876782-1191373775504/indiainnovationfull.pdf

23 Government of India (2010) "*The Foreign Educational Institutions (Regulation of Entry and Operations) Bill, 2010*" Available at: http://prsindia.org/uploads/media/Foreign%20Educational%20Institutions%20Regulation/Foreign%20Educational%20Institutions%20Regulation%20of%20Entry%20and%20Operations%20Bill%20%202010.pdf

- Pharmaceuticals;
- Materials;
- Information technology;
- Biology;
- Earth systems and exploration (including on- and off-shore geophysical studies); and
- Energy.[24]

Within central government are emphasized funding for atomic energy and space and ocean exploration. In addition to promoting S&T advancement, these three areas present dual-use opportunities. A specific national goal is to develop indigenous technologies to protect itself from denial of technology (by other countries).

The Department of Science & Technology has set up the Technology Information, Forecasting and Assessment Council (TIFAC) to look ahead in technologies, assess the technology trajectories and support technology innovation by network actions in select technology areas of national importance.

In 1996, TIFAC formulated a Technology Vision for the country in various emerging technology areas. The outcome of the Technology Vision 2020 exercise led to the set of 17 documents, including sixteen technology areas and one on services.

The "Technology Vision 2020," lays out a recommended set of actions that India should undertake to become a developed nation by the year 2020. It identifies five broad areas for development that can leverage India's core competencies and address its critical needs:

- Agriculture and food processing;
- Infrastructure with reliable electric power;
- Education and healthcare;
- Information and communication technology; and
- "Critical technologies" (defined as nuclear, space, and defence).

TIFAC is focusing on the identification of technologies for detailed sectors e.g. "Technology Road Map for Indian Aluminium Industry" (2009-10); quality seed production, crop diversification, deep water rice cultivation for agriculture; "Technology Roadmap for Electric and Hybrid Electric Vehicle introduction" etc. TIFAC is also facilitates commercialization through the establishment of relevant centres.

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24 DST (2006) "*Report of the Working Group on CSIR, Eleventh Five Year Plan, 2007-2012.*" Department of Science and Technology, Government of India; Available at: http://www.dst.gov.in/about_us/11th-plan/rep-csir.pdf.

The following are the key programmes specified in the 11th Five-Year Plan 2007-2011.

Space, Biotechnology, Ocean, Atomic Energy, CSIR open-source drug discovery programme; Department of Science and Technology drinking water and Technology for Rural Enterprises and Employment programmes.

It is important at this point to mention the success of the Software Technology Parks (STP) of India, which has contributed substantially in the development of the ICT industry. A primary objective of the STP has been the provision of international data communication facilities. However a set of comprehensive incentives contributed to developing a successful ICT sector. The incentives offered include:

- STP units are exempted from payment of corporate income tax up to 2010;
- Capital invested by foreign entrepreneurs, know-how fees, royalty, dividend etc., can be freely repatriated after payment of Income Taxes due on them, if any;
- Repatriation of foreign currency for payments can be freely done;
- Rebates on cost of land;
- Reimbursements of stump duties;
- Concessionary power tariffs;
- Exemptions from labor regulations;
- Duty free imports;
- 100% Foreign Equity is permitted;
- Approvals are given under single window clearance scheme; and
- A company can set up STP unit anywhere in India.

2.7 Korea

Korea is of particular importance for the institutional infrastructural approaches that it utilizes and we discuss them below. It is important to notice that Korea has set the objective of investing 5% of their GDP on R&D be 2012 – this ratio is one of the highest in the world. (“Science and Technology Basic Plan: 577 Initiative” 2008)

Korea has a well established science, technology and innovation system. At the top administrative level, the key actors are the National Science and Technology Council (NSTC, www.nstc.go.kr) which was re-established at the end of March in 2011 as a top control body for the coordination and allocation of government R&D budget including prioritization of R&D area, and the Senior Secretary to the President for Education, Science and Culture within the Office of the President and the Presidential Committee on Green Growth (PCGG). The Presidential Advisory Council on Education, Science and Technology (PACEST) also plays a role as an advisory body chaired by the President.

Ten strategic industries were identified in August 2003 as future growth engines: bio-medical products, next-generation computer displays, next-generation semiconductors, next-generation batteries, future automobiles, intelligent robots, digital TV and broadcasting, next-generation mobile communications, intelligent home networks and digital content and software solutions.

Similarly government identified technologies in key areas such as future core technologies (*e.g.*, biotechnology and nanotechnology), mega-science (*e.g.*, space and marine technologies), energy, and public welfare (*e.g.*, health, transportation).[25] It should be emphasized that Korea was taking an IT-focused strategy. More than 30 per cent of Government R&D expenditures were going to ICT applications during the 2000s. Simialrly at least six out of the ten growth-engine industries fall into the IT product category. Two other industries—future automobiles and intelligent robots— were also highly correlated with IT applications in the industry. Only two industries— next-generation batteries and biotechnology (BT) new medicines and organs—were not in the IT domain.[26]

During 2008 the government established the Ministry of Knowledge Economy (MKE) amalgamating functions dispersed within several Ministries such as industrial policy, industrial R&D policy, IT policy, energy policy and investment, regional policy and so on. One of the bodies managed by MKE is the Korea Research Council for Industrial Science and Technology. The later fosters the Government-funded Research Institutes (GRIs) in the field of industrial science and technology and manages them systematically under the Act on the Establishment, Management and Promotion of GRIs. The Government Research Institutes (GRIs) were reoriented during the 2000 so their activities focus to assist industry. The GRIs had to be re-positioned to do more upstream research or to become more focused on research of collective interest (e.g. health, transport, etc). A larger part of their budget has to be secured in the form of institutional funding.

The Council contributes to the development of knowledge-based industries and strengthens the creation of new industries. Its mission among others is “to cultivate new industries by constructing and operating a support system that provides field support and technological innovation for small and medium enterprises.”

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25 UNU MERIT (2005) “*Monitoring and Analysis of Policies and Public Financing Instruments Conducive to Higher Levels of R&D Investments: Country review Korea.”* Maastricht.

26 World Bank (2006) “*Korea as a Knowledge Economy: Evolutionary Process and Lessons Learned.”* The World Bank, Washington D.C

There are key supporting bodies for management, policy studies, planning, technology foresight, evaluation and coordination and so on. The Korea Institute of Science and Technology Evaluation and Planning (KISTEP, www.kistep.re.kr) supports the NSTC as a public institution specialized in national S&T planning, technology foresight, evaluation and coordination.

The Techno-parks in 16 regions play an institutional role for the implementation of the Government's programmes. According to the five-year plan (period between 2008 and 2012), the Government has allocated the government budget on R&D to five areas as follows:

Development of basic and original technology: Increasing the volume of R&D investment on this area to the total government R&D budget by 50% in 2012 from 25% in 2008; Enhancing the number of small scale basic research including young individual researchers in universities; and Promoting the development of core original technology through collaboration between industry, university and public research organisations.

Development of new growth-generation industries in the foreseeable future: Fostering new industry such as green car, next generation Wise Ship; Supporting technology- based SMEs; and Strengthening R&D investment in knowledge-based service industry such as cultural contents and design.

Stimulation of Korea's low carbon green growth through investment in green technology: Enhancing investment in development of eco-friendly new renewable energy and green energy such as solar and hydro-fuel batteries.

Enlargement of international collaboration: Attracting globally talented researchers, nurturing world class universities and enlarging collaborative research with foreign research organisations.

Enhancement of efficiency and effectiveness of R&D investment: Increasing institutional funding for government-supported research institutes by more than 70% by 2011; and Improving R&D management both removal of unnecessary regulations and stronger punishment of researchers who offend research ethics.

In 2009, the largest proportion of government R&D investment that accounted for 30.2% was designed to the development of economy and industry. It is a higher rate compared to other countries.

There is significant concentration of investment in electronic equipment, automobiles and components which take up a large portion of the national investment. The R&D investment sum of the top three companies, Samsung Electronics, LG, and Hyundai Motor is a major contributor to national investment.

It should be mentioned however, that in the areas of pharmaceuticals and biotechnology, not a single company was listed in the world's top 1 000 companies in terms of R&D investment.

Particular emphasis is placed in stimulating greater private R&D investment. A matching fund system for R&D performing firms has been strengthening since 2000 and is the major instrument. The industrial part should put matching funds of some proportion into those projects in order to participate as a major actor. The largest portion of those matching funds is going to big companies with high R&D capabilities. The major part of research fund in GRIs comes from competitive tendering for national R&D programmes. It should be noted that the majority of research projects of GRIs consist of collaborative projects with private companies.

The Korean government offers a variety of tax incentives related to R&D including deduction of income or corporate tax as much as 10% of money invested in research and human development facilities; 50% cut of income tax of foreign experts; exemption of local tax on real estate owned by corporate in-house R&D institute et cetera. It also introduced public procurement policies in 2006 for innovation-oriented SMEs and has increased procurement of innovative goods and services based on new technology with various instruments such as obligatory procurement of some proportion by local governments and national companies, giving a priority for products with technology certification such as NEP (New Excellent Product), NET (New Excellent Technology), the GS (Good Software), and the EPC (Excellent Performance Certification) by parastatals.

In the early 2011, MEST announced 'The Second Basic Plan for Nurturing Human Resources in Science, Engineering and Technology over the period of 2011-2015".[27] The new Plan emphasizes inter-linkage between science and technology and humanities, lifelong learning and support for human resources in science and technology, more collaboration between the related ministries and more efforts for government establishments and private research institutes to attract more students into the area of science, engineering and technology. In January 2009 the "New Growth Engine and Development

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[27] MEST (2011) "*The Second Plan to nurture the Human Resources in Science, Engineering and Technology*." Ministry of Education, Science and Technology, Korea

Strategy" identified three areas with seventeen topics as priorities. These were: Green growth industry;. High-tech convergence industry; and high value service industry

2.8 Malaysia

Recent policy changes in Malaysia include the announcement during 2011 in the 10th Malaysia Plan, that the government intends to establish the National Science and Research Council, an apex body mandated to provide advice, set priorities and streamline R&D activities.

The 10th Plan identified the following national key economic areas (NKEAs):

1. Oil and gas;
2. Palm oil and related products;
3. Financial services;
4. Wholesale and retail;
5. Tourism;
6. Information and communications technology;
7. Education;
8. Electrical and electronic;
9. Business services;
10. Private healthcare;
11. Agriculture; and
12. Greater Kuala Lumpur.

An NKEA is defined as a driver of economic activity that has the potential to directly and materially contribute a quantifiable amount of economic growth to the Malaysian economy.

Similarly the results of the foresight exercise were announced. The Malaysian Industry-Government Group undertook the National Technology Foresight 2010 exercise for High Technology (MIGHT).[28] It evolved from a technology road mapping exercise - a programme commissioned by the Ministry of Science, Technology and Innovation (MOSTI).

The foresight initiative has identified nine technology areas that Malaysia should give priority to drive future growth. The nine technology areas identified are:

- Advanced Manufacturing;

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28 MIGHT (2011) *"Foresight Areas Unveiled: Understanding the Drivers of Change."* Malaysian Industry-Government Group for High Technology available at http://www.myforesight.my/download/myForesight%202nd%20Edition.pdf

- Domestic Security and National Safety;
- Environmental Management;
- Food Security;
- Future Energy;
- Medical & Healthcare;
- Plantation Crops;
- Transportation; and
- Water Security.

In addition, a further five areas have been identified as a cross cutting and converging areas whereby development of these technology areas will have an effect on multiple sectors and areas as well as it wide ranging and cross cutting applications.

The five cross cutting and converging areas are:-

- Biotechnology;
- Electronics;
- ICT;
- Materials Science; and
- Nanotechnology.

