Providing science advice to government in South Africa: Review and proposals

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EXECUTIVE SUMMARY

The National Advisory Council on Innovation (NACI) is a statutory body that advises the Minister of Science and Technology on various matters pertaining to the National System of Innovation (NSI). In 2004 NACI decided that it was necessary to review its own role and mandate and subsequently delivered advice to the Minister in this regard in 2006. One of the recommendations to the Minister was that the entire system by which science advice is delivered to government should be reviewed.

The purpose of this report is to offer proposals that can contribute towards the development of an enhanced structure to provide science advice to government in South Africa. The report is produced by the University of Pretoria, and made available to NACI and other interested parties. This study encompassed research on structures that provide science advice to government in South Africa and abroad. A comprehensive investigation of international practices was undertaken, and is documented in a supplementary report entitled *A review of international bodies that provide scientific advice to government*.

The importance of science, technology and innovation as essential contributors to economic growth and prosperity, competitiveness, quality of life and the social well-being of a country's citizens was again confirmed. It is also evident that the provision of science advice to government is an essential element of any modern national system of innovation, and that South Africa is no exception. It is shown that one of the major functions of providing advice to government, is to enhance the decision making capabilities of policy makers, and that external advice should be viewed as a decision support tool.

It is necessary to ensure that the best practices regarding "good advice" are imbedded in the structures that provide science advice to government in South Africa. In addition to the processes of rendering advice, attention must also be paid to the processes of receiving and acting on advice. It is pointed out that "science advice to government" entails much more than just the "scientific facts". Social, economic, environmental and a host of other implications, including specifically also political implications, must be accounted for. Policy analysis with impact assessment where appropriate, is necessary to convert the scientific facts into decision support.

It is emphasized that there must be clarity about the definitions and interpretations of the terms "science", "innovation", "technology", "advice" and "government". Confusion and misunderstandings in this regard can ultimately lead to flawed and unstable policy.

Within the context of providing "science advice to government", the term "science" spans a very wide spectrum, which includes the natural sciences, technology and innovation in its broadest form. It is noted that "science" is often interpreted to imply the natural sciences, engineering and life sciences. An alternative definition of science pertains more to disciplines where the scientific method is used to advance knowledge, and will then also include the social sciences and humanities. These differences, subtle as they may be, are ultimately reflected in national science policies, technology policies and innovation policies.

Various interpretations of the term “innovation” were subsequently investigated, and a working definition that includes an invention component as well as a market exploitation component is proposed. The invention component includes the creative and idea generation processes as well as research, whereas the market exploitation component includes the wider diffusion of the innovation into the market. The importance of the social sciences and humanities in the innovation process, including technological innovation, is pointed out. Hence the rationale for social scientists to be represented on advisory structures that provide science advice to government.

The term “government” should also be interpreted broadly, and includes the executive, legislative and judicial branches of government on the national, provincial and local levels where appropriate. The resulting government-science space is a vast one. It is clear that no single body can adequately provide “science advice to government”. A constellation of bodies, arranged in a structured system, is therefore required. These can include individuals, standing committees (such as NACI), ad hoc committees, forums, national academies, universities and science councils as well as international organisations.

The government must ensure that it is adequately served with science advice. It must rely not only on its internal centres of expertise, but also on adequate independent external bodies that can provide autonomous science advice to government. A structure, which accommodates these bodies, must be synthesized to ensure that the entire government-science space is adequately covered. This includes science advice to the President, Cabinet and Ministers, as well as the various government departments and the Parliament. The Minister of Science and Technology and the Department of Science and Technology, in particular, must be adequately served with independent and autonomous external advice.

It is pointed out that a national system of innovation is underpinned by an innovation model, either implicitly or explicitly. The perils of the linear model must be guarded against in this regard. The notion of an underlying innovation model, albeit an explicit or implicit one, that determines the construct of a national system of innovation can be extended to rethink the portfolios of Ministers and government departments, i.e. the allocation of portfolios and combinations of portfolios of Ministers and departments can be based on an underlying innovation model. This approach will, if the model is correct, enhance the workings of the NSI significantly.

Public participation in science advice is advisable, with as high a degree of transparency as possible. This will help to allay fears and suspicions regarding science and technology as well as the associated political processes. Appropriate confidentially should of course be respected, particularly where it affects the relationship of trust between the advisory body and the decision maker.

NACI has, during its almost decade of existence, served the Minister of Science and Technology well with advice that addressed a multitude of issues pertaining to numerous aspects of the NSI. The environment in which NACI was conceived more than a decade ago has, however, changed significantly. Whilst it is essential that a statutory body such as NACI advises the government on issues pertaining to the NSI and competitiveness, it is necessary to reposition NACI and revise its mandate to align it with the future needs pertaining to the provision of science advice to government in South Africa. Given the importance of innovation and competitiveness on the one hand, and their cross-cutting natures on the other, consideration should be given towards the establishment of a NACI-like advisory structure that operates at the level of the Presidency or Cabinet. The Minister of Science and Technology should, however, also ensure that s/he is adequately served by independent and autonomous external advice, preferably by a body such as NACI but with a mandate that is closer aligned to the Minister's portfolio. In order to render independent and autonomous advice, the advisory structure(s) serving the Minister should be de-coupled from the Department of Science and Technology.

The lack of policy analysts and related expertise in the country is noted, and it is recommended that capacity be created to not only perform policy analysis but also to train more policy analysts. It is proposed that this function is established at universities. The establishment of an institute that can perform impact assessment is also proposed in this regard.

Although the promotion of innovation is important, the ultimate national goal should be competitiveness. Innovation is a necessary (but not sufficient) condition to attain competitiveness. The development of a national competitiveness policy, with concomitant advisory structures, is proposed.

Chapter 1
Introduction

The purpose of this report is to offer proposals that can contribute towards the development of an enhanced structure to provide science advice to government in South Africa.

Since the publication of the White Paper on Science and Technology in 1996, the environment in which science and technology policy make an impact and influence life in almost all respects, has changed dramatically. There has been a steady advancement of the country's standing in the international arena, an evolvement of the Government's national policies as well as significant changes in the national and international science, technology and innovation domains. Whereas the establishment of the Department of Arts, Culture, Science and Technology (DACST) after the 1994-elections was in itself a new and welcome development in South Africa, its subsequent unbundling led to the establishment of the Department of Science and Technology (DST) in 2002. This paved the way for a more focused national science, technology and innovation strategy. There have also been significant developments with regard to best practices in respect of providing science advice to government, internationally as well as locally. This has contributed to substantial learning from experience from NACI itself as well as from international best practices regarding the nature of providing science advice to government and the nature and structure of such advisory bodies.

The National Advisory Council on Innovation (NACI) is a statutory body that advises the Minister of Science and Technology on aspects relating to the National System of Innovation (NSI). NACI reviewed its own mandate with regard to providing advice to the Minister of Science and Technology, and provided advice to the Minister in this regard in 2006. It found that not only was it necessary to review NACI's role in the NSI, but that it was also necessary to rethink the entire apparatus whereby science advice is provided to government. Given the importance of science, technology and innovation to economic prosperity and growth, competitiveness, the quality of life and the social well-being of the citizenry, and subsequently also the necessity for government to be provided with science advice, it was foreseen that it would be necessary to establish a more structured system and constellation of organisations to provide "science advice to government". This report aims to address this need.

In order to arrive at proposals for an enhanced structure to provide science advice to government in South Africa, it is necessary to explore the notion of "providing science advice to government" in some depth, and then to consider characteristics of organisations and structures that provide science advice to government. It is also necessary to investigate international practices in this regard, and to extract best practices as they may apply to South Africa. This report is accompanied by a supplementary report, which describes international practices with regard to the provision of science advice to government.[1] The supplementary report and its

[1] Sara S. Grobbelaar, *A review of international bodies that provide science advice to government*, University of Pretoria, 2008.

annexure should be read with this one to gain insight into the entire landscape of the provision of science advice to government.

Chapter 2 of this report highlights the importance of science, technology and innovation (STI) as contributors to the country's economic growth and competitiveness as well as its social well-being and the quality of life of its citizens. It is pointed out that it is necessary to manage STI on the national level, and that the National System of Innovation is a well-suited vehicle to accomplish this.

It is evident that in order for the government to manage STI through the NSI, it is essential that it is provided with science advice, and that this advice is then used and applied. Providing "science advice to government" is an essential element of any modern national system of innovation. A structured system for providing science advice to government is however, required.

The nature of science advice is discussed in Chapter 3, within the context of "speaking truth to power". It is pointed out that the main purpose of providing science advice to government is to provide decision support for the decision makers and policy makers. In order to suggest proposals for a new structure to provide science advice to government, it is necessary to explore the terms "science", "advice" and "government" in some detail in this context. This inevitably also leads to a discussion of the definition and interpretation of innovation and competitiveness. Subsequently the notions of science policy, technology policy and innovation policy are also considered. The discussion above provides the backdrop for the challenges regarding the provision of science advice to government. The major role players in the current science advisory structure in South Africa are reviewed in Chapter 4, with an extensive discussion on the National Advisory Council on Innovation (NACI).

Conclusions and recommendations are given in Chapter 5. It needs to be stressed however, that the nature of the discussions in the report and particularly the recommendations and proposals are couched in terms of options and alternatives with an indication of preferred options where appropriate rather than strict and dogmatic directives. This approach was deliberately taken with the knowledge that a new President and Cabinet will be instilled in South Africa in 2009. The new government will most likely implement new policies and possibly new structures. STI policy as well as the best-suited structures to provide science advice to government will then need to aligned within the greater policy framework and government structure. Hence the emphasis in this report is on principles and options.

Even though the main focus of the report is on structures to provide science advice to government, many aspects of the report are actually science advice per se. This is necessary to provide the context of "providing science advice to government", but the science advice may in itself may also be useful.

The recommendations and proposals are based on the premise that the importance of the contributions of science, technology and innovation as well as scientific research is generally accepted, also by the government. It is further assumed that the government considers it important not only to promote these, but that it has an important role and responsibility to manage the National System of Innovation, recognising the role that the various role players (including the industry, science councils and higher education) must play, and that the government has a responsibility and duty to create the space and regulatory environment for them to do so.

The main thrust of the recommendations and proposals is that it is essential for the government to ensure that it is served by quality science advice. In addition to using its own internal centres of expertise, the government *must* ensure that it is also served adequately by autonomous external structures that can provide independent advice on science.

In order to synthesize a new structure to provide science advice to government, it is necessary to consider the contextual meanings, implications and subsequent definitions of the terms “science”, “advice” and “government”, as well as associated terms such as “innovation” and “competitiveness”, very carefully. Ambiguousness and misunderstandings will lead to confusion, overlap and voids and subsequent suboptimum advice, which can ultimately result in flawed or unstable policy.

The point is made that the terms “science” and “government” should be interpreted very broadly. Together they define a conceptual government-science space. The challenge is then to design an appropriate system consisting of a constellation of bodies operating in this space, that together can provide “science advice to government”.

Careful attention should be paid to the question of what the ultimate policy goal is. Is the goal to obtain science success, technology success, innovation success or successful competitiveness? The organisational structures of government, including portfolio responsibilities of Ministers and government departments, should then be aligned with these aims and goals. This line of thinking may suggest alternative portfolio configurations for Ministers and government departments that may differ from the current position, as well as a new approach to cross-cutting and higher level priorities such as innovation and competitiveness. These must all be supported by appropriate autonomous advice structures at the different levels, including structures that provide science advice.

It is clear that not only is there a space but indeed also a necessity for an advisory body such as the National Advisory Council on Innovation. It is also true that the National System of Innovation, the policy environment and South Africa’s international stature has evolved significantly since NACI’s inception a decade ago. There have also been significant advances in scientific and technological developments, as well as in best practices regarding the provision of science advice to government. NACI’s impact can be significantly enhanced by refining its mandate and repositioning it within the new constellation of structures that must provide science advice to government.

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Chapter 2
The importance of "science advice to government"

This chapter provides the contextual background for the discussion on the processes of providing science advice to government. The chapter is introduced by acknowledging and emphasising the importance of science, technology and innovation as drivers of economic growth and prosperity, competitiveness, quality of life and the social well-being of citizens. This is followed by a discussion on the management of science, technology and innovation, particularly on the national level as it is manifested in the notion of a National System of Innovation as a policy vehicle. The concept of providing "science advice to government" is then introduced, emphasising its importance as an essential element of any modern national system of innovation.

2.1 Science, technology and innovation as drivers of economic growth, competitiveness and quality of life

The importance of science, technology and innovation (STI) as drivers of economic growth, competitiveness as well as major contributors to the quality of life, are generally acknowledged and accepted as a premise of this report. The quality of life issues include those pertaining to health, social well-being and the alleviation of poverty, safety and security, education and the environment. In fact, a nation's standard of living is one of the most significant indicators of its economic performance[2]. In the African context, a recent report on achievement of the Millennium Development Goals emphasises the contribution of science, technology and innovation towards these goals[3].

Alan Greenspan, a former Chairman of the Federal Reserve in the USA, noted that at least 70% of the growth in the United States' Gross Domestic Product (GDP) in the latter half of the 20th century can be directly attributed to the implementation of new technology[4]. In an interesting analysis entitled *The Innovation Premium*, Jonash and Sommerlatte note that "Wall Street places a higher value on innovation than on any other approach to generating bottom- and top-line growth….More than a change of leadership, more than a merger or an acquisition, more than a renewed commitment to cost reduction, investors consistently reward – and pay a premium for – innovation. We call this the *innovation premium*"[5]. They find that there is strong evidence of the innovation premium in every industry. Kash remarks that "The changing character of technology and, specifically, technological innovation has become the strongest engine driving society[6]". On a national level, countries must

2 Michael Borrus and Jay Stowsky, "Technology policy and economic growth" in *Investing in Innovation*, Lewis M. Branscomb and James H. Keller (eds), MIT Press, 1999.
3 Calestous Juma and Lee Yee-Cheong (coordinators), *Innovation: Applying knowledge in development*, UN Millennium Project Task Force on Science, Technology and Innovation 2005, Earthscan, London.
4 D. Alan Bromley, "Technology Policy", *Technology in Society*, Vol 26, 2004, pp. 455-468.
5 Ronald S. Jonash and Tom Sommerlatte, *The Innovation Premium*, Perseus Publishing, 1999.
6 E. Kash, *Perpetual Innovation*, Basic Books, 1989.

also find ways to exploit the innovation premium. This is what the national systems of innovation and associated innovation strategies must do.

The importance of science, technology and innovation are also well recognised in South African public policy. The South African White Paper on Science and Technology of 1996 laid the foundation for much of South Africa's subsequent science and technology policy development[7]. Not only is the importance of science and technology per se stressed in the White Paper, but particularly also the importance of innovation. In his introductory remarks in the White Paper, the then Minister of Arts, Culture, Science and Technology, Dr Ben Ngubane, noted that, "Science and Technology (S&T) are essential components of the government's strategy for creating the South Africa of the future. The importance of S&T is recognised outside government as well, by other political parties, by business, the higher education sector, the science councils, labour, NGOs and civil society…The vision for South African Science and Technology presented in this White Paper …is one where, on the one hand, South Africa uses S&T to become economically competitive on a global scale, and on the other hand to provide essential services, infrastructure and effective health care for all South Africans. We believe that this is best done by embedding our S&T strategies within a larger drive towards achieving a winning National System of Innovation. In such a System, institutions such as universities, technikons, science councils, private sector research laboratories and market intelligence divisions would cooperate in a nationally optimal way towards solving real problems, whether these occur in industry, agriculture, defence or basic research". The White Paper stresses that, "Innovation has become a crucial survival issue. A society that pursues well-being and prosperity for its members can no longer treat it as an option…Government therefore needs to work hard at creating an environment that is supportive of innovation".