The country is also well known for its success of the Multimedia Super Corridor. The Malaysian government has a long history supporting small and medium enterprises and innovation. During the past few years, the Government of Malaysia has launched a variety of initiatives designed to keep the country on top of the latest advances in the ICT services sector. “Corridors” or regional development zones for specific industry capabilities have been given priority in a substantial national effort.

In particular, the Multimedia Super Corridor (MSC) was a bold initiative to integrate S&T with industry. Geographically, the MSC is 15 km wide and 50 km long, stretching from Kuala Lumpur city centre to the New Kuala Lumpur International Airport in Sepang. It intends to deliver a number of sophisticated investment, business research and lifestyle options.

Companies in the corridor enjoy financial and non-financial incentives. These are:

- Pioneer Status -100% exemption from taxable statutory income. This incentive is granted for a period of 5 years for the first round;

- A 100-%Investment Tax Allowance (ITA);

- Eligibility for R&D grants (for majority Malaysian ownership MSC-Status companies);

- Freedom to source capital and borrow funds globally;

- Non-Financial Incentives;
- Duty-free importation of multimedia equipment (DFI);
- Intellectual property protection and a pioneering and comprehensive framework of cyber laws can be enjoyed by MSC-status companies irrespective of location;
- No censorship of the Internet;
- High-powered implementation agency to act as an effective one-stop super shop - the MDC;
- World-class physical and IT infrastructure if companies are located within the MSC;
- Globally competitive telecommunication tariffs and services guarantees if MSC-status companies are located within the MSC;
- High-quality planned urban development if MSC-status companies locate within the MSC;
- Excellent R&D facilities, including the region's first Multimedia University if companies are located within the MSC; and
- Green environment protected by strict zoning if located within the MSC.

Further the Malaysian government provides a Bill of Guarantees. The 10-point Bill of Guarantees provides to MSC companies the following:

- A world-class physical and information infrastructure;
- Allow unrestricted employment of local and foreign knowledge workers;
- Ensure freedom of ownership by exempting companies with MSC Status from local ownership requirements;
- Give the freedom to source capital globally for MSC infrastructure, and the right to borrow funds globally;
- Provide competitive financial incentives, including no income tax for up to 10 years or an investment tax allowance, and no duties on import of multimedia equipment;
- Become a regional leader in intellectual property protection and cyber laws;
- Ensure no Internet censorship;
- Provide globally competitive telecommunications tariffs;
- Tender key MSC infrastructure contracts to leading companies willing to use the MSC as their regional hub; and
- Provide an effective one-stop agency – The Multimedia Development Corporation (MDC).

The 10th Malaysia Plan it is identified that in the creative industry (that currently contributes about 1.6% to GDP), emphasis will be on creative multimedia, especially animation for simulation, advertising and entertainment, and games development. The plan suggests that a National Creative Industry Policy will be formulated and the National Digital Terrestrial Television Broadcasting (DTTB) project will be rolled-out to help spur the expansion of related creative industries. With DTTB technology, more content will be delivered more efficiently.

In summary all countries investigated identify technologies of importance for their industries and societies. Similarly all countries identify cross cutting technologies impacting more than one sector. A number of such technologies are currently identified by all countries covered in this investigation. These are:

- ICT;
- Renewable energy;
- Advanced materials and nanotechnology
- Advanced manufacturing technologies; and
- Aerospace technologies.

Different countries define to a different extent the various technologies. For example, Japan through the foresight exercises identify technologies to a fine level of detail e.g. “Ultra-large storage memory of 1PB (peta byte) or more capacity, including atomic memory, molecular memory, and self-organising memory, that is beyond the concept of the conventional semiconductor device (i.e. flash memory)”. Other countries like the USA use coarse levels of detail (e.g. ICT). The later is the result of the debate whether governments have the capability and should aim to pick up winners.

Similarly certain countries (e.g. Brazil through the sectoral funds) link technologies to particular sectors while the majority of the countries aim to produce technologies without stating explicitly the intended users. It should be mentioned that a number of the experts interviewed suggested that “there is a new trend in both sides of the Atlantic to move away from technology identification and into solutions of industrial and societal challenges”.[29] The trend is apparent in the USA and Japan. Japan has restructured their foresight exercised according to national and international challenges.

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29 Personal interview with Professor Vonortas N. Director: Center for International Science and Technology Policy, George Washington University; and Dr Jonathan Linton: Power Corp Professor for the Management of Technological Enterprises, University of Ottawa, Canada and Dr Yamashita A: Japan Science and Technology Agency (JST), Singapore Representative Office.

The identification of important technologies in conjunction with the sectors/industries that they affect has received particular interest recently. The identification of technologies and the sectors they affect by the Government Office for Science in the UK (table10) and the "Sectoral Innovation Watch" by the European Commission (Chapter 3) are such examples. Identification of sectors for technology support also varies from country to country. Korea for example during the last ten years focused mainly in the ICT sector; Brazil has 14 sectoral funds and in addition has identified four strategic sectors i.e. capital goods; software; microelectronics and pharmaceuticals while the USA aims at following a broad strategy across all sectors. It is interesting to be noted that the UK has identified high value manufacturing as of critical importance for the country. High value manufacturing includes aerospace, automotive, chemicals, pharmaceuticals and foods.

Innovation and technology support strategies appear to have a number of commonalities. Coordination is probably the most important commonality. In Korea the NSTC has this responsibility; in India coordination is embodied in the 5-year plans and in Brazil in the Science and Technology Development Plans (Plano de Desenvolvimento Científico e Tecnológico). This role has been entrusted to TSB in the UK and in the USA coordination is taking place in the White House and the National Science Foundation advices the President through the publication of the Science and Engineering Indicators[30] reports. In this context it should be mentioned that the Government Research Institutes (GRIs) in Korea were explicitly reoriented during the 2000 so their activities coincident with the interests of industry.

Institutionalization of priorities is another commonality in the support strategies followed. Institutionalization can be manifested in the development of partnerships or/and the establishment of new institutions. Examples of partnerships include the "Manufacturing Extension Partnership Centers" in the USA; the "Joint Technology Initiatives" in the EU and the "Innovation Highway Concept—Public–Private Sector Collaboration in Japan. Examples of the establishment of new institutions include the establishment of the New Energy and Industrial Technology Development Organisation (NEDO) in Japan as well as the establishment of the "World Premier International Research Centres Initiative" by the Ministry of Education, Science, and Technology; the "Technology and Innovation Centres" in the UK and others.

[30] NSB (2010) "*Science and Engineering Indicators 2010"* National Science Board, Arlington VA

Finally the utilisation of science parks/corridors is a commonly used instrument promoting collaboration and synergy. Examples are the multitude of science parks in the USA (e.g. Silicon Valley); the techno-parks in Korea; the Software Technology Parks of India and Malaysia and the multitude of technology parks in Brazil.

3. Technology Identification Survey

Identification of priority areas in technology have been undertaken in South Africa irregularly. The earliest investigation was undertaken by the Foundation for Research Development[31] (now National Research Foundation) in the early 1990s. The first official foresight exercise was undertaken by the Department of Arts Culture, Science and Technology. The DACST undertook and published the National Research and Technology Foresight (NRTF) during 1999. The exercise was inaugurated in July 1996 and was conducted over two years i.e. 1997-1999. The results were published[32] during 2001. During 2004, **the dti** published the report "Benchmarking of Technology Trends and Technology Developments".[33] And recently it commissioned an investigation of the electronics industry[34] in the country. Similarly the Department of Labour has produced a number of sector investigations containing information related to their priorities. The findings of the above investigations are outlined in appendix 5: Review of Technology Priorities in South Africa.

In the context of this effort a questionnaire related to technology trends identification was developed, approved by **the dti** and sent to a number of stakeholders (appendix 1). The stakeholders covered industrial establishments in the sectors of interest to **the dti**; and researchers with close contact with industries (e.g. THRIP, CSIR). The response rate (41 responses-22%) is considered adequate for such

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31 Blankley OW. and Pouris A. (1993). "Identification of strategic priority areas in technology development" *South African Journal of Science* **89**:169.

32 DACST (2001) *"Foresight Synthesis Report: Dawn of a New Century."* Department of Arts Culture Science and Technology, Pretoria.

33 Department of Trade & Industry (2004) *"Benchmarking of Technology Trends and Technology Developments"* Pretoria

34 **The dti** (2010). "Study to Identify Electronic Assemblies, Sub-assemblies and Components that may be manufactured in South Africa." Study prepared by Kaiser Associates Economic Development Practice; Pretoria.

exercises as the rate for the national foresight exercise was approximately 10%. The profiles of the respondents are as follows:

- The responses covered all sectors. Ten responses were from chemicals and pharmaceuticals; eight from the automotive sector; six from energy; six from metal fabrication, capital and transport equipment, seven from clothing, textiles, leather and footwear and others.
- Most of the respondents declared that they were in manufacturing with production, distribution and assembling following.
- The age profile of the companies ranged from two years old to more than hundred years old. The average age of the companies was 33 years old.
- The average company was employing 900 people. The declared range was from one or two people to 5000 employees.
- Sixty three % of the companies declared that they were exporting their products internationally.
- The exported products covered auto components, canopies, gear box covers, valves, steel sections, tin cans, agro-processing products, knitted fabrics, woven fabrics, sport clothing, furnishing fabrics, software, satellite subsystems, electronic warefare equipment, printed materials, radio-chemicals, oncology products, patient data, wind turbines and accessories, biodiesel equipment, polymer nano-composites and chemically impregnated dry scrubbing media.
- The countries of export cover the entire world. A number of respondents answered that their exports are worldwide, and a number of them referred to continents (i.e. USA, Africa, Europe etc).
- Twenty four of the respondents declared that they were importing products. Imported products covered glass fibre, polypropylene, loomstate fabric and yarn, fabrics, polyester yarns, excavators, tooling fasteners, metal powders, structural steel, iron castings, various chemicals, medical devises, intellectual property, components for wind solutions, inverters for wind turbines, activated carbon and alumina, electronic components, tinplate and aluminium aerosol slugs, pharmaceutical products and bumper replacements.
- The majority of the imported products are coming from Europe and the USA. However, there were a number of respondents who mentioned as country of import Japan, China and India.
- The respondents identified as potential markets Europe, USA, Africa, China and Asia
- Their declared turn-over ranged from one million rand to more than two billion rand.

The questionnaire asked the responses to identify from a given list "technologies which are of importance for their industry". Simialrly the questionnaire included open ended questions aiming to identify current technologies of importance to the sector and their status in the country and specific future technologies. From the 20 technologies in the list (Appendix 1) the most often identified technology as important was advanced manufacturing technology (58% of respondents). "Modelling and simulation for improving products, perfecting processes, reducing design-to-manufacturing cycle time and reducing product realization costs" was the second most often identified technology (34% of respondents) and "intelligent sensor network and ubiquitous computing" third with 16% of respondents identifying it.

The following technologies were identified by the various industries as of current importance. The status of the technologies is stated in parenthesis as was mentioned by the respondents.

Aerospace and defence

- Industrial robotics (we are consumers and purchase products from overseas suppliers);
- Micro-manufacturing (infancy);
- Precision mechanical manufacturing (very important);
- Data fusion software (in process);
- Infrared optical systems (in process);
- Electro-chemical processes;
- High speed machining;
- Additive manufacturing technologies;
- Space grade sub-systems (in process); and
- Radar, RF, Microwave, Electro Optics.

Electronics and ICT

- Biometrics- (limited);
- RFID – (limited);

Agro Processing

- Electronic human interaction platforms (technology available only in imported third and fourth tier end user devices and applications. No visible first or second tier end user support for ICT in the sector);
- Modern can & closure manufacturing (status is evolving);
- Modern metal deck printing technologies;
- Barrier technologies for safer food storage (not available in SA); and
- Food biotechnology.

Chemical and Pharmaceuticals

- Barrier technologies for safer food storage, (not available in SA);
- Biopolymers, antibacterial polymers, (not available in SA);
- Sensing and smart polymers – (not available in SA);
- Advanced process control systems, (chemical transformation unit operations);
- Powder technology/sintering;
- Sterile manufacturing; and
- Biotechnology (application that are industrially relevant).

• PDA's (available but without local support);	**Creative Industries (Craft, film, television, music, games etc.)**
• Geographic register for South Africa;	• IT Security;
• Secure and reliable communications;	• Digital animation;
• Precision mechanical manufacturing (very important);	• Secure Communications; and
• Space grade sub-systems (in process); and	• Security Printing (Personalized, tamper-proof, docs).
• Linux software development, (mid to high importance for free software).	**Energy**
Clothing, textiles, leather and footwear	• Renewable solutions, design and manufacture;
• Energy efficient processing machinery;	• Small wind turbine design and manufacture;
• Industrial robotics (imported);	• LED lighting technologies;
• Colour physics;	• Induction cooking for mainly residential market;
• Micro-manufacturing (infancy); and	• Heat pumps water heating high in both residential, commercial and industrial markets; and
• Micro-processor controlled machinery with interactive capability.	• Renewable technologies for mainly residential market.
Automotive	**Metal Fabrication, Capital and Transport Equipment**
• Biotechnology- specific application that are industrially relevant;	• Router moulding, plastic injection moulding;
• Stainless steel manipulation;	• Complex brackets using different materials;
• Automation of the manufacturing process;	• Robot welding;
• High speed machining;	• Casting, forgings manufacturing;
• Hybrid Injection moulding machine – advanced;	• On-board computer electronics;
• Robot Welding – (Available);	• Display modules;
• Vacuum Forming – (Available);	• International partnerships for technology (not sufficiently available);
• Electro-chemical processes;	• Automotive tier 1&2 manufacturing supply upgrade technologies (not nearly sufficiently available);
• Powder technology/sintering;	• Automotive raw material supply chain and value add (not nearly sufficiently available);
• Automotive raw material supply chain and value add – (not nearly sufficiently available);	• Casting;
• Automotive tier 1&2 manufacturing supply upgrade technologies – (not nearly sufficiently available);	• Wear casting – (available);
• International partnerships for technology – (not sufficiently available);	• Electro-chemical processes;

- GRP manufacturing processes – (Not fully available in SA);
- Film for covering glass for security and heat load – (Not available in SA); and
- Better utilization of available energy resources, including solar energy and fuel cell technology.

- High speed machining;
- Additive manufacturing technologies;
- Industrial robotics (we are consumers and purchase products from overseas suppliers); and
- Micro-manufacturing (infancy).

The respondents were also asked to identify future technologies (next 5 to 10 years) relevant for their sectors. The following technologies were identified:

Aerospace and Defense

- Infrared imaging technology manufacturing;
- Laser communication systems;
- Embedded software for space systems for radiation tolerant systems;
- Improved industrial robotics;
- More energy and eco-friendly systems; and
- Radar, RF, microwave, electro optics.

Clothing, Textiles, Leather and Footwear

- Flock printing;
- Coating;
- Anti-microbe technology;
- Alternate means of treatment and disposal of factory process effluent;
- Micro fluidic sensors and diagnostics, lab on a chip;
- Improved industrial robotics;
- More energy and eco-friendly systems; and
- Renewable energy.

Automotive

- Develop further use of polyurethanes;
- Metal pressing;
- Manufacturing expertise for renewable energy;
- Automotive tier 1&2 manufacturing facilities;
- World class infrastructure manufacturing support;
- High temperature sintering;
- 5-axis high speed machining (HSM);
- Additive manufacturing technologies;
- Material technology change;
- Manufacture of plastic canopies; and
- Polyurethane technology.

Agro-processing

- Oil stabilisation;
- Catalysis to upgrade fuel;
- Water gas shift;
- Hydrogenation of pyrolysis oils;
- Modern can and closure manufacturing equipment;
- Tool & die design and manufacturing;
- Modern metal deck printing technologies;
- Emulsifiers; and
- Gasification.

Chemicals and Pharmaceuticals

- Biotechnology - specific application that are industrially relevant;
- Pyrolysis, oil stabilization, catalysis to upgrade fuel, gasification, water gas shift;
- Hydrogenation of pyrolysis oils;
- Micro fluidic sensors and diagnostics, lab on a chip;

Electronics and ICT

- Biometrics;
- Infrared imaging technology manufacturing;
- Laser communication systems;
- Geographic register for South Africa;

• Polymers based on bio-sources;	• Secure and reliable communications;
• Sensing and smart polymers; and	• Embedded software for space systems for radiation tolerant systems; and
• Automated sterile manufacturing.	• Space grade sub-systems.
Metal fabrication, capital and transport equipment	**Energy**
• Router molding, plastic injection molding;	• Small wind technology;
• Complex brackets using different materials;	• LED lighting technologies;
• Robot welding, casting, forgings manufacturing, on-board computer electronics, display modules;	• Hot water systems;
• World class infrastructure manufacturing support;	• Renewable sources;
• Automotive tier 1&2 manufacturing facilities;	• Improved industrial robotics;
• Improved industrial robotics;	• Plasma technology, nuclear technology, nanotechnology, mineral beneficiation;
• Plasma technology, nuclear technology applications, nano technology, mineral beneficiation; and	• Small wind technology;
• More energy and eco-friendly systems.	• Manufacturing expertise for renewable energy; and
Creative Industries	• Better utilization of available energy resources, including solar energy and fuel cell technology.
• Secure fast internet lines; • Visualization of complex data; • Security printing (personalized, tamper-proof documents); • Secure communications; and • Co-creation tools.	

Respondents were asked to identify policy measures that will be useful for their activities. The instruments most often mentioned were:

- Fiscal incentives (23 votes);
- Innovation programmes (21); and
- Technology platforms (20).

Among the barriers of technological innovation the most often mentioned were:

- Innovation costs too high;
- Inadequate funding; and
- Lack of appropriate finance.

Table 5 shows the technological innovation barriers identified by the respondents. More than 50% of the respondents identified funding as a critical high barrier.

Table 5: Barriers to technological Innovation

Barriers of Technological Innovation (Please rate according to your tick as appropriate)			
	Low	**Average**	**High**
Innovation costs too high		10	18
Inadequate funding		11	20
Lack of appropriate finance		12	18
Excessive perceived economic risk	4	11	15
Licensing constraints	19	7	2
Lack of qualified personal	3	15	12
Lack of customer responsiveness to new goods and services	8	14	8
Insufficient flexibility of regulation of standards	11	9	10
Organisation inertia within company	8	12	6
Lack of marketing information	12	10	5
Lack of technology Information	13	8	6
Lack of cooperation with other firms	12	12	5
Other, specify………………			2

Fifty -six of the respondent mentioned that they acquire technology through R&D (table 6). The second most often approach (33%) is through formal agreements with companies locally and 30% through formal agreements with local companies. Only 18% of the companies mentioned that acquire technology through imitation. It should be emphasized that a number of companies mentioned that their research was done abroad.

Table 6: Acquisition of Technologies

How do you acquire Technologies? (Please tick as appropriate)	
Undertake own research and development	22
Through formal agreements with companies abroad (e.g. licensing)	12
Through formal agreements with local companies	13
From Universities and research councils	10
Through embodied technology in equipment & machinery	9
Through imitation	7

Table 7 shows the policy measures identified by the stakeholders as useful for their activities. Fifty one percent identified fiscal incentives and 43% innovation programs and technology platforms.

Table 7: Useful policy measures

Which of the following policy measure will be useful for your activity? (Please tick as appropriate)	
Cluster Initiative	11
Technology Platform	20
Innovation Program	21
Regulation	10
Competition Regulation	5
Quality Regulation (Labeling, Procurement)	8
Fiscal Incentives	23

The participants offered a number of suggestions in order to promote and support local production. Examples include:

- The need to provide more training on local product development skills;
- The need to improve exports;
- Skills development access to capital for investment;
- Raw materials available at world competitive prices;
- Budget and time to spend on concept testing;
- Labour law relaxation;
- Good transport logistical infrastructure;
- Reduce duty exemptions for SADC countries; and
- Others.

Forty seven % of the participants declared that they participate in government technology support programs. Measures that could improve government support programmes include:

- More R&D funding;
- Funding of capital equipment;
- Postgraduate students to be paid more;
- Enhanced skills development and education;
- Quicker responses;
- Less bureaucracy;
- Provide commercialization opportunities for local developers and inventors; and
- Others.

It is interesting to discuss the findings in the light of the results of the foresight exercise of 1999 and of the international experience. An important finding of the foresight exercise was that the participants/stakeholders did not allocate importance to “futuristic technologies”. The report states: “The typical topics recommended for future development in the foresight processes of the Pacific-Rim countries were only given moderate importance, and in some cases fall into the bottom 10 technologies e.g. nano-technology and micro-fabrication. Likewise, the power of simulation technologies, which are acknowledged worldwide as a cost-effective component of new product and process development, was given limited prominence”. In contrast the current survey identifies that the stakeholders recognize the importance of emerging and enabling technologies. ICT related technologies such as secure internet communications, biometrics, robotics, sensors and similar, biotechnology technologies and clean energy technologies have been identified as being of current and future by the stakeholders. Similarly the stakeholders identified “advanced manufacturing technologies” “modelling and simulation for improving products, perfecting processes, reducing design-to-manufacturing cycle time and reducing product realization costs” and “intelligent sensor network and ubiquitous computing” as of critical importance for their operations. It should be mentioned that these technologies are in the forefront of priorities internationally. As we elaborated advanced manufacturing technologies, manufacturing on demand and similar are attracting currently the attention of most governments the same way that nanotechnology has attracted international support in the beginning of 2000s. The USA government is leading the field allocating substantial resources for advanced manufacturing technologies.

It becomes evident that since the foresight exercise of 1999 globalisation has infiltrated the country’s stakeholders and currently they recognise the importance of enabling and emerging technologies. In this context it should be mentioned that in contrast to other countries which monitor and disseminate information related to new technologies, in South Africa there is no such mechanism. As we discussed most countries have institutionalised the monitoring of international priorities and the development of local ones with Japan’s foresight exercises being the most well known. The lack of South African efforts in the field may be detrimental to the country’s manufacturing sector. We discuss further this issue in the recommendations section.

It should also be emphasised that the stakeholders identified lack of funding for technology development as a critical barrier for innovation in the country and they suggested that “innovation programs" will be useful for their competitiveness. As we discuss further these are programs lacking in the country.

4 Overview of Innovation and Technology Support in South Africa

South Africa has a pluralistic system of governance of its national system of innovation traditionally. In a pluralistic system, government departments receive an appropriation and decide how much money to spend on research and innovation and on its various elements. No formal supervision or co-ordination is present and science and innovation policies are the sum total of the activities of the various departments. Under such a system the onus is upon the individual departments to ensure that their requirements for R&D and innovation are met. A number of policies/strategies provide the framework for technology and innovation policy. Examples include the Ten Year Innovation Plan; the New Growth Plan; the Industrial Policy Action Plans and others.

Currently the following are the major policy instruments supporting technology in the country[35]:

The **Technology and Human Resources for Industry Programme** (THRIP) is a partnership programme that is funded by the Department of Trade and Industry and managed by the National Research Foundation (NRF).

THRIP promotes partnerships in pre-commercial research between business and the public-funded research base including universities and research institutions.

On a cost-sharing basis with industry, THRIP supports Science, Engineering and Technology (SET) research collaboration focused on addressing the technology needs of the participating firms. The dti takes on third of the cost of the project (i.e. 2:1 cost sharing). There is also scope to double the support if certain conditions are met.

THRIP also encourages and supports the development and mobility of research personnel and students among participating organisations.