In order to foster and stimulate innovation, the concept of a National System of Innovation (NSI) was introduced in the White Paper, where it is noted that, "…The stimulation of a national system of innovation will be central to the empowerment of all South Africans as they seek to achieve social, political, economic and environmental goals. The development of innovative ideas, products, institutional arrangements and processes will enable the country to address more effectively the needs and aspirations of its citizens This is particularly important within the context of the demands of global economic competitiveness, sustainable development and equity considerations related to the legacies of our past. A well-managed and properly functioning national system of innovation will make it possible for all South Africans to enjoy the economic, socio-political and intellectual benefits of science and technology….Thus, a national system of innovation can only be judged as healthy if the knowledge, technologies, products and processes produced by the national system of science, engineering and technology have been converted into increased wealth, by industry and business, and into an improved quality of life for all members of society… A well-managed and properly functioning national system of

[7] Department of Arts, Culture, Science and Technology, *White Paper on Science and Technology – Preparing for the 21st Century*, 4 September 1996.
http://www.dst.gov.za/publications-policies/legislation/white_papers/Science_Technology_White_Paper.pdf

innovation will make it possible for all South Africans to enjoy the economic, socio-political and intellectual benefits of science and technology."

On the national level, the notion of a National System of Innovation (NSI) is certainly a useful concept and also one that is used as such in the South African context, as was pointed out above. In an NSI, the various institutions that must play their roles, such as universities, science councils as well as industry and industrial laboratories and the various governmental departments and agencies, are important elements. Equally important are the contributions with regard to national education, economic development, competitiveness, quality of life, financial and physical infrastructure, the intellectual property regime and competition environments as well as social welfare and health. In the current time frame in South Africa, human resources and skills availability have become critical components of the NSI. The linkages between the various role players, domestic as well as internationally, are significant characteristics of any NSI.

It will be shown that the system of providing scientific advice to government is also an essential element of any modern NSI. In order to put the concept of "science advice to government" into perspective, it is necessary to first explore the concepts of science, technology and innovation (STI) as well as those of associated science policy, technology policy and innovation policy. These are the policy issues that the government must be advised on, and hence an understanding of these policies is required in order to appreciate the required advisory functions and structures that must support them.

Twelve years after the publication of the White Paper on Science and Technology, the recognition of the national importance of STI remains current. In the Department of Science and Technology's (DST) recent *Ten-Year Innovation Plan*, the Minister of Science and Technology, Mr Mosibudi Mangena, notes that "…Knowing that the level of economic growth envisaged by our country requires continual advances in technological innovation and the production of new knowledge, and in our common determination to build a better world, we are strengthening our role in the development and growth of South Africa"[8].

Innovation, though, is not an end in itself, but rather a necessary contributor towards economic growth, an increased quality of life and an enhanced national competitiveness. It is important that the importance of competitiveness and the competitiveness-innovation link be recognised in this regard. Harvard professor Michael Porter points out that the "…competitiveness of nation depends on the capacity of its industries to innovate"[9].

2.2 The management of science, technology and innovation on the national level

The impact of science, technology and innovation on nations, institutions and individuals span a very wide spectrum, and affects practically all aspects of life, be it

[8] Department of Science and Technology, *Ten-Year Innovation Plan*, 2008.
[9] Michael E. Porter, *The Competitive Advantage of Nations*, Macmillan Press, 1990.

on the national, organisational or personal level. In all these environments decisions in which science, technology and innovation feature prominently, are taken daily, explicitly and implicitly. These decisions do, by their very nature and as argued earlier, have significant impact on economic growth and prosperity, competitiveness as well as quality of life. It is evident that, given the omnipresent role, importance and impact of science, technology and innovation, the government has a mandate, duty and responsibility to govern and regulate STI on the national level. In contemporary policy parlance, science, technology and innovation must be *managed*. An important aim of the management of technology on the national level is the creation of physical, regulatory and intellectual infrastructure as well as an enabling policy environment to empower the various institutions that play their roles in the National System of Innovation to make their contributions.

The practice and disciplines of the *management of technology and innovation* on the institutional, organisational and national levels are recognised globally. It is an accepted academic discipline, and many universities world-wide offer programmes in technology and innovation management, focusing on the organisational as well as the national level. Just as companies must manage their STI, in an analogous manner, so must states also manage science, technology and innovation on a national level[10]. South Africa is no exception.

The existence of a national Department of Science and Technology (DST) in South Africa and the general use of the concept of the “National System of Innovation” (NSI) [11] are evidence of an acknowledgement that STI are not only important, but must be managed on a national level. STI related strategies and policies originating from the DST (and DACST[12] before it) date from the *White Paper on Science and Technology* referred to above (*Preparing for the 21st Century*, 1996), through the *National Research and Technology Foresight* (1999) and the *National Research and Development Strategy* (2002) to the DST’s recent *Ten-Year Innovation Plan* (2008). There have also been and continues to be numerous other STI-related initiatives, including for example bills and acts relating to tax breaks for research and development, the regulation of the exploitation of intellectual property, an agency to promote the commercialisation of research, a space agency and even an outer space policy.

From a governmental viewpoint, STI are however, certainly not limited to the domain of the DST. In fact, one can hardly imagine one government department in which STI does not feature in one way or another. Examples abound in the Departments of Trade and Industry, Health, Agriculture, Education, Defence, Environment, Water Affairs and Communications. Many government departments have published STI-related policies, strategies and legislation. In fact, the National R&D Strategy of

[10] See for example Lewis M. Branscomb and James H. Keller, *Investing in Innovation*, MIT Press, 1999 and Richard R. Nelson (ed), *National Innovation Systems*, Oxford University Press, 1993.
[11] OECD, “OECD Reviews of Innovation Policy: South Africa”, 2007.
[12] The Department of Arts, Culture, Science and Technology was established in 1994. It was unbundled in July 2002 when the Department of Science and Technology (DST) and the Department of Arts and Culture (DAC) became two separate departments.

2002[13] notes that "From a budget perspective there is no holistic view of science and technology spending by the government…The fragmented management, frozen institutional arrangements and funding structures for government-led science and technology does not provide the right platform for leadership and strategic response in this domain. A range of technology-intensive institutions and programmes are currently being driven by different government departments with very little coordination in strategy or sharing of learning". It should be noted that progress in addressing these deficiencies noted in the National R&D Strategy has since been made, much of which can be attributed to the efforts of the DST.

Current examples of national science and technology-related programmes and policies that are driven by departments other than the DST include the eNATIS transportation system, programmes to combat AIDS, malaria and tuberculosis, environmental issues, defence procurement, strategies to address the energy crisis, telecommunications and the issuance of licenses for service providers, internet in schools, transport infrastructure in the country, the Gautrain, science parks, the SALT telescope and the Pebble Bed Modular reactor (PBMR) to name but a few. It is notable that *South Africa's National Research and Development Strategy* was prepared by the "Government of South Africa", rather than by a specific department (although the Minister of Science and Technology's foreword and his Department's address are given). STI policy also impacts on South Africa's international relations. Many of the country's international treaties impact on science and technology. There are also a number of international cooperation programmes, such as the *Cooperation Framework on Innovation Systems between Finland and South Africa* (COFISA).

The government's mechanisms for managing science, technology and innovation (STI) are typically manifested in policies. In a later section the differences between science policy, technology policy, research and development policy, innovation policy and industrial policy and are discussed. The delivery of "science advice to government" pertains very strongly to these policies, and hence it is necessary to explore the nature of these policies in more detail in order to appreciate the issues regarding advisory structures. It will be shown that it is important to emphasize the differences between these various policies, since misunderstandings can lead to confusion and flawed policy.

2.3 Providing "science advice to government"

Science and technology-related policies cannot be formulated in a scientific vacuum. It is essential that the government must ensure that its science, technology and innovation-related policies and decisions are based on scientific facts and truths, technological feasibilities and innovative realities. The natural sciences are governed by Mother Nature, and although she is generous in sharing the fruits of her secrets for the benefit of humanity to those who have the determination, capability and knowledge to uncover them, she is also unforgiving towards those who transgress her laws. They are absolute and universal, and not open to a debate between

[13] Government of South Africa, *South Africa's National Research and Development Strategy*, August 2002.

Mother Nature and mortal human beings. This is one of the fundamental differences between the natural sciences and the social sciences. The laws of nature are not constructed or mandated by humans, nor are they subordinate to the norms of a particular society or culture. The latter are often characteristic of the humanities and social sciences.

In developing STI-related policies, the government therefore has a duty to ensure that it relies on the best *scientific* advice. Hence, it is important therefore to explore the implications of the notion of "best advice" within the context of providing "science advice to government". It will be argued in a later section, however, that what is needed is in fact not only advice relating to the "scientific" aspects of a matter at hand, but rather an interpretation and analysis within broader societal contexts in order to provide decision support for the policy maker. These include social, economic, environmental and also political perspectives.

The notion of "government" in this context will also be explored in more detail in a later section, but suffice it to say here that the "government" is ultimately composed of individuals (even if they may work in smaller or larger groups or committees), some of whom are politicians and others officials and bureaucrats. All of them are not necessarily scientists and engineers however, and even those that are, will normally only command expertise in a relatively narrow field. From this perspective, a case can therefore also be made that government cannot and should not rely only on its own internal and in-house expertise, but *must* be served by external and independent science advice.

A recent report by the Federation of American Scientists[14] notes that,

> "The need for effective science and technology advice continues to increase while the infrastructure for providing such help is in a state of crisis…While technical analysis is almost never sufficient to make wise choices, absent competent, timely, targeted scientific and technical analysis, these decisions will depend on unchallenged assertions by special interests and ideologues. Programs are likely to be poorly designed and subject to costly mistakes. Even worse, lacking competent advice, the nation may fail to act on problems until they are costly and difficult to solve or fail to seize important opportunities to achieve public objectives in security, education, health care, the environment, or other critical areas…
>
> …Most public policies and political decisions depend at least in part on some scientific or technical analysis, whether the allocation of publicly-owned spectrum, voting technology, the risks of climate change, debates over intelligence on weapons of mass destruction, or the ethics of reproductive research. While there are few cases where technical analysis alone is adequate for making a decision, almost all participants in these debates recognize or at least have to publicly agree, that complex decisions are improved if they are informed by sound scientific

[14] Henry Kelly et al, *Flying Blind: The rise, fall and possible resurrection of science policy advice in the United States*, Federation of American Scientists, Occasional Paper No. 2, December 2004.

> and technical analysis. This is often a difficult process. Differing perspectives result in different weights to risks, costs, and benefits in any decision and resolving those differences is, naturally, a large part of any healthy political debate in a free society".

Quibbling with Mother Nature…

An example from the United Stated illustrates the follies that can result when the scientific facts are ignored, or discarded as in the case below, when making public policy.

The mathematical constant π is equal to the circumference of a circle divided by its diameter. The value of π is well known, and is equal to 3.14159265….It is a universal constant, with an infinite number of digits.

In 1897 Representative T.I. Record introduced House Bill No 246 in the House of Representatives in the State of Indiana. The bill suggested three different numbers for the mathematical constant π, one of these being 3.2, but none the true value mentioned above[15]. The Bill was first sent to the Committee on Swamp Lands, who referred it to the Committee on Education. This committee "passed" the bill and sent it to the House, where it was approved unanimously with a vote of 67-0. The bill was then sent to the State Senate, where it was referred to the Committee on Temperance. It passed a first reading, but (luckily) went no further.

It is said that Professor C.A. Waldo of Purdue University, who happened to be passing through, intervened in the Senate proceedings. When asked if he would like to be introduced to the author of the bill, he purportedly declined, noting that he was acquainted with as many crazy people as he cared to know. The bill subsequently died a quiet death, and the people of Indiana were spared the embarrassment of quibbling with Mother Nature about the validity of her laws. A local newspaper was said to report that, "Although the bill was not acted on favourably, no one who spoke against it intimated that there was anything wrong with the theories it advances. All of the Senators who spoke on the bill admitted that they were ignorant of the merits of the proposition…".

The example above is a trivial one, but it demonstrates the principle of the importance of providing science advice to government.

In the preface of a report on science advice in the United Nations system, it is noted that,

> "In the international effort to advance human health, welfare and development while better managing and conserving the environment and natural resources, there is a clear and growing recognition of the role of scientific and technical knowledge in global governance. This has created an urgent need for the United Nations to equip itself with the capability to bring scientific knowledge to inform international decision-

[15] M. Granger Morgan and Jon M. Peha (eds), *Science and Technology Advice for Congress*, p.9, referring to the website *The Straight Dope* (http://www.straightdope.com/classics/a3_341.html)

> making. The failure to do so could reduce the ability of the United Nations to continue to be a credible player in international diplomacy….Carrying out this task requires the continuous access to scientific and technical information, which can be provided in the form of 'science advice'"[16].

As part of the research that supports this study, an extensive study of science advisory structures around the world was done. A discussion of these findings is presented in the supplementary report[17] accompanying this one. The supplementary report relies heavily on a study of the science advisory structures that advise the governments of 20 European countries. It provides a very useful overview of international practice with regard to "science advice to government". It is very clear that the necessity of providing "science advice to government" is accepted globally as an essential component of the public policy process. It is inconceivable that a modern national system of innovation can function properly without an adequate national science advisory structure. There is general agreement amongst science, technology and innovation policy specialists world-wide that governments must ensure that they have adequate and relevant scientific advisory bodies in place to advise them on various aspects of science[18].

As an example to illustrate this point, consider an analysis of China's science and technology policy which concludes that,

> "In the market economies of industrialized countries, scientific research and technological development are widely distributed between the public and private sectors, among government institutions, universities, and the enterprises. This has led governments to seek advice on new policy directions from people engaged at these different kinds of institutions, as input to decision-making, which remains the prerogative of government. Each government has institutionalized the process of advice-receiving in a form appropriate to its system, but all the systems share in common the idea that senior political leaders should be able to receive such direct inputs to their work. As China's socialist market economy evolves, the Government of China should give thought to how it can tap into the growing experience of enterprises, universities, and R&D institutes as it

[16] National Research Council, *Knowledge and Diplomacy, Science Advice in the United Nations System*, The National Academies Press, Washington DC, 2002.

[17] Sara S. Grobbelaar, *A review of the international bodies that provide science advice to Government*, University of Pretoria, 2008.

[18] See for example: M. Granger Morgan and Jon M. Peha (eds), *Science and Technology Advice for Congress*, Resources for the Future (RFF Press), Washington DC, 2003; Calestous Juma and Lee Yee-Cheong (coordinators), *Innovation: Applying knowledge in development*, UN Millennium Project Task Force on Science, Technology and Innovation 2005, Earthscan, London; Government of Canada, *A Framework for Science and Technology Advice: Principles and guidelines for the effective use of science and technology advice in government decision-making*, Industry Canada, Ottawa, 2000 (Cat No. C2-500/2000); Jerry Ravetz, "Science advice in the knowledge economy", *Science and Public Policy*, October 2001, pp. 389-393; Albert Weale, "Science advice, democratic responsiveness and public policy", *Science and Public Policy*, December 2001, pp. 413-421; Pawan Sikka, "Science advice in India", *Technology in Society*, Vol 17, No 4, 1995, pp. 349-363.

continues to evolve policies for the promotion of innovation and technological change in the light of the ever-changing global economic system"[19].