The objectives of THRIP are:

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35 **The dti** (2012). *"A Guide to **the dti** Incentive Schemes 2011/12"* Department of Trade and Industry, Pretoria

- To contribute to an increase in the number and quality of people with appropriate skills in the development and management of technology for industry;
- To promote increased interaction among researchers and technology managers in industry, Higher Education Institutions (HEIs) and Science, Engineering and Technology Institutions (SETIs) through the mobility of trained people among the sectors with the aim of developing skills for the commercial exploitation of Science and Technology;
- To stimulate industry and government to increase their investment in research, technology development, diffusion and the promotion of innovation;
- To promote increased collaboration between large and small enterprises, HEIs and SETIs by conducting research and development activities that lead to technology transfer and product or process development; and
- To promote large (thematic) collaborative research and development projects in **the dti** priority areas.

The priorities of THRIP are:

- To support an increase in the number of black and female students who intend to pursue technological and engineering careers;
- To promote technological know-how in the Small, Medium and Micro-Enterprise (SMME) sector through access to skills from HEIs and SETIs;
- To facilitate and improve the competitiveness of Black Empowerment Enterprise (BEE) and black-owned enterprises through technology and human resources development; and
- To facilitate and support multi-firm projects in which industry partners collaborate and share in the project outcomes, strongly encouraging SMME participation;

THRIP considers support for projects in which the primary aim is to promote and facilitate scientific research, technology development, and technology diffusion, or any combination of these. Discipline-specific and multi- or trans- disciplinary projects are considered. All projects funded by THRIP must include human resource development.

Dti contributes approximately R160 million to the programme.

The **Support Programme for Industrial Innovation** (SPII) is designed to promote and assist technology development in South African industry. It is an innovation support programme supported by the dti and administered by the IDC. The programme consists of 3 schemes:

- <u>The Product Process Development Scheme</u> provides financial assistance – between 50% to 85% (depending on extent of BEE ownership) of the total qualifying costs incurred in pre-competitive development activity – for small, very small and micro firms during the technical development stage (with a maximum grant of R1m per project);
- <u>The Matching Scheme</u> is also targeted at SMMEs (medium firms are not included in the Product Process Development Scheme). Financial assistance consists of a 50% to 75% grant with no payback, for innovative development of new products and processes (maximum grant of R3m); and
- *The Partnership Scheme* (PII) is open to all companies. Funds are provided in the form of a conditionally repayable grant of 50% (minimum grant of R3m) of the qualifying cost incurred during development activity – repayable on successful commercialization of the project.

The funds dispersed by SPII during 1010-11 were just below R50 m.

The dti established the **Strategic Industrial Projects (SIP)**. The SIP was designed to encourage investments into South African industry from both local and foreign investors. Its primary aim was "to significantly contribute to the growth, development and competitiveness of specific industry sectors by providing industrial investment allowances, in the form of tax relief, to qualifying industrial projects. Emanating from this industrial investment to South Africa is the key objective to create much needed employment opportunities and involve the full spectrum of the country's economic citizenry in the benefits thereof."[36] The programme assisted in acquiring embodied in equipment technology.

The Clothing and Textile Competitiveness Improvement Programme (CTCIP) aims to build capacity among clothing and textile manufacturers and in other areas of the apparel value chain in South Africa to enable them to effectively supply their customers and compete on a global scale. Such competitiveness encompasses issues of cost, quality, flexibility, reliability, adaptability and the capability to innovate.

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[36] **The dti** (2012). *"Strategic Industrial Projects: Report to Parliament on Approved Projects."* The Enterprise Organisation, Department of Trade and Industry, Pretoria

The Manufacturing Investment Programme (MIP) is a reimbursable cash grant for local and foreign-owned manufacturers who wish to establish a new production facility; expand an existing production facility; or upgrade an existing facility in the clothing and textiles sector. Benefits are Investment grants of 15% to 30% of the investment cost of qualifying assets (machinery and equipment, buildings and commercial vehicles) for new establishments or expansions.

Under the **Production Incentive (PI)** scheme applicants can use the full benefit as either an upgrade grant facility or an interest subsidy facility, or a combination of both. Eligible Enterprises are:

- Clothing manufacturers.
- Textile manufacturers.
- Cut, Make and Trim (CMT) operators.
- Footwear manufacturers.
- Leather goods manufacturers.
- Leather processors (specifically for leather goods and footwear industries).

A benefit, equal to 10% for the year ending March 2011, of a company's Manufacturing Value Addition (MVA).

The **seda Technology Programme (STP)** offers up to R800 000 for tools, machinery and equipment on a 35:65 cost-sharing basis (contribution by **the dti** = 35%; contribution by the enterprise = 65%).

The **Automotive Investment Scheme (AIS)** is an incentive designed to grow and develop the automotive sector through investment in new and/or replacement models and components that will increase plant production volumes, sustain employment and/or strengthen the automotive value chain. The AIS provides for a taxable cash grant of 20% of the value of qualifying investment in productive assets, as approved by the dti. An additional taxable cash grant of 5% to 10% may be made available for projects that significantly contribute to the development of the automotive sector.

DST developed the **advanced manufacturing technology strategy**[37] during 2002. The strategy identified a number of technologies as of critical importance: advanced materials; product technologies;

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[37] AMTS (2001) *"A National Advanced Manufacturing Technology Strategy for South Africa."* Department of Science and Technology; available at http://www.info.gov.za/view/DownloadFileAction?id=127106

production technologies; logistics; cleaner production technologies; ICT in manufacturing; SMMEs development and Standards, Quality, Accreditation and Metrology Technology issues.

The strategy argued that implementation will be achieved through a combination of centers of innovation, innovation networks and specific initiatives or projects. The report identified existing centers – Automotive Industry Development Centre at the CSIR; the National Product Development Centre at the CSIR- and suggested the establishment of the Logistics Innovation Centre and the National Textile and Clothing Innovation Centre. Simialrly identified a number of networks and special projects including projects like aluminium, magnesium and titanium light metals development; Coating technology innovation, incl. paints and thin films with a focus on nanotechnology and others.

During 2007 it was announced that R16 million were allocated to establish 10 Fabrication Laboratories, also known as "FabLabs", around the country, providing disadvantaged communities with opportunities in the design, testing and fabrication process. FabLabs are a state-of-the-art resource venue aimed at promoting cutting-edge design, product development and process technologies for crafters and designers.

During 2009 Deputy Minister Hanekom reported the following as successes of the AMTS:

- “The Smart Factory project is offering our small, medium enterprises (SMEs) a low-cost measurement and reporting system that will improve the efficiency of their manufacturing processes and lead to improved quality.
- Good progress has also been made in developing the capability to produce high-quality castings in titanium alloys for aerospace applications.
- We have registered 25 PhD and 60 MSc. students, and one PhD and 14 MSc students have already graduated.
- We have conducted two external reviews of the projects in the Advanced Production Technologies Programme and in fibre-reinforced composites. Both these reviews have reported positively on the quality of the work and focus areas of the projects.”[38]

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[38] Address by Deputy Minister Derek Hanekom, at the 2009 Advanced Manufacturing Technology Strategy (AMTS) Annual Symposium” available at http://www.info.gov.za/speech/DynamicAction?pageid=461&sid=3947&tid=4092

The DST annual report 2010-11 stated “we invested over R300 million in the Advanced Manufacturing Technology Strategy in the past seven years, primarily in the form of research grants for flagship programmes and human capital development.”

Discussions with officials of the DST and TIA identified that most existing AMTS programmes are phased out during 2012 and that during 2013 the available budget is only R35 million. This amount is expected to be invested on unmanned aerial vehicles and materials for agro-processing.

Another DST initiative is the **Centres of Excellence initiative**. Centre of Excellence have been created in South Africa, to stimulate the sustained distinction in research whilst generating highly qualified human resource capacity in order to impact national and global knowledge and innovation generation. There are currently 7 centres including: The Centre of Excellence in Biomedical TB Research, The Centre of Excellence in Invasion Biology, The Centre of Excellence in Strong Materials; The Centre of Excellence in Birds as Keys to Biodiversity Conservation at the Percy FitzPatrick Institute; The Centre of Excellence in Catalysis; The Centre of Excellence in Tree Health Biotechnology at FABI and The Centre of Excellence in Epidemiological Modeling and Analysis.

The **Research Chair initiative**, developed by DST and NRF, aims to attract and retain the best and the brightest to South African higher education institutions. Currently, 192 Research Chairs have been appointed in research and knowledge areas that are important for South African needs and priorities covering science, engineering, social sciences and humanities.

During the mid-2000s the DST allocated resources for the **South African Nanotechnology Strategy.** The DST established two national nanotechnology innovation centres (NIC) in 2007, housed at the CSIR and at Mintek. The National Centre for Nano-Structured Materials at the CSIR focuses on research into energy and materials. The centre at Mintek is concerned with health, mining and minerals, and water.

The NRF Nanotechnology Flagship Programmes aim to support, over a three-year period, platform projects in the field of nanoscience and nanotechnology. The *NRF (2007/08) Nanotechnology Flagship Manual* states that: “Its purpose is to demonstrate the benefits of nanotechnology and nanoscience and its impact on some of the key challenges facing South Africa”. The programme invested just above R 60 m to nanotechnology (excluding R30 m in relevant research chairs) during 2010. However it should be mentioned that the South African government spends for nanotechnology less than one fifth in comparison to the governments of India, Italy, South Korea and others.

The Technology Innovation Agency (TIA) is a new public entity which will attempt to address the lack of home-grown technology and commercialization available to South African firms. It was created by the TIA Act (Number 26 of 2008) and falls under the management of DST. Existing entities that have been incorporated into the TIA are the Biotechnology Regional Innovation Centres (BRICs), the Innovation Fund, AMTS and the Tshumisano Trust. TIA has just activated certain programmes and it is not clear their impact and direction. It should be emphasized that BRICs were the only vertical programme in the country, supporting biotechnology across the whole of the innovation chain.

The above show that government recognizes the importance of science, technology and innovation for the economy. Furthermore, the list indicates that the majority of the incentives are of horizontal nature (they apply to all disciplines, technologies, sectors etc) and they have relatively limited budgets. For example, the South African government spends for nanotechnology less than one fifth in comparison to the governments of India, Italy, South Korea and others and after TIA took over the biotechnology regional innovation centers there is not programme supporting biotechnology in the country currently. Simialrly the AMTS has a budget of R 35 millions while in the USA the relevant programme aims to provide more than US$ 1 billion.

The horizontal policies used in South Africa are a general characteristic of the country's national innovation system. They are supporting all sectors and products. However, horizontal policies may not have a direct impact on the effectiveness of the production system and of course they do not have the capability to create priorities and new industries.

Vertical instruments may create a favorable context for targeting RTD to specific areas and sub-areas of knowledge and technical know-how even though it has been suggested[39] that they are prone to criticism by political parties, on the basis that they may create distortions in free competition. Finland, for instance, although traditionally was placing more reliance on horizontal than vertical policy to build up the knowledge base, since the mid 1990s concentrated its resources for basic research in bio-centers and during the 2000s introduced a growing number of biotechnology specific programmes.[40]

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39 Deniozos D. (1994) "Steps for the Introduction of Technology Management in Developing Economies: the Role of Public Governments." *Tehnovation* 14(3):197-203.

40 European Commission (2003) "*Efficiency of Innovation Policies in High Technology Sectors in Europe (EPOHITE)"* Final Report from STRATA Accompanying Measures, EUR 20904

In the research system the use of horizontal instruments, by definition, affect all scientific disciplines. As a consequence strong/overemphasized disciplines have the opportunity to improve further their dominance in the research system. For example, overemphasis may be the result of the availability of more researchers in a discipline. As the policy instrument distributes incentives equally to all researchers, the research activity of the overemphasized discipline has the potentials to strengthen even further. The larger number of researchers in the particular discipline has the potential to attract more post-graduate students; the marketing is easier for larger disciplines et cetera. Strength brinks further strength.