The necessity of having a structured system whereby "science advice is provided to government" is certainly also true for South Africa[20]. This notion was also emphasised in the White Paper on Science and Technology (1996), where it is stated that "Government has a constant need for informed advice about the problems and opportunities facing our country, and in no area is this more true than in the concern for the stimulation of innovation in the pursuit of our national vision". The White Paper then continues to envision a body that later became the National Advisory Council on Innovation (NACI). NACI, its mandate as well as current and future roles are discussed in more detail in later sections.

The recent OECD report on the South African National System of Innovation (2007) also refers to the necessity of the science advice function[21]. The report notes inter alia, that "…There needs to be an extramural market for analysis and policy advice in order to provide criticism, ensure the openness needed in a democracy and provide capacity that ministries and agencies cannot afford to maintain in-house".

2.4 Summary

In this chapter the importance of science, technology and innovation as drivers of a nation's economy and competitiveness as well as major contributors to the quality of life and social well-being of its citizens were highlighted. Government has a duty and responsibility to manage STI on a national level, and does so through various STI-related policies. These policies must be supported by scientific facts, technological feasibilities and innovative realities. In the development and execution of the STI-related policies, the government must be served by appropriate advice. "Science advice to government" must not only account for the scientific facts, technological feasibilities and innovative realities, but must be analysed and interpreted in a broader societal context in order to provide appropriate decision support to the policy maker.

The question is thus not whether there should be scientific advisory bodies that advise the government, but rather how the constellation of such bodies should be constructed and what their mandate, role and structure should be.

[19] International Development Research Centre (IDRC) of Canada and the State Science and Technology Commission of the People's Republic of China, *A decade of reform, Science and technology policy in China*, IRDC, 1997.

[20] The matter was deliberated extensively during the *ASSAf Double Symposium on Evidence-based practice: Problems, possibilities and politics*, Pretoria, 3 March 2006.

[21] OECD, "OECD Reviews of Innovation Policy: South Africa", 2007.

Chapter 3

The nature of "science advice to government"

An understanding of the dynamics, elements and organisational characteristics of the process of "providing science advice to government" is necessary to participate in a discourse on the development of a future structure to provide science advice to the South African government. This chapter provides the theoretical background to put the discussion in context.

The concept of providing "science advice to government" is often referred to in terms of "speaking truth to power", and this line of argument is used as an introductory section. It is then shown that science advice to government should be considered in terms of its value in providing decision support for policy makers. Aspects of decision making and decision support are explored in order to better appreciate this aspect of science advice.

In the previous chapters the importance of clarity regarding the terms "science", "advice" and "government", as well as associated terms and concepts such as "technology", "innovation" and "competitiveness", and also the associated policies, including science policy, technology policy, innovation policy, competitiveness policy and industrial policy, were emphasised. This chapter explores these concepts in some detail. This is not merely an academic semantical indulgence. In order to synthesise a structure that can provide science advice to government, it is necessary to have a clear and concise vision of the nature of the advice that is to be provided and also to whom it should be rendered. It will be shown that the government-science space is a vast one, and that a constellation of bodies and organisations is necessary to cover the space. On the one hand it is necessary to ensure that there is no unnecessary overlap and on the other hand "white spaces", i.e. areas that are not addressed by advisory bodies, should be avoided. A substantial discussion on the meanings and implications of the terms "science", "advice" and "government" as well as "innovation" and "competitiveness" and the associated policies is therefore presented.

3.1 Speaking "truth to power"

In the previous chapter the necessity of the principle of providing "science advice to government" was discussed. The point was made that this is a necessary component of any modern national system of innovation.

The goal of this study is to explore future structures to provide scientific advice to the government in South Africa. In order to make recommendations for such a system, the nature and dynamics of the process of providing "science advice to government" must be explored and understood in some detail. This in turn, requires an analysis of the advice process and specifically the components "science", "advice" and "government". In order to do this, it is useful to interpret the process of "providing science advice to government" as a decision support instrument for policy making, specifically on STI-related policies. It is important that there is clarity about the nature of the various types of policies, their purposes and characteristics. Confusion and lack of clarity regarding the nature of advice that should be rendered will lead to suboptimum advice, which can in turn lead to confused, ineffective and unstable policy. In order to synthesize a future structure for science advice to government, it is therefore important to ensure that there is agreement on the terms "science" and "government" in this context, as well as the terms "technology" and "innovation".

In discussing progress towards achieving the Millennium Goals, the authors of a report sponsored by the UN Millennium Project, Task Force on Science, Technology and Innovation[22] note that,

> "Advice on science, technology and innovation needs to reach policy makers. For this to happen, an institutional framework needs to be created and commitment needs to be garnered to support it…Advisory structures differ across countries. In many countries science advisors report to the president or prime minister and national scientific and engineering academies provide political leaders with advice.
>
> Whatever structure is adopted, the advising function should have some statutory, legislative, or jurisdictional mandate to advise the highest levels of government. It should have its own operating budget and a budget for funding policy research. The advisor should have access to good and credible scientific or technical information from the government, national academies and international networks. The advisory processes should be accountable to the public and be able to gauge public opinion about science, technology and innovation.
>
> …Science, technology, engineering, medicine and agriculture academies can play important roles in providing advice to governments.
>
> …Successful implementation of science, technology, and innovation policy requires civil servants with the capacity for policy analysis – capacity that most civil servants lack…Training diplomats and negotiators in science and technology can increase their capacity to handle technological issues in international forums".

The process of providing science advice to government is often referred to as "speaking truth to power", implying that the scientists that give the advice are conveying the clinical scientific facts (the "truth") to the government (the "power"). The realities of the process are, however, much more complicated. Lewis Branscomb, a former professor at the Kennedy School of Government at Harvard University, former chair of the National Science Board and advisor to the USA Congress and Presidents notes that, "It is an illusion that the legitimacy of scientific expertise rests on the idea that 'truth speaks to power'. No one has better expressed the scepticism with which politicians view the demands of experts for a hearing than Lord Salisbury, Prime Minister of England in 1885-92 and 1895-1902. 'No one seems to be so deeply inculcated by expertise of life as that you should trust experts', wrote Lord Salisbury. 'If you believe doctors, nothing is wholesome; if you

[22] Calestous Juma and Lee Yee-Cheong (Lead authors and coordinators), *Innovation: Applying the knowledge in development*, UN Millennium Project, Task Force on Science, Technology and Innovation, Earthscan, London, 2005.

believe theologians, nothing is innocent; if you believe soldiers, nothing is safe'. Nevertheless, scientists cannot influence policy in constructive ways if their advice is not sought. Science advising puts both one's idealism and one's practical knowledge to the test".[23]

The UN report on science advice in the United Nations quoted earlier notes further that, "A science advisor cannot be one individual who 'tells truth to power', in part because no imaginable science advisor can possess more than a small part of the knowledge that is relevant to most complex scientific questions. The role of the advisor is to serve as a link between decision makers and the scientific community. The science advisor's key value is the ability to know how science works, and to be known and trusted in the scientific community to ensure that the process of science advice involves a broad perspective and produces the best balanced advice possible, with explicit explanation of its uncertainties and remaining unknowns".[24]

A Canadian report in support of the work of the Council of Science and Technology Advisors[25] concludes that politicians as well as the general public have become increasingly less confident of the scientific advice they receive, and hence question the "truth" spoken to them. The report notes that "The undermining of the positive model of science as 'truth' and a source of certified, neutral knowledge, uncorrupted by the influence of politics has tended to further isolate the two groups" [scientists and policy decision makers].

Although the principle of providing "science advice to government" is a simple one, it practical realities are complicated. It is obviously not merely a simple matter of "speaking truth to power". In order to synthesize a structure of scientific advice for the nation, it is necessary to understand the basic reasons why scientific advice is essential, specifically as it pertains to decision support, and then to analyse what is implied by the various terms in the phrase "science advice for government". As was mentioned above, a failure to do so, can easily lead to a dysfunctional or at least underperforming system, that can be prone to either flawed advice and/or policy areas that are not addressed by any advisory structures.

3.2 Decisions and decision support – the role of science advice in policy formulation

The formulation and execution of public policy are essentially processes of making and implementing decisions. The basis of good advice is to support these decision-making processes, viz. to be decision support instruments. Recall the quote from the report on science advice in the UN system and its reference to the "capability to bring scientific knowledge to inform international decision-making". In order to ultimately arrive at recommendations regarding a science advisory infrastructure for

[23] Lewis M. Branscomb, *Confessions of a Technophile*, American Institute of Physics, 1995.
[24] National Research Council, "Knowledge and Diplomacy, Science Advice in the United Nations System", The National Academies Press, Washington DC, 2002.
[25] William Smith and Janet Halliwell, *Principles and Practices for Using Scientific Advice in Government Decision-making: International Best Practices*, Report on the S&T Strategy Directorate, Industry Canada, January 1999.

the country, it is therefore necessary to consider aspects of good advice as they pertain to decisions and decision support, including a number of core principles of decisions and decision-making.

Decisions are manifestations of choices that have been made, often selecting amongst or combining various priorities. In order to make decisions, the decision maker must avail him or herself of information pertaining to the issue. Such information can include various forms of knowledge and background information, including facts and opinions, constraints and boundary conditions as well as assumptions. Very often decisions must be made under more or lesser degrees of uncertainty, either about prevailing conditions or the future. In the latter case, it is necessary to anticipate the impact and consequences, as was discussed in a previous section. Probability, risk, and risk management therefore also enter into the domain of issues that the decision maker must take into account, and on which advice must be provided.

Defining the right problem and asking the right questions are key towards arriving at a solution or "answer". The nature of complex problems is, however, such that there is usually not "one right answer". Various options and alternatives must therefore be investigated, all within context. One is typically confronted between better solutions and worst-case scenarios, where decisions usually involve compromises and trade-offs. Once plans have been made, the decisions must be executed. This in turn, leads to another set of decisions, typically made by those to whom the execution of the decision has been delegated.

The *process* whereby decisions are made is clearly an important but certainly not a trivial one. Much has been written about decision-making and the associated processes[26]. This includes analyses of good practices as well as analyses of where decision-making goes wrong. In an analysis of why decisions fail, Nutt, for example, mentions three blunders and seven traps that often occur[27]. The typical blunders are described as using failure-prone processes, premature commitments and wrong-headed investments. The traps, on the other hand, are described as a failure to reconcile claims, a failure to manage forces stirred up by a decision, ambiguous directions, limited search and no innovation, misuse of evaluation, ignoring ethical questions and a failure to learn. He concludes that "Failure can be directly linked to the actions of decision makers. Forces beyond the decision maker's control, such as changes in customer tastes, budget cuts, and the like, can also prompt failure, but the practices followed to make a decision are the most important determinants of success…Decision makers are prone to using tactics with poor track records, applying them in two-thirds of their decisions. Success will increase as much as 50 percent if better tactics are used". These are all areas on which advice can and should be provided.

[26] See for example, James Parkin, *Management decisions for engineers*, Thomas Telford, 1996; Jack Byrd Jr and L. Ted Moore, *Decision models for management*, McGraw-Hill, 1982; Rossall J. Johnson, *Executive Decisions*, 3rd Ed, South-Western Publishing, 1976; Luda Kopeikina, *The right decision every time*, Pearson Prentice Hall, 2005.

[27] Paul C. Nutt, *Why decisions fail*, Berret-Koehler, 2002; Luda Kopeikina, *The right decision every time*, Pearson Prentice Hall, 2005.

Given the complexities that decision makers face when making (or not making) decisions – either in making or executing policies - it is essential that they utilise all the decision support available to them. Decision support tools include processes to stimulate creativity, a wide variety of computer simulations and modelling tools, various processes for investigating and evaluating options and alternatives as well as a range of appropriate risk management strategies. The use of independent advice is one tool that can also be used as to support and enhance decision-making. There is a wide body of literature and experience regarding the nature of advice in this regard, including not only the scope, nature and processes of giving advice, but also on taking advice[28].

The necessity of government to make decisions regarding science, technology and innovation, particularly as it is manifested in policy, was discussed above. The decision can, for example, be to make or change a policy. In other cases decisions that pertain to content of the policy itself must be made. Alternatively, the decision can be that no action or intervention from the government is required. Very often the decisions relate to the allocation of resources, and the priorities associated with that. As in all such decisions, *decision support* is also required. In the case where decisions refer to the making of national science, technology and innovation policy, "science advice to government" is commonly regarded as an essential element of decision support, rather than a "nice to have" or an optional extra.

In addition to the scientific and technical aspects, a decision regarding science and technology taken by policy makers and politicians must usually account for a variety of facets. The economic, social, health, safety and environmental aspects as well as the political aspects are but some of the issues that must be taken into consideration, as was discussed in Section 2.3. The "science advice" must, in the ideal case, not only account for all of these aspects, but also their interactions. Very often, compromises must be made in order to balance various interests.

In order to enhance the decision-making capability of the receiver of the advice, it is also necessary to explore options and alternatives, highlighting the pros and cons of each, as well as their possible implications, consequences and impacts. The policy aspects of science, technology and innovation therefore also include the area of *impact assessment*, where the direct and obvious as well as the indirect, unintended and delayed impact of science and technology on a variety of areas such as economic, social, ecological and health, are assessed[29]. This can be done in the scientific and technological, social, cultural, behavioural, health, economic, environmental, political and related arenas. In this regard impact assessment is closely related to the assessment of risks. Foresight exercises, of the type that was conducted in South Africa a number of years ago, also assess emerging technologies. This is typically done with regard to their potential impact on society as well as their potential for commercial exploitation.

[28] See for example Dan Ciampa, *Taking advice, How leaders get good counsel and use it wisely*, Harvard Business School Press, 2006.
[29] See for example R. Smits and J. Leyten, *Technology Assessment*, Kerckebosch BV – Zeist, 1991.

Technology assessment is a class of policy studies which systematically examine the effects on society that may occur when a technology is introduced, extended, modified or discontinued[30]. Braun defines technology assessment as "a systematic attempt to foresee the consequences of introducing a particular technology in all spheres it is likely to interact with"[31]. The type of assessments referred to above are known as *impact assessment*.

The importance of impact assessment, particularly with regard to providing science advice to government, is underscored by the fact that the US Congress was served by an agency known as the *Office of Technology Assessment* (OTA) during the period 1972 until 1995[32]. The United States' *Technology Assessment Act of 1972* determines in Section 2 that, "…The Congress hereby finds and declares that:

(a) As technology continues to change and expand rapidly, its applications are –
   1. large and growing in scale; and
   2. increasingly extensively, pervasive and critical in their impact, beneficial and adverse, on the natural and social environment.

(b) Therefore, it is essential that, to the fullest extent possible, the consequences of technological applications be anticipated, understood, and considered in determination of public policy on existing and emerging national problems.

(c) The Congress further finds that:
   1. the Federal agencies presently responsible directly to the Congress are not designed to provide the Legislative Branch with adequate and timely information, independently developed to the potential impact of technological applications; and
   2. the present mechanisms of the Congress do not and are not designed to provide the Legislative Branch with such information.

(d) Accordingly, it is necessary for the Congress to –
   1. equip itself with new and effective means for securing competent, unbiased information concerning the physical, biological, economic, social, and political effects of such applications; and
   2. utilize this information, whenever appropriate, as one factor in the legislative assessment of matters pending before the Congress, particularly in those instances where the Federal Government may be called upon to consider support for, or management or regulation of, technological applications".

Section 3 of the *Technology Assessment Act of 1972* defines inter alia the scope of the OTA's work in paragraph (c) as follows,

> "The basic function of the Office shall be to provide early indications of the probable beneficial and adverse impacts of the applications of

[30] A.L. Porter et al, *Forecasting and Management of Technology*, John Wiley and Sons, 1991.

[31] Ernest Braun, *Technology in Context, Technology Assessment for Managers*, Routledge, 1998.

[32] Robert M. Margolis and David H. Guston, "The origins, accomplishments, and demise of the Office of Technology Assessment" in *Science and Technology Advice for Congress* by M. Granger Morgan and Jon M. Peha (eds), RFF Press, 2003.

technology and to develop other coordinate information which may assist the Congress. In carrying out such function, the Office shall:

1. identify existing or probable impacts of technology or technological programs;
2. where possible, ascertain cause-and-effect relationships;
3. identify alternative technological methods of implementing specific programs;
4. identify alternative programs for achieving requisite goals;
5. make estimates and comparisons of the impacts of alternative methods and programs;
6. present findings of completed analyses to the appropriate legislative authorities;
7. identify areas where additional research or data collection is required to provide adequate support for the assessments and estimates described in paragraphs (1) through (5) of this subsection".

It should be noted that the OTA supported the legislative branch of the US government, i.e. the Congress, and not the executive branch. This principle is discussed again in some detail later. It is interesting to compare the OTA's mandate with that of the National Advisory Council on Innovation (NACI), described in more detail in Section 4.3 as well as Appendix A. A case can be made that South Africa also needs an assessment capability that can serve the national needs in this regard.

The provision of decision support necessitates the availability of not only scientific knowledge and the "scientific facts", but also for an interpretation that converts or "translates" the data, facts and information pertaining to a number of different perspectives (including economic, social, health, safety and environmental in addition to the scientific and technological) into relevant and appropriate knowledge and ultimately decision support. This function is known as *policy analysis*, and is as essential in the formulation of policy as it is in the rendering of policy advice. Policies are usually political in nature, and hence the political aspects must certainly also be addressed. Partial perspectives must be integrated into a "big picture". Morgan et al point out that "…Members of Congress are not interested in a physics or chemistry lesson; they absorb specialized information to apply it in a broad, value-laden context. Members of Congress may wish to learn from the leading scientists in a field but reserve for themselves the task of synthesizing the framework for decision. More commonly, however, elected representatives will find it convenient to deal with specialized inputs that have already been to some degree screened, synthesized and packaged into a more manageable form for them. The filtered analysis is more easily digested by the members. The nature of Congress's work – the reverse of scientific endeavour – is to want to assemble parts into a whole, to blur the sharp edges of issues in the hope of achieving consensus and fostering compromise"[33].

[33] M. Granger Morgan and Jon M. Peha (eds), *Science and Technology Advice for Congress*, RFF Press, 2003.

3.3 Interpreting the terms "advice", "science" and "government"

The notion of "science advice to government" as a decision support instrument was introduced above. The next step is to now consider the terms "advice", "science" and "government" in this context. Although this may, at first, seem like an unnecessary semantical indulgence, a clear and common understanding and agreement about the terminology is essential. If this is not the case, confusion will lead to misunderstandings and an underperforming science advisory structure, as was mentioned before.

3.3.1 "Science" – science, technology and innovation and the associated strategies and policies

In the context of understanding "science advice to government", the term "science" spans a wide domain. An attempt to find an appropriate definition of "science" very quickly leads one to the many definitions, discussions and deliberations on the topic, ranging from the practical to the esoterical and philosophical. Discourses on the definition of "science" in the context of providing "science advice to government" include questions of what science is and what is science, as well as the similarities, differences and interactions between science and technology; and if that is not enough, the complicated discussions pertaining to the definitions of innovation also enter the debate. It is important, however, to consider what is meant and implied by the term "science" in this context, since it has a direct bearing on the scope of what should be covered the advice that is to be given, and specifically also on what is not included.

Firstly, it is important to establish if the intent is to refer specifically to what is broadly understood to be the natural and life sciences on the one hand, and to what extent the social sciences and humanities should also be included on the other. Secondly, it is also important to determine whether the intent is to include the notions "technology" and "innovation" within the concept of "science".

From a policy viewpoint, and particularly when we consider the notion of providing "science advice to government" and what the appropriate structures in this regard should be, it should also be noted that distinctions exist between various types of STI-related policies and their associated strategies. There are marked differences between science policies, technology policies, industrial policies, innovation policies, research and development policies as well as economic policies. Even though these policies may overlap in some regards and (hopefully) promote the same ultimate national goals and outcomes, they have different characteristics and are typically championed by different government departments. Coordination is thus very important. In the context of providing advice and proposing a national science advisory structure, it is therefore necessary to investigate the nature of these various types of policies and their relations to one another. This is done by first examining the terms "science", "technology" and "innovation" and then their commensurate policies.

3.3.1.1 Science and science policy

Consider first the term "science". A typical dictionary definition of "science" informs one that it is "the systematic study of the nature and behaviour of the material and physical universe based on observation, experiment and measurement, and the formulation of laws to describe these facts in general terms"[34]. This definition is very much biased towards the natural sciences as opposed to the humanities and social sciences.

The same dictionary however also includes a definition for "science" as "any body of knowledge organized in a systematic manner". The notion of the application of a "scientific method" is very prevalent here. From this viewpoint, the human and social disciplines are also regarded as sciences. Disciplines in the humanities, economics, management and law all fall into this category.

The first interpretation of the term "science" in the context of providing "science advice to government" is interpreted to imply broadly the *natural sciences*, which will include the life sciences as well as engineering and technology. It should be recognised immediately that the social sciences and humanities very strongly come into play when policy analysis and hence advice about natural "science" is to be developed. However the focus of the advice will be the natural sciences, its implications and impacts. Science policy will typically imply policies that pertain to research in the natural sciences as well as possible applications (development).

The other interpretation of "science" in this context is to invoke the definition that it is a body of knowledge organized in a systematic manner. In this context, s*cience policy* typically relates to the development and impact of all the sciences that adhere to these criteria. It is very often associated with *research* and the creation of new knowledge. When the term *science policy* is used in this manner, the social sciences and humanities are typically also included, and the implied definition is not restricted to the natural sciences. "Science policy" in this case will usually refer to a more general research policy, with application to all sciences – natural as well as social – that rely on the scientific method.

Science policy was recognised as such during and after the Second World War, with Vannevar Bush's famous report *Science: The Endless Frontier* playing a major role. This report defined the role of science policy as contributing toward a nation's security, health and also economic growth, emphasising the strong links between investments in science and economic growth. The potential value of a formal science strategy was illustrated by the technical success of the Los Alamos project, and was fuelled by the Cold War arms race between the US and the USSR. It is interesting to note that this report strongly emphasised the "linear model" of innovation implying that basic research and its funding were both necessary and sufficient conditions to promote innovation[35].

The "linear model" endorses the development model from invention, through development, to technology and finally commercialisation in a linear fashion, allowing

[34] *Collins Dictionary of the English Language*, Collings, 1985.
[35] David C. Mowery and Bhaven N. Sampat, "Universities in National Innovation Systems", in *The Oxford Handbook on Innovation*, Oxford University Press, 2005.

for neither iterative loops nor the possibility that technology rather than science is often the main driver. Figure 3.1 shows a simple conceptual expression of a linear model. The linear model is widely accepted to be over-simplistic and flawed. It is discussed in some detail in Section 3.3.1.4.

The flaw in the linear model is that it proposes a linear causal progression of one step in the innovation process to the other. This is a different proposal from assuming that all the steps typically contained in a linear model should be present in the innovation process. The criticism against the linear model is thus not the fact that it contains all the steps – they are all essential – but rather the way in which the linkages and causality amongst them are depicted.

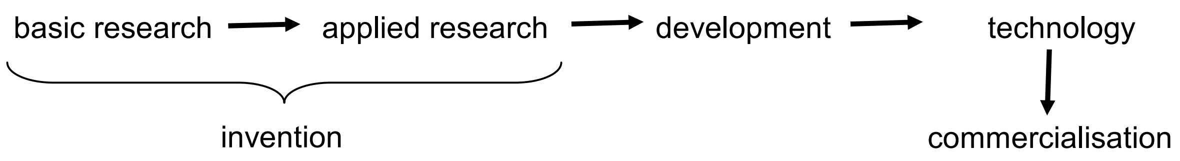

Figure 3.1: A simplistic view of the (flawed) linear processes

Notwithstanding the importance of basic science and its funding, as well as the role of basic science in technology and innovation, it is widely accepted that the linear model does not describe the innovation process accurately - not by a long shot. There may be many cases where a particular innovation adhered to this model to a more or lesser degree, but in general it does not describe the innovation process. The problem is of course that policies and strategies that are built on the premise that the linear model is the dominant one for innovation, will be flawed. Appendix B of this report describes one example, i.e. how an inherent assumption of the linear model can lead to flawed curricula for engineering students.

Science policy is very much concerned with research in the sciences, and as such also addresses the allocation and distribution of resources as well as their effective and efficient use. Human resources as well as institutions in which the research is done, (such as universities – and how they link with other role-players and the STI-environment), feature prominently in science policies. Niiniluto notes that "Science policy is a systematic effort for promoting and directing the development of science. According to the most ambitious programmes for national science policy, the task of science policy is to identify problem areas within the progress of society, to express these social problems as the goals of scientific research and development, to find means for achieving these goals, to allocate resources for various branches of research and to advance the utilization of the results of research. On the basis of such programmes, a demand is often made to the effect that the organization and administration of the national research system (universities, research institutes, etc.) has to be structured so as to make the general aims of science policy possible"[36].

[36] Ilkka Niiniluoto, "Is Science Progressive?", in *Finalisation, Applied Science and Science Policy*, 1984.

"Science policy" is considered by Branscomb to be concerned with the "health and effectiveness of the research enterprise", and is something that should be included in a technology policy, together with "other elements of the innovation process, including design, development, and manufacturing, and the infrastructure, organization, and the human resources on which they depend"[37].

Two major policy debates in science policy focus on the degree to which progress in science is correlated with progress in general, and the degree to which science should be the handmaiden of the state versus being "autonomous". In a university environment, the latter notion finds application in the argument for academic freedom and to what extent scientists should be allowed and funded to pursue what they consider the appropriate areas and directions for research, as opposed to state mechanisms for identifying "priority areas" and steering researchers there, mainly through funding mechanisms. These can include subsidies and ring fenced funding for universities, matching funds for industry-sponsored research as well as tax breaks for industry funded-research. Intellectual property rights and their exploitation are receiving increasing attention in this regard as well. Neither of the arguments (academic freedom versus steered research) can be discounted and both have merits. Hence the policy must attempt to find the optimal compromises. The latter argument is often championed by policy makers and politicians, with an associated demand of "value for money", often manifesting in requiring scientists, very often a priori, to demonstrate the "practical or economic value" of their research. From an accountability viewpoint this approach is understandable. However, it certainly has the potential to stifle the progress of science and ultimately also innovation. Hence it should be applied with caution and certainly be balanced with the arguments favouring academic freedom in research. This debate is in itself also a legitimate object for science advice.

"Everything that can be invented has been invented…"[38]

The virtues of having a focused national R&D strategy are illustrated by another example from the USA. In the late 1890s the Commissioner of the US Patent Office was one Charles H. Duell. He was apparently keen to find another job in the Federal Government, and figured that if he could convince President McKinley to abolish the Patent Office, they would have to offer him another job elsewhere in the government. Hence his pronouncement in 1899 that "everything that can be invented has been invented" was an attempt to show why the patent office should be abolished. More than a hundred years later we know that was certainly not the case then, and also that we can safely say that it is certainly not true today, nor will it be true tomorrow.

In a similar vein, it is said that the journal *Scientific American* reported in its issue of January 1909 to the effect "…that the automobile has practically reached the limit of development is suggested by the fact that during the past year no improvements of a radical nature have been introduced". A hundred years later, we know that this prediction was very far off the mark…

[37] Lewis M. Branscomb (ed), *Empowering Technology*, MIT Press, 1993.
[38] William G. Howard and Bruce R. Guile (eds), *Profiting from Innovation*, The Free Press, 1992.

The point was made that "measuring" science is a necessary element of science policy, and that it should be addressed. Many nations, including South Africa, gather R&D data for this purpose. It is essential, however, to ensure that the measurement promotes the advance of science, rather than encouraging mediocrity and complacency. Managers know that the act of measuring a specific criteria has a strong tendency to focus effort on the criteria being measured. It is very important to therefore ensure that the measurement in itself does not create perverse incentives.

3.3.1.2 Technology and technology policy

The next step is to consider the term "technology". Definitions for "technology" abound, and it is certainly not the intention to attempt to list even a subset of these here. It is however, necessary to point out that there are significant differences between science and technology, and that these affect the interpretation and application of "science advice to government". It is also important to consider the causal relationship between science and technology – the "linear model"-problem. The issue of whether science leads technology or whether technology can lead science have important policy implications, and as such should also be the object of science advice to government.

Branscomb refers to "technology" as "the aggregation of capabilities, facilities, skills, knowledge, and organization required to successfully create a useful service or product"[39]. He then defines "technology policy" as being concerned with "the public means for nurturing those capabilities and optimizing their applications in the service of national goals and the public interest". He points out that that the "boundaries that distinguish technology policy from economic and industrial policy are fuzzy at best", noting that a sound macroeconomic environment is a necessary but not sufficient condition for innovation and technological progress. As a side note, he mentions that "Trade policy is a poor surrogate for technology policy".

Mowery defines "technology policy" as "policies that are intended to influence the decisions of firms to develop, commercialize or adopt new technologies"[40]. Writing in 1995, he notes that "In the last two decades, 'technology policy' has emerged as a discrete area, separated from science policy, in most industrial governments outside of Japan, where technology policy was established well before World War II. Previously, governmental R&D budgets and policies towards innovations were the province of science policy. But there are important differences between these spheres of policy, and the efforts of some governments to simply change the demands that they place on their scientific research infrastructure, without also altering the structure and internal incentives of that infrastructure, may ultimately prove fruitless….Although many public policy makers now recognize that technology and science policy are distinguishable spheres, the assumptions that underpin many of the technology development programs developed during the past decade in the US and Western Europe display many signs of continued adherence to the linear model of innovation". Recall the earlier discussions regarding the flaws of the linear model.

[39] Lewis M. Branscomb (ed), *Empowering Technology*, MIT Press, 1993.
[40] David Mowery, "The practice of technology policy", in *Handbook of the Economics of Innovation and Technological Change*, Paul Stoneman (ed), Blackwell, 1995.

Technology policy focuses on technologies and the sectors in which they are prevalent. As such the nature of technology policies will be very different for developed versus developing nations, for example, as it will be different for larger versus smaller countries. In the USA, the implicit technology policy from the 1960s to the 1980s was related to Cold War thrusts, particularly the arms race and the space race.

Other countries had a focus on strategic technologies and “industrialising industries”. France, UK and Germany promoted national champions, whereas technology policy in countries such as Japan, Taiwan and Korea were aimed at catching-up.

Policy debates in technology policy include the following[41]:

- The “legitimacy” of the state to intervene with the aim of enhancing private companies’ commercial success, as opposed to focusing the policy more on aspects such as national security and social benefits.
- Should technology “winners and losers” be selected and certain technologies be championed?
- Where and at what stage should the state support be focused? Basic research, “pre-competitive development” or in bringing products to market, for example?
- What competences should be developed and maintained in the public domain?
- How can and should competition be stimulated?

All of these are also appropriate topics for “science advice” (interpreted broadly) to government.