It should be noted that the South African list of incentives (policy instruments) is relatively short in comparison with those in other countries. For example the main innovation related programmesof dti are the THRIP and SPII. As we discussed in the European Union each country has on average more than 50 programs/incentives.

Finally, it is observed that a number of incentives like the Automotive Investment Scheme and the Strategic Industrial Projects are tax-based benefits. Such schemes assist in technology adoption embodied in new equipment and machinery. However, they don’t facilitate indigenous technology development.

As we have identified government support internationally is focused on the development of cluster/science parks; the provision of incentives for innovation and the provision of fiscal incentives. These instruments are those which support the development of high technology, high value addition industries. In South Africa there is a number of fiscal incentives (e.g. R&D tax incentives; strategic industrial projects etc) but support for innovation programs and development of science parks is limited.

It can be argued that the limitation in innovation support is the result of the fact that innovation is considered the responsibility of DST. However, DST has a limited budget and aims to cover not only industrial needs but needs across the total spectrum of national domain (from health, nature conservation, blue sky research etc). Consequently limited resources are becoming available for **the dti** domain of responsibilities.

In summary we identify that:

- South Africa has limited number of incentives in comparison with the other countries;

- The majority of the incentives are of horizontal nature (they apply to all disciplines, technologies, sectors etc.); and
- The country's incentives have relatively limited budgets.

The above structure of incentives does not facilitate the establishment of new industries such as high technology industries. It should be emphasised that high technology industries include a number of high value adding industries which are supported internationally (i.e. aircraft and spacecraft; pharmaceuticals; office, accounting, and computing machinery; radio, television, and communication equipment; and medical, precision, and optical instruments).

5. Indicators: South Africa and Selected Countries

One of the most efficient and objective methods of assessing innovation/technology performance is through indicators. An indicator is defined as "statistics of direct normative interest which facilitates concise, comprehensive and balanced judgments about the condition of major aspects of a society. It is in all cases a direct measure of welfare and is subject to the interpretation that, if it changes in the "right" direction, while other things remain equal, things have gotten better or people better off."[41]

Below we present certain comparative statistics of the various SA sectors in comparison with each other and a number of other regions/countries. It should be emphasized that the groupings of industries at **the dti** are not the same with the international classifications and the classifications utilized by various organizations (e.g. OECD). For example, aerospace is a subcategory of transport equipment in the standard industrial classification of all economic activities. Creative industries and energy: alternative and biofuels are not identifiable industries in the international industrial classifications. Alternative energy may be classified in the electronics or chemicals industry. Similarly ICT (information and communications technologies) is an umbrella term that includes any communication device or application, encompassing: radio, television, cellular phones, computer and network hardware and software, satellite systems and so on, as well as the various services and applications associated with them. A more detailed outline of the various indicators (value added indicators, imports-exports, bibliometrics, patents and R&D expenditure) appears in appendix 6.

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[41] DHEW (1970) "*Towards a Social Report*" Department of Health, Education and Welfare University of Michigan Press, Ann Arbor

Table 8 shows the value added by high technology industries in South Africa and a number of selected countries during 2010. Value added is a measure of the value of goods and/or services produced by a particular sector. It is an indicator of the contribution that the particular sector makes in the gross domestic product of the economy. High technology industries, have attracted particular interest

internationally during the last twenty years. High-technology manufacturing industries include aircraft and spacecraft; pharmaceuticals; office, accounting, and computing machinery; radio, television, and communication equipment; and medical, precision, and optical instruments.

	Computers and office machinery	Aircraft and spacecraft	Communication equipment	Medical and measuring equipment	Medical, precision, and optical equipment	Semi-conductors	Pharma	ICT industries
USA	29 776	69 401	39 073	75 374	95 644	60 142	91 903	729 169
EU	10 449	34 574	17 594	54 210	83 775	36 082	90 418	624 549
UK	3 063	9 377	1 485	7 926	10 367	2 957	14 744	115 595
Japan	11 469	4 722	42 354	15 311	20 329	69 045	30 015	336 409
India	697	132	1 265	807	1 124	851	7 531	43 354
Malaysia	918	281	1 515	605	847	3 612	152	13 478
S. Korea	1 300	899	17 619	2 737	4 671	22 605	6 813	67 549
Brazil	881*	1016*	2772*	722*	965*	560*	4218*	15 649*
S. Africa	4*	38*	189*	71*	87*	14*	458*	5 948*

Table 8: Value added high technology industries: SA and selected countries: 2010

Governments all over the world support the development of high technology industries based on the conviction that knowledge- and technology-intensive economies create well-paying jobs, contribute high-value output and ensure economic competitiveness. Comprehensive approaches are utilised for this objective ranging from the establishment of relevant “parks”; tax incentives for foreign direct investments, technology support programmes and similar. The table shows that the high technology industries contribute much less in South Africa than in the other economies.

Further analysis of the manufacturing trade balance in South Africa shows that the country has substantial deficits in electronics (televisions, computers), pharmaceuticals, aircraft etc – areas classified as high technology and requiring substantial R&D expenditures.

Table 9 shows the activity index of the various scientific disciplines for the period 2006-2010. The activity index characterizes the relative research effort a country devotes to a given subject field. An indicator equal to one indicates that the country's research effort in the given field corresponds precisely to the world average. Indices higher than one reflect higher than average effort dedicated to the field under study and vice versa.

South Africa's emphasis is in plant and animal sciences, environment/ecology and social sciences. Industrial related disciplines like chemistry; engineering; computer sciences; material sciences and similar are underemphasized.

Table 9: Disciplinary revealed priorities–South Africa 2006-2010

Discipline	Activity index 2006-10
Multidisciplinary	2.71
Plant and Animal Science	2.66
Environmental/Ecology	2.36
Social Sciences, General	2.07
Geosciences	1.85
Immunology	1.85
Space Science	1.78
Economic and Business	1.46
Microbiology	1.32
Agriculture Science	1.19
Psychiatry/Psychology	1.17
Mathematics	0.98
Biology and Biochemistry	0.92
Clinical Medicine	0.76
Pharmacology and Toxicology	0.71
Chemistry	0.66
Engineering	0.64
Computer Science	0.47
Material Sciences	0.47
Physics	0.47
Molecular Biology	0.41
Neuroscience and Behaviour	0.37

Analysis of the world ranking of South African technology classes according to patents awarded to South African inventors by the USPTO shows that South Africa is ranked third in the world on Fischer-Tropsch processes; and 12th in specializes metallurgical processes and chemistry of hydrocarbon compounds. It is emphasized that this emphasis is mainly due to the inventive activities of SASOL on these processes[42]. The high international rankings reveal areas of technological strength which can be exploited further for national commercialization benefits. In the UK areas of technological strength are supported through the establishment of the Catapult centres (Innovation and Knowledge Centres). We discuss the issue in the recommendations section.

As far as the most often used indicator characterising the innovation system is concerned – expenditures on research and development as a percentage of gross domestic product – South Africa with less than 1% of GDP is well below the other countries which aim to spend in the region of 3% of GDP. This indicator confirms the opinions of the stakeholders who identified lack of funding as the most important obstacle for innovation in the country.

In summary South Africa has an underdeveloped high technology industry. The value added indicators, imports-exports, patents and R&D expenditure make that point. Similarly the country's publication profile shows that the country's research system is not geared to support the high technology industry. Critical disciplines like engineering, material sciences, computer sciences and molecular biology are underemphasized in the country. The small research and development efforts coupled with lack of relevant policy instruments undermine the development of high technology, high value industries.

Finally the patent analysis identifies the technologies in which South Africa has a leading position internationally. South Africa is ranked third in the world in Chemistry: Fisher-Tropsch Process or Purification or Recovery of Products.

6 Findings and Recommendations

The objective of the effort is to identify technology trends internationally and recommend the development of supporting actions for the country's industries. In this chapter we discuss the findings of the investigation according to the set objectives and develop appropriate recommendations.

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[42] Pouris A. (2009). "Quantitative assessment of South Africa's inventive outputs: International patent analysis." *South African Journal of Industrial Engineering* **20(1):** 13-29.

6.1 International Trends Related to Technology Development

There are four broad international trends that shape the development of technology currently. These are:

Convergence of technologies: the Rand Corporation[43] concluded that the world is undergoing a global technology revolution that is integrating developments in biotechnology, nanotechnology, materials technology and information technology at an accelerating pace. Furthermore, they argued that this "convergence" will have profound effects on society, including promoting rural economic development, promoting economic growth and international commerce, improving public health, improving individual health, reducing resource use and improving environmental conditions, strengthening the military and war-fighters of the future, strengthening homeland security and public safety and influencing governance and social structure.

The trend of interactive technologies creates implications for industries and countries. Because of the added complexity, accelerating pace of technology development and the rapid improvement of capacity to acquire and implement technology applications, maintaining country position in relative capacity to implement technology applications will require continuing efforts to ensure that, for example, laws, public opinion, investment in R&D, and education and literacy are drivers for, and not barriers to technology implementation.

Digitisation — ICT is probably the most important technology area currently and in the foreseeable future. The Institute of Electrical and Electronics Engineers (IEEE) recently sought the opinions of 40 leading technology developers concerning the most important technology of the past 40 years and the most important technology of the coming decade. The vast majority of the responses to the former question included the integrated circuit, the computer or the Internet, and many of the answers to the latter included either the Internet or wireless communication, with several respondents noting the likely impact of biology and a few mentioning nanotechnology.[44]

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43 Antón SP., Silberglitt R. and Schneider J. (2001) *"The Global Technology Revolution: Bio/Nano/Materials Trends and Their Synergies with Information Technology by 2015."* Santa Monica, Calif.: RAND Corporation, MR-1307-NIC.

44 Applewhite A. (2004). "The View from the Top: Forty Leading Lights Ponder Tech's Past and Consider Its Future." *IEEE Spectrum* 41(11): 36–51.

The new related technologies affect also the organisational structures and relations. The pervasive adoption of connected, cloud, and mobile technologies across industries — is transforming every company's interactions with its customers, its suppliers, and its global talent. For example, the use of social media is increasing both within the enterprise and as a tool for marketing and sales, even as e-commerce offerings are built out further. Similarly the movement toward cloud computing is forcing the technology industry and its customers to rethink established ways of doing business.

A recent investigation[45] finds that digitisation creates substantial economic, social and political benefits. Digitisation offers incremental economic growth: countries at the most advanced stage of digitisation derive 20 %more in economic benefits than those at the initial stage. Digitisation has a proven impact on reducing unemployment, improving quality of life, and boosting citizens' access to public services. Finally, digitisation allows governments to operate with greater transparency and efficiency. They estimate that digitisation contributes positively to job creation, with a 10% increase in digitisation reducing the unemployment rate by 0.84%.

Emphasis on High Technology Industries: Governments all over the world are acting on the conviction that knowledge- and technology-intensive economies create well-paying jobs, contribute high-value output and ensure economic competitiveness. In response to changing opportunities, knowledge-intensive services industries and high-technology manufacturing industries have grown more rapidly than other segments of economic activity. High-technology manufacturing industries include aircraft and spacecraft; pharmaceuticals; office, accounting, and computing machinery; radio, television, and communication equipment; and medical, precision, and optical instruments.

In 2010, these knowledge- and technology-intensive industries combined contributed just under $18.2 trillion to global economic output—about 30% of world GDP.

China has used high technology industries in order to support its economic growth. China's share of the world's high-technology manufacturing rose six-fold from 3% in 1995 to 19% in 2010, surpassing Japan in 2007. Its share grew rapidly across all high technology manufacturing industries, reaching nearly 50% in computers, 26% in communications, and 17%–18% in pharmaceuticals and semiconductors.