3.3.1.3 Science and technology policy

It is of course also possible to have a national “science and technology” policy, rather than just one of the two or two separate policies. These are not necessarily mutually exclusive and can certainly overlap. Again, in order to avoid confusion, there must be clarity about the intention of the term “science” as explained above.

Stine defines “science and technology policy” (from an American perspective) to be concerned with “the allocation of resources for and the encouragement of scientific and engineering research and development, the use of scientific and technical knowledge to enhance the nation’s response to societal challenges and the education of Americans in science, technology, engineering, and mathematics”[42]. She notes that there are generally four facets of science and technology policy, viz.

- Science for policy
- Technology for policy
- Policy for science
- Policy for technology

[41] Bengt-Åke Lundvall and Susana Borrás, “Science, Technology and Innovation Policy” in *The Oxford Handbook of Innovation*, Jan Fagerberg, David C. Mowery and Richard R. Nelson (eds), Oxford University Press, 2005.
[42] Deborah D. Stine, “Science and Technology Policymaking: A Primer”, *Congressional Research Service*, 18 April 2008, Order Code RL34454.

Science and technology for policy occurs when scientists[43] provide analysis, data and knowledge to inform policy makers with the goal of enhancing their decision-making capabilities. In order to react to the AIDS pandemic, malaria and tuberculosis, develop positions on climate change or pursue policies regarding the hydrogen economy, for example, it is necessary that the policy makers be informed about the scientific aspects of the policies that they are contemplating.

Policy for science and technology, on the other hand, occurs when policy makers take actions that influence and regulate the science and technology environment. Laws regulating patents and the exploitation of intellectual property or the allowable emissions from automobiles, are examples of cases where policies are made to regulate the scientific environment.

The White Paper on Science and Technology (1996) noted five broad interrelated themes which are regarded as fundamental to the expression of a sound S&T policy:

- Promoting competitiveness and employment creation
- Enhancing quality of life
- Developing human resources
- Working towards environmental sustainability
- Promoting an information society.

Furthermore, the importance of knowledge generation, the role of the human sciences in innovation as well as the importance of finance, management and performance were noted as being important areas for informing S&T policy.

Case study: Singapore's science and technology policies

Singapore's performance in terms of economic success and international competitiveness is undisputed. It is evident that a structured technology policy contributed significantly towards the success. In an analysis of the competitiveness of the Singaporean economy, the authors note that "…the potential efficiency level and consequently the economic output will be increased with technological progress associated with technology transfer, adoption, adaption and innovation" [44]. Structured and formal technology policies were central to Singapore's road to success in the 1990s. These were "consciously and systematically crafted and fostered" to be aligned with the broader economic and national objectives. The National Science and Technology Board (NSTB) was formed in 1991. Soon after, the *National Technology Plan for Singapore* was unveiled by the NSTB[45]. The immediate thrust was on economically relevant downstream research. The fact that the plan focused on "technology" rather than "science and technology" was deliberate.

At the same time, the Ministry of Trade and Industry produced a *Strategic Economic Plan*. This plan emphasised the creation of a climate conducive to innovation. Loh

[43] In general references in this report to the term "scientists" should be interpreted to imply natural scientists, engineers and health care professionals, as well as social scientists where appropriate.

[44] Toh Mun Heng and Tan Kong Yam (eds), *Competitiveness of the Singapore Economy*, Singapore University Press and World Scientific, 1998.

[45] Lawrence Loh, "Technological policy and national competitiveness", in Toh Mun Heng and Tan Kong Yam (eds), *Competitiveness of the Singapore Economy*, Singapore University Press and World Scientific, 1998.

notes that "Innovation was, in fact, explicitly recognised as an underpinning that prevails in all aspects of the economy, covering all functions and sectors in Singapore. This was a somewhat broader perspective that views innovation as a foundation for other direct input factors of competitiveness".

A number of targets that were to be achieved during the period 1991-1995 were set. Some were significantly surpassed. For example, the target of Expenditure on R&D (GERD) was 3%, whilst 16% was obtained. The target for the number of R&D scientists per 10 000 of population was 40% whilst 42% was attained, and the target for private sector contribution to GER was 50% whilst 63% was attained.

The next technology plan, known as the *National Science and Technology Plan*, was unveiled by the NSTB in 1996. One of the aims was for Singapore to build a world-class science and technology base in selected fields. It is noteworthy that the second plan included the term "science", whereas the first one did not. The first plan was deliberately aimed at downstream developments and R&D, where there were more obvious and direct linkages to economic growth. By the time the second plan took effect, there was a realisation that the time had come to develop and also focus on the development of upstream activities. Hence the inclusion of "science" in the second plan. Loh notes that "Such a move will not only consolidate competence building in the fundamental sciences, but more importantly, it will contribute to a general climate of creativity and thinking in Singapore".

3.3.1.4 Innovation and innovation policy

Having explored the terms "science" and "technology", it is appropriate to now turn to the term "innovation". It is necessary and important to make an effort to develop an understanding of the concept of the notion of "innovation". The concept has become central to many national policies and is also embraced by industries world-wide as an essential business process. Given the important roles of innovation, particularly science and technology-related innovation, in the economic welfare, competitiveness and quality of life of nations and their citizens, it should come as no surprise that many countries have developed innovation policies (as opposed to science or technology policies).

In this section various aspects of innovation are subsequently discussed in some detail, the purpose of which is to inform the discussion on the nature of "innovation" – related advice that should (or should not) be included in "science advice to government" and the structures that are required to provide such advice.

The limitations of the "linear model" of innovation

Some references were made to the linear innovation model in previous sections, particularly also to its flaws. Mowery's reference in a previous section to the "linear model" of the innovation process has important implications within the context of providing science advice to government. In the linear model (natural) science and related research and developments lead to the development of new technologies and the products upon which they are based. He notes that "despite the faith in science as the source of all innovation, there are important differences between the processes that create scientific and technological knowledge and in the characteristics of each body of knowledge". Kline and Rosenberg have shown that scientific research often lags behind technological knowledge and in some cases even rely on it.[46] Rather than relying on science in a linear and causal manner, technological development and ultimately innovation, are messy and iterative processes rather than clean, linear ones. Furthermore, the core of a technology is often embedded in tacit rather than codified knowledge, thereby also distinguishing it from scientific knowledge, which almost by definition is evidence-based (and hence must be reproducible as such). Fagerberg explains the argument as follows[47],

> "Basically, the 'linear model' is based on the assumption that innovation is applied science. It is 'linear' because there is a well-defined set of stages that innovations are assumed to go through. Research (science) comes first, then development, and finally production and marketing. Since research comes first, it is easy to think of this as the critical element. Hence, this perspective, which is often associated with Vannevar Bush's programmatic statements on the organization of the US research systems (Bush, 1943), is well suited to defend the interests of researchers and scientists and the organizations in which they work.
>
> The problems with this model, Kline and Rosenberg point out, are twofold. First, it generalizes a chain of causation that only holds for a minority of innovations. Although some important innovations stem from scientific breakthroughs, this is not true most of the time. Firms normally innovate because they believe there is a commercial need for it, and they commonly start by reviewing and combining existing knowledge. It is only if this does not work, they argue, that firms consider investing in research (science). In fact in many settings, the experience of users, not science, is deemed to be the most appropriate source of information (von Hippel 1988[48]; Lundvall 1988). Second, the 'linear model' ignores the many feedbacks and loops that occur between the different 'stages' of the process. Shortcomings and failures that occur at various stages may lead to a reconsideration of earlier steps, and this may eventually lead to totally new innovations".

Betz notes that "Since industry directly uses technology in its production of goods and services and not science, industry needs science when (1) new basic technologies need to be created from new science, and (2) technological processes in an existing technology cannot be made without a deeper understanding of the science underlying the technology"[49]. This observation is certainly dependent on the nature of the technology and the underlying science. It is generally acknowledged that modern biotechnology companies, for example, are very dependent upon the science itself.

[46] S.J. Kline and N. Rosenberg, "An overview of innovation" in *The positive sum strategy*, Ralph Landau and Nathan Rosenberg (eds), National Academy Press, 1986.
[47] Jan Fagerberg, "Innovation, A Guide to the Literature", in *The Oxford Handbook of Innovation*, Jan Fagerberg, David C. Mowery and Richard R. Nelson, Oxford University Press, 2005
[48] E von Hippel, *The Sources of Innovation*, Oxford University Press, 1988.
[49] Frederick Betz, "Targeted basic research: Industry-university partnerships", in Gerard H. Gaynor (ed), *Handbook of Technology Management*, McGraw-Hill, 1996.

Definitions of innovation

There is no single or “best” definition for the term “innovation”. A review of the literature shows that there are a myriad of definitions and interpretations of the term. It is a futile exercise to review them all here. A few definitions, however, are discussed in order to bring the notions of “innovation policy” and related advice into context. The list of definitions discussed here is by no means intended to be exhaustive, nor are any of the definitions necessarily endorsed. All of the many textbook definitions for innovation are open to interpretation. Most contain some elements of truth rather than the whole truth. It is dangerous to hail any one definition of innovation as *the* definition. A number of definitions for the term “innovation” are nevertheless discussed below, illustrating not only the various types and approaches to definitions, but also the different aspects that are highlighted by each.

Many definitions of “innovation” include the “creative processes”, particularly when they refer to science and technology-related innovations. It is very important to acknowledge that “creativity” and “innovation” are different, albeit related processes.

Creativity is an essential element of the process of idea generation. There are many ways in which ideas can be generated. They can, for example, be borrowed (when imitating others’ ideas), stolen (the illegal use of others’ intellectual property), bought (where someone else is paid to perform contract research) or rented (paying others royalties for the use of their ideas). “Creativity” is the process of generating one’s own ideas. Very often new ideas arise when existing ideas are combined or modified. There are many processes and techniques that can be applied to stimulate creativity[50].

A definition for innovation often used in Shell is “Innovation is bringing an insightful idea successfully to the market”[51]. Verloop mentions that this definition stresses a number of important aspects, viz.

- Innovation is a dynamic process. It constantly changes with time. It is not an incident, but rather a journey.
- Innovation cannot happen without insight - creativity alone won’t do. The new idea requires a thorough understanding of the technical merits as well as the market.
- Entrepreneurship is required. This notion is also stressed by Drucker, who notes that “Innovation is the specific instrument of entrepreneurship. It is the act that endows resources with a new capacity to create wealth”[52].
- Ultimately the fate of an innovation is determined by the market. Success can only be accomplished if the innovation adds value to the customer.

Many definitions take the line that the invention process includes all aspects leading to the creation of a new concept which, at least in principle, is workable. The innovation process takes a new concept, or combines several new or old concepts

[50] See for example Edward de Bono E, *Serious Creativity*, Harper Collins, 1992. Dr de Bono has written many books on the topic of creativity, and they are highly recommended.
[51] Jan Verloop, *Insight in Innovation*, Elsevier, 2004.
[52] Peter F. Drucker, *Innovation and Entrepreneurship*, Heineman, 1985.

into a new scheme (another invention), and then develops it into a commercially useful product, process or service. While the lines between invention and innovation are often blurred in business practice, the distinction focuses on the exploitation of a new concept toward commercial application and value.

Rogers defines innovation as “an idea, practice or object perceived as new by an individual or other unit of adoption”[53]. Utterback and Abernathy define it as “…a new technology or combination of technologies introduced commercially to meet a user or market need”[54], while Rabe defines innovation as “…the application of an idea that results in a valuable improvement”[55].

Girifalco refers to innovation as “…the process by which the invention is first brought into use. It involves the improvement or refinement of the invention, the initial design and production of prototypes, pilot plant testing and construction of production facilities…diffusion is the process of the spread of the innovation into general use as it is adopted by more and more users”[56]. Berry and Tagart note that they “…look upon innovation as the total process from the inception of an idea through to the manufacture of a product and finally to its ultimate sale. It therefore includes invention and the many stages of implementation such as research, development, production and marketing”[57].

Sahal notes that “An invention is essentially the creation of a new device. An innovation additionally entails commercial or practical application of the new device…first application of an invention”[58]. In a similar manner, Faberberg considers “invention” to be the “first occurrence of an idea for a new product or process” whilst he defines “innovation” as “the first attempt to carry it into practice”[59]. He points out that there is very often a considerable time lag between the two – this is an aspect that must be accounted for in a science/innovation policy, particularly when the funding of proposals for more basic research is considered.

Alan Bromley, President George W.H. Bush’s science advisor, gives the following definitions:

“Invention…	refers to the devising or fabricating of a novel device, process or service. It describes the initial conception of these new products, processes or services but does not address their application.
Innovation…	encompasses both the development of these ideas and their application. For example, it can include the use of an existing

[53] E.M. Rogers E.M., *The Diffusion of Innovations*, Fourth edition, The Free Press, 1995.
[54] Jim M Utterback and William J. Abertnathy, “A dynamic model of product and process innovation”, *Omega*, Vol 3, No 6, 1975, pp. 639-656.
[55] Cynthia Barton Rabe, *The Innovation Killer*, American Management Association, 2006.
[56] Louis A. Girifalco L.A., *Dynamics of Technological Change*, Van Nostrand Reinhold, 1991.
[57] M.M.J. Berry and J.H. Taggart, "Managing Technology and Innovation: A Review", *R&D Management*, Vol 24, No 4, 1994, pp. 341-353
[58] D. Sahal, "The Multidimensional Diffusion of Technology", *Technological Forecasting and Social Change*, Vol 10, 1977, pp. 277-298.
[59] Jan Fagerberg, “Innovation, A Guide to the Literature”, in *The Oxford Handbook of Innovation*, Jan Fagerberg, David C. Mowery and Richard R. Nelson, Oxford University Press, 2005.

product in a new application or the development of a new device for an existing application. It encompasses a wide variety of related activities, including scientific discovery, technical and market research, manufacturing and marketing, to the extent that they support the administration and application of the new idea.

Commercialization… refers to the attempt by an organisation to profit from innovation through the sale or use of new products, processes or services."[60]

Types of innovations

Rothwell and Gardiner remind us that "…Innovation does not necessarily imply the commercialisation of only a major advance in the technological state of the art (a radical innovation) but it includes also the utilization of even small-scale changes in technological know-how (an improvement or incremental innovation)"[61]. The point that Rothwell and Gardiner make is that there are many different types of innovations. The taxonomy of innovations distinguishes, for example, between radical and incremental innovations, product and process innovations, disruptive innovations, architectural and modular innovations, competency enhancing and competency destroying innovations and many more. The *management of innovation* teaches us that there are different types of success strategies associated with every type of innovation, and that success depends on identifying the nature of a particular type of innovation and the subsequent application of the appropriate strategy. Furthermore, one should also not labour under the illusion that all innovations are technological or scientific. Marketing innovations, organisational innovations and financial innovations, to name but a few, are examples of non-technological innovations.

It should be stated that although many people immediately associate the term "innovation" with a scientific or technological innovation, innovation could of course happen in every field. Hence we can for example find marketing innovations, organisational innovations and social innovations as was mentioned above. In the context of this study, we are focusing on science and technology-related innovations.

In the case of S&T-related innovations, the scientific part of the invention component deals with the laws of nature, whilst the rest of the innovation process is much more predicated on human nature and the laws of mankind. Commercialisation, the exploitation of markets, adoption and diffusion are all processes that rely heavily on behaviour science (a social science) rather than a natural science. The impacts of the S&T-related innovations are also very often in the domain of the social sciences and humanities.