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45 Booz & Co (2012). *"Maximising the Impact of Digitization."* available at http://www.booz.com/media/uploads/BoozCo_Maximising-the-Impact-of-Digitisation.pdf

Recognition of Importance of Transnational Corporations: Countries recognize the importance of transnational organisations and develop policies in order to attract them. Transnational organisations account for more than 60% of all R&D in world – most of it on the side of development and commercialization. Simialrly, they account for 2/3rds of world trade and they account for more than 27% of global value added[46]. Transnational corporations are key innovation agents that need to be taken into account in developing effective knowledge strategies.

6.2 Identification on Global Basis Emerging and Enabling Technologies

The importance of new technologies for economic growth and national competitive advantage is well recognized internationally and governments aim to identify and support their development. Emerging and enabling technologies are of particular importance.

Emerging technologies are defined as those that are still emerging from the science base, that are at an early, pre-commercial stage and that have the potential to enable innovations that will disrupt the marketplace.

In more detail emerging technologies are defined as those that:

- "Enable something to be done that was previously not possible or was possible only in theory;
- Lead to new products and services;
- May be adopted by existing industries or may result in new industries; and
- May arise from:
    - A major scientific breakthrough like radar or the transistor
    - The integration of several technologies like the 5.25 inch disk drive or
    - A single advance that enables a much bigger innovation, such as switching circuits for mobile phones."[47]

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46 Dahlman JC. (2012). *"The Changing Geography of Innovation: The Rise of the BICs-Challenges and Opportunities."* Paris Policy Symposium; The New Geography of Innovation and the Economic Crisis; January 19, 2012

47 TSB (2010). "*Emerging Technologies and Industries Strategy 2010-2013."* Swindon "http://www.innovateuk.org/_assets/pdf/corporate-publications/ tsb%20emerging%20technologies%20%20industries%20strategy%20%202010%20-%202013.pdf

It is apparent that emergence is a matter of stage of development and that emerging technologies are a subset of enabling technologies.

Currently the enabling technologies are:

- Advanced materials;
- Advanced manufacturing systems;
- Micro and nano-electronics;
- Nanotechnology;
- Industrial biotechnology; and
- Photonics.

Different parts of a technology can be in different levels of maturity and of course their maturity changes with time. As we have discussed in the UK currently emphasis is on secure information technologies, regenerative therapies and devices, functional industrial coatings and smart infrastructure and construction. In the USA emerging technologies such as electromagnetic rail guns, launch systems for next-generation aircraft carriers, underwater-unmanned vehicles and information technology are rising to the top of the list. The foresight exercises that we have discussed (i.e. from Japan and South Africa) reveal emerging technologies.

Error! Reference source not found. Table 10 shows 40 emerging technologies and their expected level of maturity. “M” means mature, “G” in growth and “E” expected. Among the technologies identified only five will be in a mature stage by 2025.

Table 10: Emerging technologies and their expected maturity

Priority emerging technologies	2015	2020	2025	2030	after 2030
Supply chain management	G	G/M	M	M	M
Software technologies for transport of digital data	E/G	E/G	M	M	M
More efficient energy consumption	E/G	G	M	M	M
Image Sensors	E	G	M	M	M
Mobile communications (4th generation mobile phone)	E	G	M	M	M
Advanced technologies for virtual reality/augmented reality	E	G	G	M	M
Advanced data mining technologies and high performance data storage systems	E	G	G	M	M

Ultra-thin functional coatings	E	G	G	M	M
Bioactive materials and surfaces	E	E	G	M	M
Application of stem cells in the treatment of different diseases	E	E/G	G	M	M
Inherently smart materials	E	E	G	M	M
Low-cost high-efficiency solar cells	E	G	G	M	M
New technologies for fuel cells	E	G	G	M	M
Biofuels	E	G	G	M	M
New energy storage technologies	E	G	G	M	M
Capture and storage of CO_2	E	G	G	M	M
Air/water purification	E	G	G	M	M
Active packages	E	G	G/M	M	M
Tissue engineering	E	G	G	M	M
Individualized health services and drugs	E	G	G	M	M
Techniques for diagnosis and repairs of structures	E	G	G	M	M
Bio-genetic materials	E	E	G	M	M
Human genomes and proteomes	E	E	E/G	M	M
Embeded single-chip applications	E	E	E/G	M	M
Broadband network	E	E/G	G/M	M	M
Computer-aided surgery	E/G	G	G	M	M
Protein engineering	E	G	G	M	M
Design of structures with intelligent behavior and response	E	E/G	G	M	M
Logistic chains based thoroughly on RFIDs	E	E	E	M	M
Renewable and recyclable materials	E	G	G	G	M
Multiple intelligent and mobile robots	E	G	G	G	M
Large-scale DNA analysis	E	E	G	G	M
New tools for in-vivo diagnostics	E	E	E	G/M	M
Nanocomposites and nanomaterial reinforcements in electronics, chemistry, medicine, …	E	E	E	G	M
Complete modeling for the transformation of materials and integration in databases -Visual chemistry	E	E	G	G/M	M
Cell therapy	E	E	E	G	G/M
Nanotechnology and nano particles in therapy	E	E	E	E	E
Microsensors and nanosensors	E	E	E	E	E

Biochips	E	E	E	E	E
Fusion power	E	E	E	E	E
Intelligent artificial limbs	E	E	E	E	E

Source: EC (2006) "Emerging science and technology priorities in public research policies in the EU, the US and Japan" European Commission, Directorate-General for Research, Information and Communication Unit, B-1049 Brussels

The 40 technologies can be classified within four main scientific fields

- Nanotechnologies, knowledge based multifunctional materials, new production processes;
- Information Society Technologies (IST);
- Life-Sciences, genomics and biotechnology for health; and
- Sustainable development, global change and ecosystem.

We already have shown how the various technologies affect the various industrial sectors. It is sufficient to reiterate that certain technologies have the potential to affect more sectors than others. For example, nanotechnology and nanomaterials have the potential to affect 8 sectors (i.e. electronics, energy, aerospace, transport, chemicals, instruments, pharmaceuticals and textiles); smart bio-mimetic materials and smart interactive textiles, intelligent sensor networks and ubiquitous computing have the potentials to affect seven sectors; service and swarm robotics 6 sectors and so on (Appendix 2)

Hence, the technologies with expected high impact (as it will be manifested in effects in a multitude of sectors) are as follows:

- Nanotechnology and nanomaterials;
- Intelligent sensor networks and ubiquitous computing;
- Intelligent sensor networks and ubiquitous computing;
- Smart bio-mimetic materials;
- 3D Printing and personal fabrication;
- Industrial biotechnology; and
- Cloud computing.

6.3 Supported Technologies and Sectors Internationally

All countries investigated in this document identify technologies of importance for their industries and societies. Similarly all countries identify cross cutting technologies impacting more than one sector. A number of such technologies are currently identified by all countries covered in this investigation. These include:

- ICT
- Renewable energy
- Advanced materials and nanotechnology
- Advanced Manufacturing Technologies
- Aerospace technologies
- Biotechnology

Different countries define to a different extent the level of detail of the various technologies. For example, Japan through the foresight exercises identify technologies to a fine level of detail e.g. "Ultra-large storage memory of 1PB (peta byte) or more capacity, including atomic memory, molecular memory, and self-organising memory, that is beyond the concept of the conventional semiconductor device (i.e. flash memory)". Other countries like the USA use coarse levels of detail (e.g. ICT). The later is the result of the debate whether governments have the capability to pick up winners and whether they should do so. Consequently, thematic priorities avoid the relevant debate.

A new international trend in early stages of development is to move away from technology identification and into solutions of industrial and societal challenges. The trend is apparent in the USA and Japan. Japan has restructured their foresight exercised according to national and international challenges.

Identification of sectors for technology support also varies from country to country. Korea for example during the last ten years focused mainly in the ICT sector; currently there is significant concentration of investment in electronic equipment, automobiles and components which take up a large portion of the national investment. The R&D investment sum of the top three companies, Samsung Electronics, LG, and Hyundai Motor is a major contributor to national investment.

Brazil has developed 14 sectoral funds that are supporting technology development. The funds are funded by relevant levies of the supported sectors. In addition Brazil has identified four strategic sectors i.e. capital goods; software; microelectronics and pharmaceuticals.

In Japan the Science Basic Plan[48] focuses on research and development (R&D) and new manufacturing processes. The plan is focused around eight priority areas:

- Life sciences;
- Information and communication technology;
- Environmental sciences;
- Nanotechnology and materials;
- Energy;
- Manufacturing technology;
- Infrastructure; and
- Frontiers (outer space and oceans).

The USA aims at following a broad strategy across all sectors. It can be argued that this is appropriate as the country has a substantial and well supported national system of innovation. The recent *American Recovery and Reinvestment Act of 2009* identifies a number of priorities and makes relevant commitments. The Act committed over $100 billion to support groundbreaking innovation with investments in energy, basic research, education and training, advanced vehicle technology, innovative programmes, health IT and health research, high speed rail, smart grid, and information technology.

The UK has identified high value manufacturing as of critical importance for the country. High value manufacturing includes aerospace, automotive, chemicals, pharmaceuticals and foods. The creative industries have also been identified as such a sector and TSB supports technology developments in areas such as electronics, pervasive computing, modelling and visualization for the sector.

India in the “Technology Vision 2020,” lays out a recommended set of actions that should undertake to become a developed nation by the year 2020. It identifies five broad areas for development that can leverage India’s core competencies and address its critical needs:

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48 Government of Japan (2006). *“Science & Technology Basic Plan.”* available at *ww8.cao.go.jp/cstp/english/basic/3rd-Basic-Plan-rev.pdf*

- agriculture and food processing,
- infrastructure with reliable electric power,
- education and healthcare,
- information and communication technology, and
- critical technologies (defined as nuclear, space, and defence).

The 10th Plan in Malaysia has identified the following critical sectors as of importance for support:

1. Oil and gas
2. Palm oil and related products
3. Financial services
4. Wholesale and retail
5. Tourism
6. Information and communications technology
7. Education
8. Electrical and electronic
9. Business services
10. Private healthcare
11. Agriculture

It should be mentioned that the ICT sector and associated sectors have received particular attention during the last twenty years internationally. The Software Technology Parks of India and the Multimedia Super Corridor in Malaysia are examples of the attention in the sector and the success of the particular approach

6.4 International Innovation and Technology Support Strategies

Innovation and technology support strategies appear to have a number of commonalities.

Coordination is probably the most important commonality. In Korea the NSTC has this responsibility; in India coordination is embodied in the 5-year plans and in Brazil in the Science and Technology Development Plans (Plano de Desenvolvimento Científico e Tecnológico). This role has been entrusted to Technology Strategy Board (TSB) in the UK and in the USA coordination is taking place in the White

House (President's Council of Advisors on Science and Technology) and the National Science Foundation advices the President through the publication of the Science and Engineering Indicators reports.

Institutionalization of priorities is another commonality in the support strategies adopted internationally. Institutionalization can be manifested in the development of partnerships or/and the establishment of new institutions. Examples of partnerships include the "Manufacturing Extension Partnership Centers" in the USA; the "Joint Technology Initiatives" in the EU and the "Innovation Highway Concept—Public–Private Sector Collaboration" in Japan.

The "Joint Technology Initiatives" (JTI) of the European Commission are of particular interest. The Commission set up long-term public-private partnerships, in areas where existing schemes are inadequate in view of the scope of research and the scale of material and human resources required.

The JTI are managed by dedicated structures which are independent legal entities. JTIs have a dedicated budget and staff and provide a framework for the public and private players to work and take decisions together. They organise calls for proposals, oversee selection procedures and put in place contractual arrangements for projects set up to implement the JTI research agenda. Hence, they allow funds from different sources to be jointly managed and they are responsible for the related communication and dissemination activities.

Examples of the establishment of new institutions include the establishment of the New Energy and Industrial Technology Development Organisation (NEDO) in Japan as well as the establishment of the "World Premier International Research Centres Initiative" by the Ministry of Education, Science, and Technology; the "Technology and Innovation Centres" in the UK and others.