It is very evident that technological change is inherent to successful technological innovation. It must be noted that the process of technological change, is also well studied and that a significant body of knowledge exists[62]. A study of technological

[60] D. Allan Bromley, "Technology policy", *Technology in Society*, Vol 26, 2004, pp. 455-468.
[61] Roy Rothwell and Paul Gardiner, "Invention, innovation, re-innovation and the role of the user", *Technovation*, Vol 3, 1985, p 168.
[62] See for example Y. Sankar, *Management of Technological Change*, John Wiley & Sons, 1991; Louis A Girifalco, *Dynamics of Technological Change*, Van Nostrand Reinhold, 1991;

change indicates that, like innovation, it is a complex process. In developing an innovation strategy, be it on the organisational or national level, it is essential that an understanding of the true nature of technological change is reflected in the thinking.

The White Paper on Science and Technology of 1996, defines "innovation" as "…the application in practice of creative new ideas, which in many cases involves the introduction of inventions into the marketplace". The White Paper further notes that, "In contrast, creativity is the generating and articulating of new ideas. It follows that people can be creative without being innovative. They may have ideas or produce inventions, but may not try to win broad acceptance for them, put them to use, or exploit them by turning their ideas into products and services that other people will buy or use. Similarly, people can be innovative without being creative. For example, if they apply or implement ideas or inventions that were made elsewhere, they are being innovative, even though the inventions or creative ideas were not their own. Some innovations are truly revolutionary, while most represent modest improvements in the way we do things. Competitive companies, for example, are continually introducing incremental innovations to improve the products they sell or the processes they use in production. Only rarely will they introduce something radically new into the market place." The National R&D Strategy refers to "innovation" as the "introduction into a market (economic or social) of new or improved products and services".

A working definition of innovation

Westland refers to "innovation" as "a product or service with a bundle of features that is – as a whole – new in the market, or that is commercialised in some new way that opens up new uses and consumer groups for it". He immediately continues to note, however, that "…Beyond this very general definition, you will find the different professions perceive innovation in vastly different ways, and each profession tends to define innovation in terms of the parts with which its members are familiar. This explains the wide array of definitions for innovation put forward over the years".[63]

There are indeed very many definitions of innovation – so many authors, books and articles, so many definitions and opinions. Although most of them contain some elements of the "truth", most are incomplete in the sense that they do not capture many of the elements generally associated with innovation, or emphasise one particular element of the process. Each definition explicitly or implicitly also endorses a particular innovation model, i.e. a model that describes the innovation process. One should, therefore be very careful to adopt any particular textbook definition of innovation, without accounting for the context in which it was created. Again, this caution is of much more than semantic value.

The variations in the different definitions for innovation seem to have the following characteristics in common:

Jim M. Utterback, *Mastering the Dynamics of Innovation*, Harvard Business School Press, 1994;
Joel Mokyr, *The lever of riches*, Oxford University Press, 1990; Paul Stoneman (ed), *Handbook of the Economics of Innovation and Technological Change*, Blackwell, 1995

[63] J. Christopher Westland, *Global Innovation Management*, Palgrave Macmillan, 2008.

- Some definitions exclude the invention-component, specifically the creativity aspects, which in a scientific context may also exclude research. The White Paper on Science and Technology seems to endorse this approach. A similar notion is implied by the National R&D strategy.
- Some recognise the invention-component as part of innovation, and include creativity, discovery and research.
- Some consider the innovation to consist primarily of the market exploitation component referred to above, and broadly so.
- Some consider the market exploitation component to consist of all the process up to large-scale adoption, more or less up to the point of "first use". In these definitions, the commercialisation component is considered to be a different one than the innovation component. Bromley's definitions above fall in this category.
- Some definitions are all encompassing, including the discovery component and considerable adoption by a "market", rather than just first-use.

A working definition of innovation

A very useful working concept, however, is the notion of innovation having two components[64], viz.

innovation = invention + market exploitation

It must be stressed again that innovation is not a linear process, and hence the equation above should not be interpreted as indicating a causal relationship. The equation's usefulness is rather to illustrate that both components must be present in order to have an innovation. The definition above is closely related to that given by Michael Porter and Opstal[65], viz. that innovation is invention plus commercialisation. They consider innovation to be "a new way of doing things that is commercialized".

Ultimately the National System of Innovation in the country is also built or premised on a mental innovation model. This model may be explicitly defined and published, or it may just be implicitly assumed. Even though the designers of and role players in the NSI don't necessarily think about the underlying innovation model, it is there.

The danger is that if the model is flawed in some way, the National System Innovation and associated policies will also be flawed – recall the previous discussion on the linear model. The definition of "innovation" and related terms such as "science", "R&D" and "invention" hence become very important because they predicate the definition of the NSI and ultimately the national innovation policy. One must, therefore, pay special attention to the definitions and semantics.

It has been said that the difference between inventions and innovation are that whereas inventions create new knowledge, innovations create new wealth[66]. It is interesting to note that patents are issued for inventions, but not for innovations. A

[64] Ed Roberts, "What we've learned, managing invention and innovation", *Research/Technology Management*, 31, 1988, pp 11-21.
[65] Michael Porter and Debrah Opstal, *US Competitiveness 2001: Strengths, vulnerabilities and long-term priorities*, Council on Competitiveness, Washington, 2001.
[66] William G. Howard and Bruce R. Guile, *Profiting from Innovation*,The Free Press, 1992.

patent per se is no guarantee that the invention will be a commercial success. Hence the caution in using patent statistics as a proxy for innovative success.

The "invention" and market exploitation" components of innovation

Providing advice on matters of innovation necessarily implies that both components (the invention and market components) should be addressed in the advice. Hence even if the major focus is on *scientific and technological innovation*, the necessary contributions from the social sciences and humanities, particularly when it comes to the application, adoption, diffusion and impact of science and technology, are indispensable. This is why social scientists must also be represented on advisory structures that focus on innovation.

The essence of innovation is renewal and continuous improvement. The invention term refers to the creative component. It is where research and development resorts. The notion of "new ideas" is manifested in the creation of a new concept, which in turn is often based on a new combination of existing concepts or new inventions. Ideas frequently originate elsewhere, and one requires an alertness to recognise and learn from them. However, it is also essential that the capacity and ability exist to generate one's own ideas. This is the core of creativity. Scientific research can also be included in this domain.

Once a new idea or concept has been born, it is necessary for it to be successfully implemented in order to become useful or have an effect – turning an invention into an innovation. This aspect is indicated by the term "market exploitation" in the equation above. It refers to an adoption by users, often in a commercial but frequently also in a social sense. The former is usually associated with the notion of "commercialisation". The latter can also refer to the adoption of a "social" innovation (as opposed to a "natural" concept or technological product), such as democracy or a particular religion. The adoption component of the innovation is also related to the diffusion of the innovation[67].

New ideas and concepts that are not successfully adopted by users are not innovations – they remain inventions, ideas and concepts. There must be a market acceptance to turn the new idea or concept into an innovation. One of the major mistakes made with regard to the management of innovation is that the first component (generation of new ideas) is often over-emphasised and the second component (market acceptance or adoption) neglected.

Having explored a working concept of innovation above, it is not difficult to extrapolate this concept to national innovation strategies and the concomitant provision of "science" advice to government. It is evident that not only the similarities but also the differences between science, technology and innovation policies must be appreciated.

[67] See for example Everett M. Rodgers, *Diffusion of Innovations*, 4th edition, The Free Press, 1995; Bronwyn H. Hall, "Innovation and Diffusion", in *The Oxford Handbook of Innovation*, Jan Fagerberg, David C. Mowery and Richard R. Nelson, Oxford University Press, 2005.

National innovation strategies

Beyond science policy and technology policy, one now moves to the realm of innovation policy. The concept of “innovation policy” and its interpretations obviously span a wide spectrum. On the one end the approach is very much a non-interventionist one and the establishment of so-called policy “framework conditions”. This view is aligned with the neo-classical economics approach to innovation[68]. The neo-classical view of economics stresses that market failure is a necessary condition to warrant public policy intervention. If the markets “work”, there is no need for intervention. In an innovation context, it is often argued that private companies are not overly keen to sponsor basic research, but tend to focus more on applied research and development. The reason is that the commercial appropriability of basic research is low. Since there is certainly a need for basic research, a market failure is evident and hence public intervention is required to fund basic research. The contextual settings that promote innovation and a functional national system of innovation, are however more complex. The inadequacies of the “linear model” in explaining a successful innovation process were discussed above.

The support of basic science and education as the main “legitimate” areas of public support and encouragement for the “wealth creation” aspect is given by creating an appropriate intellectual property regime within which commercialisation can be pursued. More moderate policy encourages “entrepreneurship” whereas the other side of the spectrum embraces the notion of a national innovation system. The “system” approach emphasises the notion that all players (institutions, technologies, individuals and other related policies) are considered in terms of the contribution they can make towards the broader national innovation goals. The networks and linkages are very important, and they determine to a large extend the nature of the system, as opposed to loose grouping of individual, unconnected players. The focus on institutions and their linkages is much more prominent than in science policy (where there is a lot of emphasis on the science itself and the research implications), and technology policy (where there is a lot of emphasis on the technologies and the sectors in which they are prominent). Although the value of competition and its advantages are recognised, so is the value of cooperation.

The rise in prominence of “innovation policy” has much to do with the slowing down of economic growth in the 1970s. Although the diminishing contribution of “total factor productivity” is not well understood, there are strong indications that the absence or lack of successful exploitation of technology (and associated technological change) may have been significant contributors, coupled with measures to restrict inflation.

The major objectives of innovation policy are economic growth and the strengthening of international competitiveness. Implied in these are the quality of life issues, which, particularly in the European context, also include the notions of social cohesiveness and equality. Increasingly, “innovation” is also seen as the process through which issues such as pollution, global warming, poverty alleviation and HIV/AIDS should be addressed.

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[68] Bengt-Åke Lundvall and Susana Borrás, “Science, Technology and Innovation Policy” in *The Oxford Handbook of Innovation*, Jan Fagerberg, David C. Mowery and Richard R. Nelson (eds), Oxford University Press, 2005

An innovation policy and associated national innovation system is very dependent on the domestic innovation environment and other characteristics of the specific country, including its modes of knowledge production. Hence it is not possible to transfer “best-practices” blindly from one country to another without accounting for these contextual issues. It is therefore essential that the country and region specific issues must be accounted for, not only in the policies but also in the advice and advisory structures.

In a previous section the notions of “science for policy” versus “policy for science” were discussed. A similar notion is at play in the context of innovation policy and strategies. On the one hand there is the notion of promoting innovation within institutions (which is more aligned with science and technology policy) whereas on the other hand, there are imperatives to reform and change institutions to enhance their innovative capabilities. The term “institutions” should be interpreted broadly here, and can also include intellectual property, competition and tax regimes as well as capital and labour markets. These two views are not necessarily mutually exclusive or at cross-purposes.

Edquist describes innovation policy as “…public action that influences technical change and other kinds of innovations. It includes elements of research and development (R&D) policy, technology policy, infrastructure policy, regional policy and education policy. This means that innovation policy goes beyond science and technology (S&T) policy, which mainly focuses on stimulating basic science as a public good from the supply side. Innovation policy also includes public action influencing innovations from the demand side.”[69]

Figure 3.2[70] illustrates this concept, showing the relationship between science policy, technology policy, innovation policy and competitiveness policy. It is evident that the elements of science policy are present in a technology policy, but that both are also present in an innovation policy. In the innovation policy, the impact on the entire economy becomes important. A case is made in a later section that the concept can be extended to also provide for a competitiveness policy that will also encompass the innovation policy.

Lundvall and Borrás note that “Ministries of economic affairs or ministries of industry may be the ones playing a coordinating role in relation to innovation policy but in principle most ministries could be involved in efforts to redesign the national innovation system… Developing an interaction and dialogue on policy design between government authorities on the one hand and the business community, trade unions and knowledge institutions on the other is a necessary condition for developing socially relevant and clear policy programs that can be implemented successfully…The prevailing institutional set-up means that ministries of finance are the only agencies taking on a responsibility for coordinating the many specialized

[69] C. Edquist, “The Systems of Innovation Approach and Innovation Policy: An account of the state of the art”, DRUID Conference, Aalborg, 12-15 June 2001.

[70] After Bengt-Åke Lundvall and Susana Borrás, “Science, Technology and Innovation Policy” in *The Oxford Handbook of Innovation*, Jan Fagerberg, David C. Mowery and Richard R. Nelson (eds), Oxford University Press, 2005.

area policies. Area-specific ministries, on the other hand, tend to identify the interests of their own ‘customers’ and take less interest in global objectives of society. It could be decided to establish new types of institutions such as cross-sector and interdisciplinary *Councils on Innovation and Competence Building* at the sub national and national level...”. They mention specific examples of countries like Finland, the Netherlands and Denmark, which have experienced what they refer to as “a truly ‘innovation policy turn’” in the 1990s.

Perhaps the “science policy” component of the innovation policy should be recast as a “knowledge policy”, thereby recognising that the “invention” part of the innovation equation must account for a number of different knowledge generation modes. Creativity and performing one’s own research is certainly a very important component and should never be neglected. However, there is also a case to be made for the importance of imitation and adaption in its various forms. Ultimately one should aim for innovation success and not invention success.

The role of the OECD in science policy

The role of the OECD in not only emphasising STI-policies but also in differentiating between science policy, technology policy and innovation policy is interesting and noteworthy[71]. In 1963, the same year the Frascati meeting on a new manual to gather R&D statistics took place, the OECD published a report entitled “Rationalizing science policy and linking it to economic growth”. The report emphasises national and rational planning, as well as the strong link between better data on research and development (R&D) and a more systematic approach to policy. The idea was to broaden the domain and legitimacy of science policy beyond the narrower domains of only the ministries of science and education. The OECD’s “Brook Report” of 1970 entitled “Bringing in human and social considerations on technology policy” introduced broader social and ecological perspectives into the areas of science policy and also technology policy. The participation of the citizenry in impact was stressed. In 1980 the OECD published a report positioning innovation policy as an aspect of economic policy, with a report entitled “Technical Change and Economic Policy”. The point was made that macro-economic policy alone could not solve slow growth and unemployment. Furthermore, there was also an emphasis on the ability to absorb technology. In 1990 the OECD issued a report that defined innovation as an interactive process, strongly emphasising the concept of national innovation systems.

[71] Bengt-Åke Lundvall and Susana Borrás, “Science, Technology and Innovation Policy” in *The Oxford Handbook of Innovation*, Jan Fagerberg, David C. Mowery and Richard R. Nelson (eds), Oxford University Press, 2005.

Science policy

Focus: Production of scientific knowledge

Instruments:

- Public research funds, granted in competition
- Public and semi-public research institutions
- Tax incentives for research
- Higher education
- Intellectual property rights

Technology policy

Focus: Advancement of commercialisation of sectoral techncai knowledge

Instruments:

- Public procurement
- Public aid to strategic sectors
- Bridging institutions
- Labour force training and skills enhancement
- Standarisation and benchmarking of sectors
- Technology foresight

Innovation policy

Instruments:

- Improving individual skills and learning abilities
- Improving organisational skills and learning
- Improving social capital, especially for regional development
- Enhanced access to information
- Environmental and ethical regulation
- Corporate law, including competition law
- Consumer protection

Competitiveness policy

Institutions
Infrastructure
Macroeconomic stability
Health and education

Higher education and training
Goods market efficiency
Labour market efficiency
Financial market sophistication
Technological readiness

Business sophistication
Innovation

Figure 3.2: The relationship between science policy, technology policy, innovation policy and competitiveness policy (after Lundvall and Borrás; Global Competitiveness Report)

3.3.1.5 Industrial policies

A discussion on innovation policies, and ultimately a national scientific advisory structure, will not be complete without reference to national "industrial policies". As in the case of innovation and innovation policies, definitions and interpretations of the term "industrial policy" also abound. Industrial policies emphasise industrial sectors and industries, and are closely related to national macro-economic policies.