In this context it should be mentioned that government research organisations (funders and performers) adjust their activities according to government priorities. For example, the Government Research Institutes (GRIs) in Korea were explicitly reoriented their activities during the 2000s so their activities coincide with the interests of industry.

Increasing the support for research and development expenditures and setting relevant targets is also a strategy followed internationally. For example EU spends currently 1.77% of its GDP and has set a target of investing in R&D 3% of GDP. As is shown in table 18 with the exception of Malaysia all other countries invest substantially higher proportions of their GDP for research and development than South Africa. S. Korea spends 3.47 % of the GDP for R&D; Japan 3.44%; USA 2.68%; Brazil 1.46% and India 1.00%.

The importance of R&D is not more so evident than in the recent (2008) international recession - crisis. Countries set R&D expenditure targets and utilize R&D expenditure as stimulus for economic recovery. For example, the European Union has urged member countries to increase investment in R&D and consider ways to increase private sector R&D investments. In the USA the Government, as part of the American Reinvestment and Recovery Act of 2009, has increased its spending on R&D related to climate change by US $ 26.1 billion and to energy by US$ 6.36 billion. In addition US$ 10 billion was allocated to US National Institutes of Health (NIH) for biomedical research and an additional US$ 2.3 billion was allocated for research funded by the National Science Foundation[49].

OECD (2010)[50] states “Despite the slowdown in economic growth and the resulting fall in tax revenue government investments in R&D have outpaced outlays in other areas. Government investments or spending and tax cuts, taken together, have represented on average more than 3% of GDP in the OECD area and up to 5% of GDP in the United States and Korea”.

In this context it should be mentioned that firms in different sectors follow different innovation paths and have different needs. For instance, technology users, i.e. firms that use, adapt and modify existing technologies, in sectors such as food, textiles or the energy industry require different support (technology transfer) than firms that carry out R&D as in the ICT sector, the automotive industry or the chemical industry. Hence, R&D resources should be focused in the appropriate domains.

An investigation in 20 European countries identified the policy instruments utilised for the support of the various sectors (table 1). As far as types of instruments used is concerned, innovation support programmes are the most popular (520) followed by fiscal incentives (302) and cluster initiatives (241). It should be noted that each country uses at least 50 different supporting mechanisms on average.

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49 OECD (2009). *“Policy Responses to Economic Crisis: Investing in Innovation for Long-Term Growth.”* Organisation for Economic Cooperation and Development, Paris

50 OECD (2010). *“OECD Science, Technology and Industry Outlook 2010”* Organisation for Economic Cooperation and Development; Paris

In this context we should mention an important recent investigation - the EC project *Efficiency of innovation policies in high technology sectors in Europe*[51] which investigated the biotechnology clusters in 14 European Union member countries. Its importance arises from its objective to identify best practice in incentives promoting biotechnology (and other knowledge intensive technologies) innovation and from its methodological approach. In a first step a quantitative analysis of the performance of the national innovation systems in developing the biotechnology knowledge base and commercializing biotechnology was carried out, combining a detailed exploration of the biotechnology policy-making systems. The EU project systematically categorized the national policy-making systems and the policies for supporting biotechnology implemented at the national level.[52]

The study identified the following:

- "National policies for the biotechnology knowledge base and for its commercialization have a pronounced effect, which can be either positive or negative. In other words policy matters!
- Policies to create and sustain the knowledge base are crucial for commercialization but the reverse is not true.
- Countries that have taken a systems perspective and implemented a broad set of policies to promote biotechnology that address all the functions of the innovation system and create an environment conducive to entrepreneurial activity achieve better performances than countries with patchy and fragmented policies.
- Achieving ex ante coordination amongst strategic policy decision-makers (public or private) responsible for all the different functions of the innovation system can be extremely beneficial to developments at a national level and in avoiding policy gaps or duplication".

Finally the utilisation of science parks/corridors is a commonly used and successful instrument promoting collaboration and synergy. Examples are the multitude of science parks in the USA (e.g. Silicon Valley; the Research Triangle Park: etc), the techno-parks in Korea (e.g. Daedeok Innopolis); the Software Technology Parks of India; the Multimedia Super Corridor in Malaysia and the multitude of

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51 European Commission (2003). "*Efficiency of Innovation Policies in High Technology Sectors in Europe (EPOHITE).*" Final Report from STRATA Accompanying Measures, EUR 20904

52 Enzing C., Benedictus J., Engelen-Smeets E., Senker J., Martin P., Reiss T., Schmidt H., Assouline G., Joly P-B. and Nesta L. (1999). "*Inventory of public biotechnology R&D programmes in Europe*." Analytical Report, Luxembourg: Office for Official Publications of the European Communities, Vol. 1.

technology parks in Brazil and others. It should be emphasized that this policy instrument is not just a property venture (like the Innovation Hub in South Africa) but it includes a variety of incentives that make the relocation of organizations (both locally and from abroad) attractive.

It should be emphasised that the above approaches take place in an environment where the whole innovation chain, from basic research to commercialization is supported and monitored. The EU recent recommendations are relevant in this context. The EU suggested that:

“The EU should create a European Technology Research Council (ETRC) to promote individual excellence in technologically focused engineering research and innovation and establish the appropriate framework conditions in order to support key enabling technologies skills capacity building at national and regional level.”

“The European Commission should establish a European Key Emerging Technologies (KET) Observatory Monitoring Mechanism tasked with the mission of performing analysis and a “key enabling technologies Consultative Body” comprised of stakeholders across the entire innovation chain, to advise and monitor the progress in Europe of the high level group KET recommendations towards the development and deployment of KETs for a competitive Europe. This should include all relevant data regarding policies and strategies evolution outside EU.”

6.5 Cross Cutting Technologies that could Impact Multiple Sectors

We have already discussed the emerging and enabling technologies. Another important set of technologies are those that have the potential to affect a number of sectors across the economy.

During 2009 the European Commission identified a set of key enabling technologies (KET). The Commission defined that "KETs are knowledge and capital-intensive technologies associated with high research and development (R&D) intensity, rapid and integrated innovation cycles, high capital expenditure and highly-skilled employment. Their influence is pervasive, enabling process, product and service innovation throughout the economy. They are of systemic relevance, multidisciplinary and trans-sectorial, cutting across many technology areas with a trend towards convergence, technology integration and the potential to induce structural change”.

KET have been identified as having the capability to strengthen the EU’s industrial and innovation capacity to address the societal challenges ahead and EC proposed a set of measures to improve the related framework conditions. As such, the document COM (2009)[53] forms part of the development of EU industrial policy and of the preparation for the new European plans for innovation. The identified technologies are:

- nanotechnology;
- micro-nano-electronics;
- advanced materials;
- photonics;
- industrial biotechnology; and
- advanced manufacturing systems.

These technologies are currently accepted internationally as cross cutting and as of critical importance for future economic growth. For example they are also included in the 10th Malaysia Plan.

In a finer level of detail the UK Office of Science identified during 2010 the following technologies and the sectors that they will affect (Table 4).

Reading the table from the sector prospective we can receive a list of technologies per sector. So for example:

- Aerospace will be affected by supercomputers, modelling and simulation, service and swarm robotics, intelligent sensors, bio-mimetic, nanotechnology, and 3d printing and personal fabrication.
- Pharmaceuticals will be affected by supercomputers, intelligent sensors, synthetic biology, omics, lab on a chip, biotechnology, active packaging, nanomaterials and 3d printing and personal fabrication.
- Creative industries will be affected by supercomputers, secure communications, service and swarm robotics and smart interactive textiles.
- Agro-processing will be affected by synthetic biology, omics, biotechnology, active packaging and 3d printing and personal fabrication.

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53 COM (2009), "*Preparing for our future: Developing a common strategy for key enabling technologies in the EU*." European Commission, Brussels

- Textiles will be affected by biotechnology, smart interactive textiles, bio-mimetic materials, intelligent polymers, nanomaterials and 3d printing and personal fabrication.
- And so on

Obviously it will be cost effective to focus on technologies which will affect most sectors (e.g. nanomaterials).

6.6 The impact of cross cutting technologies

Governments all over the world support the development of cross cutting technologies based on the conviction that knowledge- and technology-intensive economies create well-paying jobs, contribute high-value output and ensure economic competitiveness across the economy in general.

Table 11 shows the estimated market potential of the various technologies. It is estimated that by 2015 these technologies will have a market of US$1.3 Trillion (approximately R 10 trillion with current exchange rates). If an economy is able to capture a small percentage of the market it can have substantial benefits.

Table 11: Global market potential for key enabling technologies

	Current market size (~2006/08) bn USD	Expected size in 2015 (~2012/15) bn USD	Expected compound annual growth rate (%)
Nanotechnology	12	27	16
Micro and nano electronics	250	300	13
Industrial biotechnology	90	125	6
Photonics	230	480	8
Advanced materials	100	150	6
Advanced manufacturing systems	150	200	5
Total	832	1282	

These technologies are expected to create new successful companies and new industries the same way that ICT has produced Microsoft, Google and Facebook and a worldwide information and communication industry. Such technologies have made an impact in Africa as well. One of Africa's most talked-about ICT success stories is the rise of mobile money transfer services, led by Kenyan mobile operator Safaricom's M-Pesa platform. In only five years since it was launched in 2007, over 14 million Kenyans have used the M-Pesa service. In 2010 an estimated US$7 billion (equivalent of 20% of Kenya's

GDP) was transferred through M-Pesa. The platform's success has led to the launch of various other similar services.

It should be emphasized that these technologies displace previous technologies and add value to products and processes. For example, 20% of the value of each car today is due to embedded electronics and this is projected to increase to an average of 35-40% by 2015; ICT is changing the character of the automotive industry.

The benefits are not only financial but also social and environmental. For example it is expected that nanotechnology will contribute substantially in the production of cheap solar energy. Cheap solar energy will contribute to economic development through rural electrification and hence rural economic development. Its contribution to providing power for improving local hygiene will affect both public health and individual health. Also, its contribution to the global energy system will have impacts on economic growth, international commerce and environmental concerns. Similarly the Nobel winning material graphene has recently been identified as having the potential to revolutionize desalination. Such a success will have the potential to solve the world wide issue of water availability.

Similarly advanced manufacturing systems, based on integrated and synthesised emerging technologies have the potential to change the way the manufacturing industry operates. Harnessed and driven appropriately, have the potential to create a new manufacturing base competitive internationally. A recent investigation[54] argued that manufacturing opens the door for innovation and the development of a knowledge society. The authors state:"the decline of manufacturing in a region sets off a chain reaction. Once manufacturing is outsourced, process-engineering expertise can't be maintained, since it depends on daily interactions with manufacturing. Without process-engineering capabilities, companies find it increasingly difficult to conduct advanced research on next-generation process technologies. Without the ability to develop such new processes, they find they can no longer develop new products. In the long term, then, an economy that lacks an infrastructure for advanced process engineering and manufacturing will lose its ability to innovate".

Appendix 2 "Impact of 2020 Technology Applications" summarizes the impact of a variety of technologies on a number of socioeconomic sectors by the year 2020. The table also shows the technical

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54 Pisano, GP. and Shih WC. (2009). "Restoring American Competitiveness" *Harvard Business Review* **87(7-8)** (July -August)

feasibility of the concept and the size of the market that the technology is expected to satisfy. Cheap solar energy and rural wireless communications are judged to be of equal importance with the internet.

6.7 Technology Areas for Development in South Africa

Governments decide the support and development of particular technologies based on international best practice and local needs. Local needs are the result of broad government policies/priorities and formal prioritization exercises such as foresight investigations, road maps and similar.

This review identifies that all governments support a mix of enabling technologies and technologies in promising sectors (i.e. renewable energy, aerospace). The supported technologies are the following:

- ICT
- Renewable energy technologies
- Advanced materials and nanotechnology
- Advanced Manufacturing Technologies
- Aerospace technologies
- Biotechnology

It should be mentioned that the identified technologies support the development of high technology industries which as we have shown are not as developed in South Africa as in other countries, despite their importance for trade, economic development and security.

The survey of the stakeholders further identified a set technologies according to various industries. It is mentioned that the particular industries are those identified by the country's policies (e.g. AsgiSA).

Finally it is emphasised that the stakeholders converged in identified as being of high importance the following technologies:

- "Advanced manufacturing technology"
- "Modelling and simulation for improving products, perfecting processes, reducing design-to-manufacturing cycle time and reducing product realization costs" and
- "intelligent sensor network and ubiquitous computing"

The topics identified from the survey are relatively close to those identified by the Sectoral Innovation Watch (SIW) SYSTEMATIC project[55] of the European Commission. This is in contrast with the results of the National Technology Foresight Exercise which had identified at the time that the local stakeholders did not recognize the importance of new technologies. It should be emphasized that South Africa does not undertake regular foresight exercises and it does not have a formal monitoring mechanism identifying new technologies and informing appropriately the stakeholders. This is an issue that we also discuss in the recommendations section.

6.8 Recommendations

This section advances recommendations for consideration by the dti. The recommendations are guided by the findings in the chapter: Indicators: South Africa and Selected Countries; and the chapter: Technology Support in South Africa.

The report identifies that in contrast to international best practice emphasizing support and development for the high technology industries, these industries are relatively small in South Africa.

As we have elaborated high-technology manufacturing industries include aircraft and spacecraft; pharmaceuticals; office, accounting, and computing machinery; radio, television, and communication equipment; and medical, precision and optical instruments.

Governments all over the world support the development of high technology industries based on the conviction that knowledge- and technology-intensive economies create well-paying jobs, contribute high-value output and ensure economic competitiveness across the economy in general. During 2010, these knowledge- and technology-intensive industries combined contributed just under $18.2 trillion to global economic output—about 30% of world GDP. The above lead to the recommendation **that dti should consider developing programmes supporting the development of high technology industries.**

As the experiences in India, Malaysia, Brazil, USA and elsewhere show, the ICT based sectors (e.g. creative industries) and research and development based sectors can develop best in "science parks" or "corridors". Science parks offer a large number of incentives to qualifying firms (financial and non financial) in order to attract them locally and from abroad and create critical mass and synergies.

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55 Europe Innova (2008) "*Sectoral Innovation Watch: Synthesis Report.*" European Commission Directorate General Enterprise and Industry

Suggested parks that can be considered are: Innovation Hub for ICT and creative industries; Automotive Supplier Park for automotive and transport; Centurion for Aerospace Village for aerospace; Stellenbosch Techno-park for agro-processing; NMMU-CSIR and the under development clusters for textiles and related, the Onderstepoort for pharmaceuticals/animal health and so on.

The parks should offer adequate incentives to attract and support the prioritized industries according to international good practise. Such incentives may include world class competitive IT infrastructure at internationally competitive cost; Uninterrupted electricity at internationally competitive cost; the provision of sector specific R&D and innovation funding; the provision of tax holidays (on application) to international companies with expertise in technologies of national interest; etc.

As we have discussed, firms in different sectors follow different innovation paths and have different needs. For instance, technology users, i.e. firms that use, adapt and modify existing technologies, in sectors such as agro-processing , textiles or the energy industry require different support through technology transfer approaches such as licensing support, commissioned R&D, links with suppliers and competitors, personnel training and others. Firms that carry out R&D as in the ICT sector, digital creative industries, the automotive industry or the chemical industry on the other hand, require innovation support. It is worth repeating here that the country has very few innovation incentives instruments in comparison with the rest of the world.

Following international best practice it is suggested **that dti should develop sector based programmes supporting technology adoption and innovation.** The programmes should be structured according to the particular sector characteristics and needs. Obviously the science park approach can be utilised appropriately for the development of all priority sectors. For sectors exhibiting mutual dependence (e.g. textiles, chemicals and biotechnology; agro-processing and packaging) parks should aim to accommodate such interactions and overlaps. Again existing parks can be focused to areas of priority (e.g. the Stellenbosch Techno-park could support agro-processing) while new parks can be established according to government priorities and industrial clustering. International experience should also guide the local efforts. For example as we discussed in the UK the creative industries have been identified as a priority sector and TSB supports technology developments in areas such as electronics, pervasive computing, modelling and visualization.

In this context it should be mentioned that the dti is already working in developing parks/corridors of various sizes. For example discussions with members of the agro-processing division indicated that the division is already establishing small scale parks by aiming to attract suppliers around large retailers (e.g. Pick and Pay) and creating technology transfer units at Universities (e.g. chocolate production facility at CPUT). Simialrly clusters are set up for textiles (KZN and Cape Town) and related industries.

An additional possible mechanism for the development of sector-based support can be the creation of THRIP based programmes. The cross cutting technologies impacting a multitude of sectors may by prioritized as cost effective. The most important are nanotechnologies for industry (affecting 8 sectors); smart bio-mimetic materials (7 sectors); smart interactive textiles (7 industries) intelligent sensors networks (7 sectors); 3D printing and personal fabrication (6 sectors); industrial biotechnology (6 sectors). As in THRIP it is the industrial participant who identifies and co-funds the project the approach is particularly suited for **the dti**.

Advanced manufacturing[56] based on integrated and synthesised emerging technologies have the potential to change the way the manufacturing industry operates. Harnessed and driven appropriately, it has the potential to create a new manufacturing base competitive internationally.

The President's Council of Advisors on Science and Technology (PCAST)[57] in the USA identified three areas that could lead to such a revolution in manufacturing. "The first area is in design tools that dramatically improve the existing systems engineering, integration, and testing process for complex electromechanical, cyber-physical systems that represent the bulk of manufactured products today—from toasters to automobiles". "The second area would develop manufacturing facilities similar to today's semiconductor foundries. The input would be verified system designs, specified and developed with the design tools above. The systems would be capable of rapid reconfiguration to accommodate a wide range of design variation. Such foundries would compress substantially the time required to go from design to product." "The third area would support generating open-source collaboration environments for the creation of large, complex, cyber-physical systems by numerous affiliated or unaffiliated designers—with the goal of democratizing the design innovation process by engaging a

56 AMT can be described as a group of computer-based technologies, including computer-aided design (CAD), computer numerical control (CNC) machines, direct numerical control (DNC) machines, robotics (RO), flexible manufacturing systems (FMS), automated storage and retrieval system (AS/RS), automated material handling systems (AMHS), automated guided vehicles (AGV), bar coding (BC), rapid prototyping (RP), material requirement planning (MRP), statistical process control (SPC), manufacturing resource planning (MRP II), enterprise resource planning (ERP), activity based costing (ABC), and office automation (OA).

57 PCAST (2011) "*Ensuring American Leadership in Advanced Manufacturing*" President's Council of Advisors on Science and Technology, Washington DC

vastly larger pool of talent than current industry models." PCAST further identified the following technologies requiring support in the above context: advanced robotics, nano-electronics, materials by design and bio-manufacturing.

As individual companies cannot justify the investment required to fully develop such important new technologies or to create the full infrastructure to support advanced manufacturing private investment must be complemented by public investment. In our survey (appendix 1) the commonest mentioned technology was advanced manufacturing technology. Unlike the existing Advanced Manufacturing Strategy/program which have minimal budget and focus in a limited number of sectors we propose that **the dti in consultation with DST should develop and support the South African Advanced Manufacturing Initiative.** The programme will work on a cofounding partnership basis. The dti should solicit relevant proposals from consortia of private and public organisations for the development of technology area with high potential payoff in employment and output. The industrial partners should be prepared to co-invest with the government. Government should further support the development of shared labs, pilot plants, technology infrastructure and creation of clusters. Where necessary, government should offer modest-sized planning grants to support the preparation of such proposals.

As it was mentioned, DST has developed and supported the Advanced Manufacturing Technology Strategy. However, the programme has limited resources and hence, limited impact. During 2013 is expected to spend approximately R 32 million (mainly for UAV and bio processing). For comparison, in the USA the PCAST suggested that the government should invest US$ 1 billion per year.

Biotechnology, pharmaceuticals, nanotechnology and the other key enabling technologies require a balanced approach in the support of the science base and the commercialization efforts. The strength of science base is critical for the success of development of such fields. Vertical policy instruments have been identified as most appropriate for such purposes. Such instruments provide knowledge based support; commercialization facilitation and framework conditions development. Knowledge based support includes development of centers of excellence, programmes for interdisciplinary research and development of students in the disciplines of interest in the relevant industries. Commercialization support includes instruments to build up technological capabilities for industry (creation of research institutes and technology centers of industrial interest, grants for industrial research), instruments to encourage the commercialization of scientific results from public research institutions (spin-off formation in biotechnology, startup companies and establishment of industry-specific public venture funds, establishment of science parks and incubators) and instruments to encourage the collaboration between public and industrial research (research programmes requiring industry involvement). Framework instruments cover regulation tools (e.g. standards, labeling etc), legislation on property rights (legal protection of inventions and share of IPR between scientists and institutions) and measures to assure the availability of financial capital in high growth sectors e.g. establishment of attractive credit market conditions for technology-based firms, venture capital market support, stock exchange markets As we identified, the science base currently is not geared towards high technology industries which require mainly engineers and scientists. **dti should consider, together with DST, the establishment of supporting instruments enlarging the parts of the science base in the disciplines of interest to dti.** The objective should be to double the available expertise in engineering and priority science fields within ten years. Such fields are materials science, computer science, chemistry, and molecular biology. In this context **the dti should aim to get directly involved in the financial support and the management of the science base.**

The patent analysis has identified that South Africa has particular strong capabilities in a number of technologies. These are: "Chemistry: Fisher-Tropsch Process or Purification or Recovery of Products;" "Specialized Metallurgical Processes, Composition for Use Therein, Consolidated Metal Powder Compositions, and Loose Metal Particulate Mixtures"; and "Chemistry of Hydrocarbon Compounds" These strengths should be further supported so they can be maintained and become future assets. In contrast to existing centres of excellence/competence which are focused on research **the dti in collaboration with the relevant sectors should consider the establishment of "Innovation and Knowledge Centres"** (similar to those in the UK).The Centers will aim to bridge the innovation chasm from research to commercialization. They will allow businesses to access equipment and expertise that would otherwise be out of reach and support prototyping, demonstrators and similar at the commercialization end of the innovation chain .Their focus will be to technology areas where South Africa has substantive strengths and it will support mainly process technology development in pilot lines, prototyping, and demonstrators accelerating commercialization. In the same context the newly institutionalised Incubation Support Program of dti could be expanded (financially) and support also development of demonstrators and prototypes.

South Africa does not have an emerging technologies identification mechanism. This creates delays in the establishment of relevant supporting programs; delays in technology transfer; lack of state of the art information in industry (particularly in the technology using industries) and similar. For example, the

USA started funding their nanotechnology programme during 2000. During 2001 there were 30 countries supporting nanotechnology internationally. In South Africa support for nanotechnology started during 2007.

Other countries have institutionalized such bodies to the benefit of their industries. For example, in the USA the Emerging Technologies Committee of the Chamber of Commerce is tasked with creating a positive environment for the long-term development and deployment of new and emerging technologies and for promoting their benefits both domestically and internationally.

The committee advocates for beneficial technology policies through interactions with Congress, the executive branch, and regulatory agencies. Within the Chamber, the committee works in a coordinated manner with the other regulatory committees to ensure that obstacles that are detrimental to long-term technological innovation and deployment are identified and removed and to ensure that beneficial policies are established.

We suggest that **dti should establish a committee for emerging technology identification and support** with the mandate to monitor and assess emerging technologies internationally and locally and undertake their dissemination; promotion and support.