Okimoto defines industrial policy as "the government's use of its authority and resources to administer policies that address the needs of specific sectors and industries (and if necessary of those of individual companies) with the aim of raising the productivity of factor inputs" [72]. He stresses the point that public policies that deal with the economy as a whole and not just with the micro-industrial parts should be defined as macroeconomics. "Between the two poles – industrial policy and macroeconomics - are gray areas that can be grouped at either end of the continuum. Fiscal budgets for instance has an impact on the whole economy, but individual items on the budget such as public procurement, research and development subsidies can be used to promote industries and hence should be included in the category of industrial policy. A corporate flat tax applied equally across all industrial sectors might be considered a macroeconomic measure. Corporate taxes that levy widely disparate rates on different industries can on the other hand be regarded as one of the most widely used instruments of industrial policy…The defining characteristic of industrial policy, then, is the custom design of policy instruments to fit the differing priorities, needs, and circumstances of individual industries, particularly with respect to factor inputs... The inventory of policy instruments to achieve these and other objectives is fairly standard, including such measures as tax incentives, R&D subsidies, restriction of foreign imports and so forth".

A cursory search on the internet yields the following definitions for industrial policy:

- "Government policy to influence which industries expand and, perhaps implicitly, which contract, via subsidies, tax breaks, and other aids for favoured industries. The purpose, aside from political favour, may be to foster competitive advantage where there are beneficial externalities and/or scale economies."[73]
- "A program of selective government interventions designed to change the sectoral composition of a country's economy by influencing the development of particular industries or sectors. Targeted sectors or industries may be aided through some combination of government loans and equity participation; tax incentives to promote investment; trade protection and export subsidies; preferential government procurement practices; or relief from regulatory constraints such as antitrust and environmental laws."[74]

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[72] Daniel Okimoto, *Between MITI and the Market: Japanese Industrial Policy for High Technology*, Stanford: Stanford University Press, 1989

[73] www.personal.umich.edu/~alandear/glossary/i.html

[74] www.itcdonline.com/introduction/glossary2_i-p.html

- "An industrial policy is any government regulation or law that encourages the ongoing operation of, or investment in, a particular industry. It is often related to, or wholly determinant of, investment policy for that industry."[75]

Industrial policy is typically utilised to achieve a number of national goals. These may include industrial catch-up, protection against foreign economic and political domination, the creation of the maintenance of full employment, raising productivity or strengthening international competitiveness.

South Africa's Industrial Policy
The Department of Trade and Industry (dti) in South Africa has also formulated a National Industrial Policy Framework (NIPF)[76]. The Department notes that, "The NIPF is a policy framework and not a blueprint for the industrial economy. Its core objective is to set out government's approach to South Africa's industrialisation trajectory and hence help align both private and public sector efforts towards this end. Although the NIPF aims to improve growth and employment conditions across much of the economy generally, its primary focus is on the relatively low-medium skill intensity industries: non-traditional tradable goods and services in the primary, manufacturing and services sectors of the economy. By 'tradable' is meant both exportable and import competing goods and services."

3.3.1.6 Competitiveness
It was mentioned earlier that the difference between invention and innovation is that whereas invention creates new knowledge, innovation creates new wealth. Hence the importance of focusing on innovation rather than on invention as the goal. In a similar manner the importance of competitiveness cannot be over-emphasised[77]. Rather than considering innovation per se to be the ultimate goal, competitiveness is an overarching goal. Recall the quote from Michael Porter that "A nation's competitiveness depends on the ability of its industries to innovate". It is evident that a tight link exists between competitiveness and innovation - innovation is an instrument to attain competitiveness.

The importance of competitiveness has been recognised in a number of South African policy documents and declarations for a long time. The White Paper on Science and Technology of September 1996 refers to "…promoting competitiveness", and "…identifying niche markets in which international competitiveness can be improved"[78]. Early in 2000 President Mbeki convened an International Investment Council which also stressed the importance of competitiveness[79]. A newspaper report of the President's keynote address at the national general council meeting of the ANC in July 2000 was headlined

[75] www.wikipedia.org/wiki/Industrial policy
[76] Department of Trade and Industry, *National Industrial Policy Framework*, 6 August 2007; http://www.thedti.gov.za/nipf/niPF-3aug.pdf
[77] C.W.I. Pistorius, "South Africa's Competitiveness Trap", *South African Journal of Science*, Vol 97, January/February 2001, pp. 9-15.
[78] Republic of South Africa, Department of Arts, Culture, Science and Technology. (1996). *Preparing for the 21st Century*, White Paper on Science and Technology.
[79] F. Chotia and J. Katzenellenbogen, "Investment path 'hard but hopeful'", *Business Day*, 7 February 2000.

"Competitiveness is Mbeki's call to arms"[80]. In August 2000 the Department of Trade and Industry announced a restructuring and confirmed that its strategy included "Strengthening the competitiveness of South African business internationally"[81]. The emphasis on competitiveness continues to be emphasized, as it should be. The NACI Act also refers to one of NACI's objectives as, inter alia, advising the Minister on "strengthening the country's competitiveness in the international sphere". The Act refers to competitiveness as a national objective. It is interesting to note that both the Department of Science and Technology and the Department of Trade and Industry put competitiveness high on their respective agendas. It is essential that the necessary coordination should be done in this regard. From an advice viewpoint, it should be noted that the NACI Act requires that a representative from the Department of Trade and Industry also serves on NACI.

Whereas a strong public policy on innovation is essential, ultimately it is competitiveness that counts. It is therefore important that competitiveness, in own right, be recognised as an important national objective, and that this importance is reflected in its treatment in public policy, organisational structures (including portfolios of government departments) as well as advisory structures.

Competitiveness spans a wider spectrum of issues than innovation. It was stressed previously that in order for a nation to be competitive, it must be innovative. This applies particularly to a nation's industries, where the industries must be interpreted to include private and public industries, manufacturing and service industries. Innovativeness is, however, a necessary but not sufficient condition for competitiveness. The government must also create an environment that promotes the competitiveness of the nation.

The *World Economic Forum* annually publishes a competitiveness index in the *Global Competitiveness Report*, where the majority of the world's economies are ranked according to their competitiveness[82]. The following factors are taken into account, and hence contribute to a nation's competitiveness:

- Basic requirements
  - Institutions
  - Infrastructure
  - Macroeconomic stability
  - Health and primary education
- Efficiency enhancers
  - Higher education and training
  - Goods market efficiency
  - Labour market efficiency
  - Financial market sophistication
  - Technological readiness
- Innovation and sophistication factors
  - Business sophistication
  - Innovation

80 L. Loxton, "Competitiveness is Mbeki's call to arms", *Pretoria News*, 13 July 2000.
81 H. Ludski, "Ruiters, Erwin pull DTI into shape", *Sunday Times*, 13 August 2000.
82 http://www.weforum.org/en/initiatives/gcp/Global%20Competitiveness%20Report/index.htm

IMD is another organisation that produces an annual competitiveness ranking for countries, known as the *IMD World Competitiveness Yearbook*[83], where a similar array of factors is taken into account with regard to the measurement of innovation.

The importance of competitiveness, whereby innovation is included as shown above, presents a strong case that a country must also have a competitiveness strategy. Such a competitiveness strategy will encompass the innovation strategy as depicted in Figure 3.2. However, it must, as is suggested above, also address a variety of other matters that are not addressed by the innovation strategy. Given the importance of competitiveness, its is essential that the advisory structures also be established to address it. It should also be included in the provision of "science advice to government", as is the case in the NACI Act as it stands. It is interesting to note the work of an organisation such as the Council on Competitiveness in the US[84], a non-governmental organisation that promotes the competitiveness of US industries.

3.3.2 "Government"

In the section above it was shown that the term "science" can and should be interpreted broadly in the context of "providing science advice to government". In order to arrive a robust structure that can provide "science advice to government, it is also necessary to interpret the term "government" in a similar manner. In the section below, the various components of government will be briefly discussed. The science advice needs of each, together with international practices are then further explored in a later section. Refer also to the supplementary report (*A review of the international bodies that provide science advice to Government*) that accompanies this report.

A typical democratic government will have three branches, viz. a legislative branch, an executive branch and a judiciary branch. The legislative branch passes legislation, including state budgets, and also has an oversight function to ensure that the executive branch executes the laws. The executive branch executes the government's policies, whereas the judicial branch upholds the laws, particularly through the courts. In a typical democracy there will be a hierarchy of courts, including a Constitutional Court, Appeal Court, Higher Courts, and also various lower courts.

In South Africa, the legislative branch is Parliament, which is composed of the National Assembly and the National Council of Provinces. Similar structures in other countries are the House of Parliament in the UK, the Congress in the US and the Bundestag in Germany. Very often the legislative branch has an upper house and a lower house.

The executive authority is vested in a head of the state or head of the government, who typically appoints government ministers. In South Africa, the President is the

[83] http://www.imd.ch/research/publications/wcy/upload/factor_breakdown.pdf
[84] www.compete.org

executive head of state and head of the national executive. In addition to the various cabinet ministers, there is also a Deputy President, who is appointed by the President. A similar situation prevails in the US. In many Commonwealth countries, such as the UK, Australia and Canada, the head of state has no real executive powers and has more of a ceremonial role. In these countries, the executive power is vested in the Prime Minister. In the rest of this report, the term “head of state” will mean the head of the executive, i.e. executive President (as in South Africa and the US) or the Prime Minister (as in the UK, Australia and Canada).

The President, Deputy President and Ministers together form the Cabinet. Each minister has a portfolio assigned to him or her by the President for which s/he is responsible and an associated government department that reports to the minister. The director-general, who reports to the minister, manages the department. Under Section 92 of the South African Constitution[85], the members of Cabinet are collectively and individually accountable to Parliament for the exercise of their powers and functions.

Many countries are divided into regions, where every region also has governing powers. In South Africa, the regions are the provinces. They have their own legislative branches and executives. Every province has a Premier and a number of MECs (Members of the Executive Council), each of which is responsible for a portfolio. In the USA, the regions are the states, each of which has a legislative branch as well as an executive, headed by the Governor. A similar arrangement is found in Australia and Canada.

On the local level, municipalities (or larger metropolitan areas) have local governments. In South Africa the executive and legislative authority of a municipality is vested in its Municipal Council. The executive function is headed by the Mayor, assisted by members of a mayoral committee (or similar structure), each responsible for a department on the local level.

It is clear that the term “government” represents a wide spectrum of bodies that are responsible for governance at various levels. The national, provincial and local levels all have executive functions, which include a head and a cabinet-type committee, the members of which are responsible for departments as well as legislatures. In addition, there is a national judiciary, with a number of different types of courts. Decisions at various levels of government in South Africa need to be coordinated in accordance of the principle of cooperative government and intergovernmental relations as set out in Chapter 3 of the South African Constitution.

All levels and branches of government are continuously faced with decisions that have science, technology and innovation (STI) components and implications. The decisions include the formulation of policy, execution of policy, monitoring of policy, allocation of resources or upholding the law. In all of these cases, it is also necessary for the government to have access to advice on the STI issues with which they must deal. Very often STI expertise is or should be available in-house. The point was made in previous sections, though, that an autonomous external science

[85] Constitution of the Republic of South Africa, adopted on 8 May 1996 and amended on 11 October 1996 by the National Assembly. Act 108 of 1996.

advisory function is necessary. This can provide independent external advice, garner and test public opinion and soundboard the reasoning of the internal expertise.

Figure 3.3 shows a conceptual “Government-Science”-space that is to be covered by appropriate structures to provide science advice to government. “Government” is presented along an axis which provides for the Executive branch (President, Cabinet, Ministers and government departments) on the national level, the Parliament as well as Judiciary branch, as well as the Provincial and Local structures. In an analogous manner, “Science” is presented on the other axis, following the discussion in the previous section. It was shown that in the context of the term of providing “science advice to government”, the term “science” must be interpreted to account for the entire spectrum, including basic and applied science, technology, engineering through the innovation components. These can include aspects such as intellectual property, tax and competition policies, promotion of science parks, commercialisation and technology transfer and international STI-agreements. The two axes then define a “Government-Science”-space. This entire space must, in the ideal case, be served by science advisory structures. No single science advisory structure can do this. This fact is borne out by an examination of international practice, where it is evident that countries all utilise a number of different science advisory structures. [86]

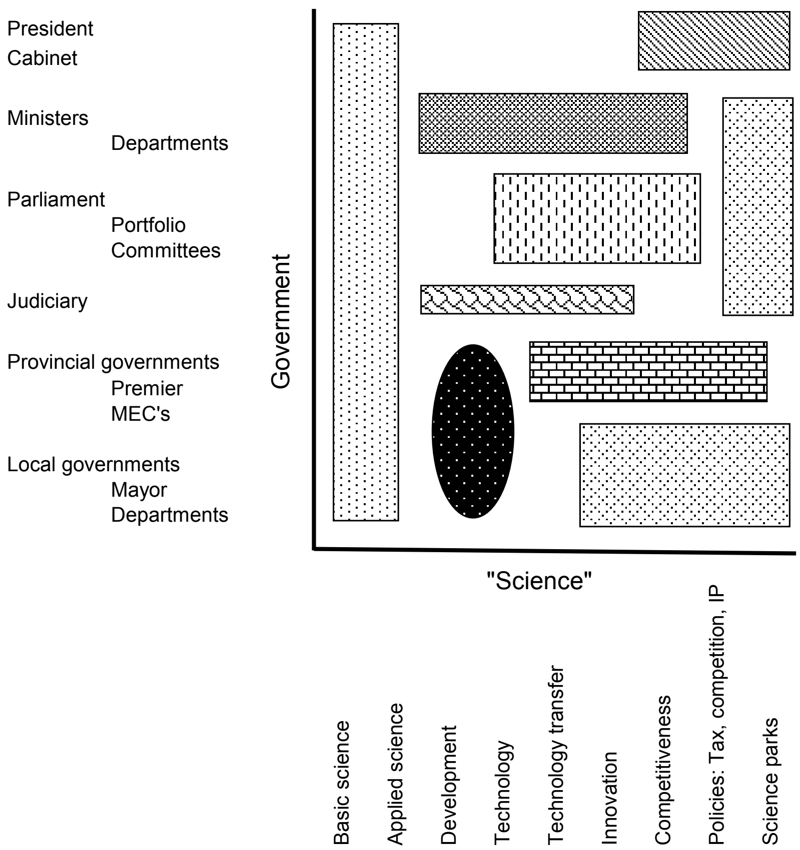

Figure 3.3: The Government-Science space
The blocks represent conceptual science advisory bodies

[86] Sara S. Grobbelaar, *A review of the international bodies that provide science advice to government*, 2008.

A constellation of science advisory bodies is required to provide “science advice to government” in a modern National System of Innovation, including that in South Africa. The purpose of this report is to make exactly this point, and then to sketch the context within which the various science advice structures can be identified and their characteristics be developed.

3.3.3 “Advice”

3.3.3.1 The nature of advice

“Advice”, also sometimes referred to as “counsel” has been defined as “recommendations as to appropriate choice of action”[87]. In this report the emphasis is specifically on providing science advice to government. Although government can and must also rely on its internal and in-house expertise, the main thrust of this report is on the necessity of external, independent and autonomous advice, and the nature of structures that should be in place to provide it.

In the context of providing “science advice to government” it is important to distinguish between the concepts of “advice”, “consultation” and “coordination”. Although most of the advisory structures and modes described below are of formal nature, it should be kept in mind that there are always modalities whereby decision makers are offered and obtain advice in informal ways. These can be very important, but are not addressed in this report.

“Advice” is interpreted as that which an advisor would render to a policy maker. The advice can be of informative nature, but should, as was discussed earlier, enhance the policy maker’s decision-making ability. It should therefore provide decision support. Once the advice has been received, the policy maker has a number of options, including accepting the advice *in toto*, rejecting the advice, partially accepting the advice, often combining it with other inputs or referring the advice back to the advisors for refinement or to someone else. The policy maker need not necessary accept or follow the advice, although in some cases legislation or other regulations provide that the policy maker must provide reasons if s/he does not. The Higher Education Act in South Africa determines, for example, that the Minister of Education must provide reasons in writing if s/he does not follow the advice of the Council on Higher Education (CHE).

“Consultation” occurs when a policy maker is in discussion with the “advisors” and interactively participates in the process. If the decision is taken “in consultation” with the advisors of others in the meeting, it implies that a joint decision must be taken, typically whilst the discussions are in process. A decision taken “after consultation” implies that the policy maker must consult with the “advisors” or others with whom the consultation is held, but can take a decision after being consulted. One may find, of course, that “advice” is given during “consultation”. The policy maker is typically not part of the advisory process – otherwise s/he would be advising her or himself. This can rather be considered to be “consultation” than advice.

[87] Collins English Dictionary.

"Coordination" often implies that a policy maker must coordinate the activities of others, be they individuals, committees, departments or groups. One can find that a body exists where STI activities must be coordinated, and that some members of such a body may be experts who provide advice. There are many examples of bodies where STI coordination is done at a high level of government. Very often advisors may be part of such coordination meetings, but the advisory function is typically secondary in this case.

The process of "providing science advice to government", usually includes a translation of the "scientific facts" into the policy domain, where the science must be interpreted within contexts that include the political, social, economic and very often also international arenas. This is a subtle, but important point. The science advice that an advisory body presents is typically evidence-based. The findings are often the consolidated view of prominent scientists and engineers, and as such emphasize the scientific and technological aspects of the issue at hand. In its "basic" form, advice on science would in some way or another refer to a consensus amongst scientists regarding the current state of knowledge regarding some aspect of science. This aspect, and advice associated with it, deals essentially with what is known about the laws of nature. One of the major purposes of providing science advice to government, however, is to support the decision-making capacity of whomever the advice is provided to. Very often these decisions must be made in a multi-faceted context where social, cultural, economic and environmental aspects, for example, also play an important role under varying degrees of uncertainty and risk, as was mentioned before.

3.3.3.2 Characteristics of "good advice"

A discussion on the structures that should provide science advice to government will not be complete without some reference to the characteristics of good advice. A brief discussion is therefore included below. This discussion is by no means comprehensive or exhaustive, but indicates the nature of the topic. It is necessary to explore the characteristics of good advice further when the structures that must provide science advice to government are formalised, since it must be embedded in their briefs and mandates.

"Good policy advice recognizes that physical truth may be poorly or incompletely known. Its objective is to evaluate, order and structure incomplete knowledge so as to allow decisions to be made with as complete an understanding as possible of the current state of knowledge, its limitations and its implications. Like good science, good policy analysis does not draw hard conclusions unless they are warranted by unambiguous data or well-founded theoretical insight. Unlike good science, good policy analysis must deal with opinions, preferences and values, but it does so in ways that are open and explicit, and allow different people, with different opinions and values, to use the same analysis as an aid in making their own decisions"[88]

Good policy analysis and advice will only be useful if it is communicated in an appropriate manner to the intended audience, typically the policy makers. As was mentioned before, policy makers are not necessarily scientists, and hence the

[88] M Granger Morgan, "Bad Science and Good Policy Analysis", *Science*, 201, September 1978, p. 971.

communication mode should couch the scientific issues in a manner which is clear to the non-scientist. Clarke and Majone[89] mention four criteria by which policy objectives should be judged, being adequacy, value, effectiveness and legitimacy. Branscomb interprets this view to the effect that "The work is seen as adequate if the data gathering, analysis and interpretation are done according to the best professional standards; the 'right' results are obtained. It has value, however, only if the problem being addressed is timely, important, and is correctly defined so that the analysis is relevant to a policy issue of importance. Adequate work of value may still be of little use if it is not effective, that is, if the management environment into which it is injected is not in a position to implement its conclusions. Only if those actions, and the analysis and policy recommendations on which they are based, are seen by the public as legitimate will anything of lasting value to society result".[90] Good scientific advice must adhere to a number of criteria, including relevance, impartiality and credibility.

Branscomb proceeds to pose a number of questions where he uses the criteria to test the institutions and also the processes of science and technology advice, viz.

- How can political leaders enhance the capacity of technical experts to provide useful advice?
- How can government enhance its managerial capacity to benefit from science advice?
- How can technical elites earn more influence over science-dependent policy decisions?
- How can science and technology advice contribute to informed and rational self-government in a world of increasing technical complexity?

He mentions four major shortcomings of the structures and processes for science advice in the US, viz.

- High-level science and technology perspectives are inadequately present in policy determinations where the issues are not seen as primarily technical.
- High-level science and technology advice to the executive branch does not effectively address long-term issues of broad technical scope, especially when the government's objectives are not clear nor strongly publicly supported.
- The objectivity of advisory bodies suffers from the self-serving nature of the advisory bodies when addressing the needs of their own community.
- The utility of science and technology advice requires that expert advisors achieve technical and political legitimacy.

Branscomb concludes by noting that, "…No institutional mechanism for advising a President can overcome a President's disinterest; no President desirous of independent advice on a scientific matter will have difficulty satisfying his need. But well-constructed and managed advisory bodies can not only help the nation take advantage of the knowledge available to its citizens, but can help empower those citizens to hold their public representatives accountable and strengthen democracy".

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[89] William C. Clarke and Giandomenico Majone, "The critical appraisal of scientific inquiries with policy implications", *Science, Technology and Human Values*, Vol 10, No 3, Summer 1985, pp. 6-19 (as quoted in Branscomb).
[90] Lewis M. Branscomb, *Confessions of a Technophile*, American Institute of Physics, 1995.

The report on the role of science and technology in achieving the Millennium goals[91] mentions a number of factors that can increase a science advisory board's effectiveness, viz.:

- The board should have some form of statutory, legislative or jurisdictional mandate, specifically to deliver advice to the highest level of the government. This will protect the advisor from "being unduly influenced by political pressures and provides the credibility and regularity to interactions between the advisory and the decision-making roles of government".
- The advisory structure must have its own budget, for operations as well as the funding of research.
- The advisory structure must have access to STI-related information, locally as well as internationally.
- The advisory structure must have some accountability to the public, including mechanisms to garner public opinion.

3.3.3.3 Types of advisory structures

The research that underpins this report has shown that there are a large number of different types of bodies that can provide "science advice to government".[92] Referring to Figure 3.2 above, these would be the types of advisory structures that are represented by the various blocks in the conceptual diagram. Each of the types of structures briefly discussed below can, in principle, be utilised to give advice to any component of the "government", in each of the areas of "science", although some will be more appropriate than others. The supplementary report (*A review of the international bodies that provide science advice to government*) provides many international examples of the various types of advisory mechanisms discussed here.

In general, the major types of advisory modes include the following:

- Individuals
    - o Individual advisors can be appointed as to advise individual policy makers, or to advise committees (such as the Cabinet). Some heads of state have a Science Advisor, for example. A Minister of Science and Technology may also appoint a specific individual or individuals as advisors. In some cases an individual may advise a committee (such as the Cabinet). Such individual advisors are usually formally appointed in this capacity, and serve at the pleasure of whoever appointed them.
    - o Opinion leaders. Specific individuals who are highly knowledgeable about a certain topic may be requested to give ad hoc advice by the policy makers, or may offer or volunteer such advice. This can either happen in public or private. Very often opinion leaders also give their advice in informal settings or modes.

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[91] Calestous Juma and Lee Yee-Cheong (coordinators), *Innovation: Applying knowledge in development*, UN Millennium Project Task Force on Science, Technology and Innovation 2005, Earthscan, London.

[92] See specifically the supplementary report *Reviewing structures to provide science advice to government in South* Africa by Sara S. Grobbelaar; and Deborah D. Stine, *Science and TechnologyPolicymaking: A Primer*, CRS Report, RL34454, 18 April 2008.

- Standing advisory committees
  A standing committee can be appointed with the specific purpose of advising an individual or other committee. Such a standing committee will have a specific brief and mandate. The members of the committee are appointed by the head of state, minister, or other official that must be advised. Members are usually appointed for a specific period, which in many cases can be renewable. Such advisory committees are often statutory committees, i.e. they are created by legislation. Examples of standing committees that provide science advice to government include the National Advisory Council on Innovation (NACI) that advises the Minister of Science and Technology in South Africa and the President's Council of Advisors on Science and Technology (PCAST) that advises the President of the United States. In the interest of trust, the deliberations and advice of such committees usually have an element of confidentiality, but their work is often also made available in the public domain.

- Ad hoc committees and working groups.
  An ad hoc or working group can be formed to provide advice on a specific topic. Such a committee will typically be constituted to address a specific issue, have a mandate to this effect and disband once the work has been done. The committees that participate in studies of the National Academies in the US are examples of such committees.

- Public and other not-for-profit organisations.
  Institutions such as universities and science councils are ideally suited to provide science advice to government, especially on an ad hoc basis with regard to specific issues. Very often they have specific research institutes or units that focus on the issues of interest. Think tanks, public or private, are also often utilised in this manner. These institutions can either be requested to respond to specific requests for advice, or can offer advice of their own accord.

- National academies
  National academies are very regularly used to provide science advice to governments. In fact, the National Academies in the United States, consisting of the National Academy of Sciences, the National Academy of Engineering, the Institute of Medicine and the operational arm, the National Research Council, were created for specifically this purpose. When a national academy provides science advice, it will usually form a task team of individuals who are knowledgeable about the topic, rather than having a standing committee to address all matters. National academies pride themselves on the independence of their advice, and the advice is usually made available in the public domain. In South Africa, the *Academy of Science of South Africa* (ASSAf), the *South African Academy of Engineering* (SAAE) and the *Royal Society of South Africa* (RSSAf) can also be contribute significantly towards providing science advice to government. According to the OECD report on South Africa's National System of Innovation, neither of these bodies appears to have a significant influence on government policy.[93]

[93] OECD, "OECD Reviews of Innovation Policy: South Africa", 2007.

- Forums
  Various types of forums are also used as mechanisms to provide science advice to government. Very often the forums are not decision-making bodies, but rather mechanisms to gather and test public opinion, and act as arenas for public debate on matters of science and technology. The *National Science and Technology Forum* (NSTF) in South Africa is an example. Forums and other forms of public meetings are also sometimes used by other structures to gather public opinion. NACI has held a number of such meetings, for example the workshop in July 2007 to discuss the findings of the OECD report on the National System of Innovation in South Africa. Public debate and opinion is very important in science and technology discourses and should be encouraged. Input from interested parties and the public can be successfully solicited electronically via email or a website. Once the input has been obtained, it is also useful and necessary to give feedback as to what was contributed and what happened to the inputs.

- Labour and professional organisations
  Labour organisations and trade unions can also contribute science advice to government. They can do this through a variety of mechanisms, including their members that may serve on other bodies and committees mentioned, in response to direct requests and also via unsolicited opinions. Professional organisations, such as the *South African Institute of Electrical Engineers* (SAIEE), and trade organisations, such as the AHI for example, can make similar contributions.

- Advocacy groups
  There are many advocacy and lobby groups who promote various causes, many of which have STI-implications. Environmental and health groups are typically very prominent world-wide in this regard.

- International STI organisations
  There are many international organisations that have STI expertise, which can be applied as science advice to government. These include, for example, the OECD (as was illustrated by their analysis of the South African National System of Innovation in 2007), the United Nations and its agencies, the World Health Organisation (WHO) and the World Bank.

3.3.3.4 Receiving advice

One of the often neglected or overlooked aspects when discussing the nature of scientific advice structures, is what to do with the advice once it has been received. It is one thing for solid and well-founded advice to be generated, but what does the Minister or policy maker do with the advice once it has been delivered to him or her? Very often the Minister has a sparsely populated Ministry, and hence the advice is often just passed on the line department instead. This may not always have a desirable outcome.

Ciampa[94] mentions a number of rules for taking advice, viz:

- "Keep an open mind and pay close attention to the advice of people who may be more objective than you are. Make sure you grasp fully what they perceive and you may have overlooked.
- Never make an important decision on the basis of how it might affect your status in others' eyes. Doing so often leads to misreading or underestimating what it takes to succeed.
- Put together a balanced advice network. Avoid over relying on the kinds of advice one feels most comfortable with at the expense of mastering new abilities.
- When help is available, use it. Never allow pride or shame to get in the way.
- When a goal is so important that you are willing to risk a lot to achieve it, pay particular heed to the advice of the people whose support you need."

He continues to note a number of fundamental principles of advice taking, viz.

- "The leader's needs should determine both the content of the advice he receives and the nature of the relationship between the leader and advisor. Advisors should adapt the help they provide to the leader' style and the situation he faces, always viewing their own role and contributions from the advice taker's point of view.
- Different challenges call for different types of advice and different types of advisors. It is the leader's responsibility to understand his needs well enough to choose among the various kinds of help available. It is then up to the leader to manage his relationships with advisors to ensure that he received what he needs in the most actionable way.
- Opinions of the leader on the part of the followers, bosses, and other stakeholders – a key component of the leader's credibility – will be enhanced by wise and skilful use of advice.
- In the most challenging leadership situations, the issues facing the leader have different impacts on success. The most problematic are political or personal in nature, and the right advice is particularly indispensable in those spheres".

Referring to the suggestion that different types of advisors may be more appropriate in different situations, it is useful to distinguish between experts, experienced advisors and advisors who act as sounding boards. Ciampa mentions a number of key success factors for successful advice takers, viz. they find advisors before problems are faced that require their skills, and build relationships with them; they give advisors access to them; and they don't expect the advisors to do the advice takers' jobs.

[94] Dan Ciampa, *Taking advice, How leaders get good counsel and use it wisely*, Harvard Business School Press, 2006.

Chapter 4
Current science advisory structures in South Africa

4.1 Introduction

South Africa is no stranger to the notion of advisory bodies that provide independent advice to government, including scientific advisory bodies. The next section gives a brief overview of South African scientific advisory bodies pre-1994, for the sake of completeness. The National Advisory Council on Innovation (NACI) is then discussed in some detail, including references in the White Paper on Science and Technology, the subsequent NACI Act and the establishment of NACI, including the Act's interpretations of the terms “science”, “technology” and “innovation”, the “First” and “Second” NACI councils, NACI's subcommittees and task teams, the setting of NACI's agendas and work programmes, NACI's roles vis-à-vis the DST and a re-examination of the NACI's role. Following the discussion on NACI, a number of other scientific advisory bodies in the country are briefly discussed, including the science councils, academies and bodies advising the President, ministers and some government departments.

4.2 Pre-1994 structures[95]

4.2.1 The period from WWI until the outbreak of WWII (1910s to 1930s)

In 1916, the Industry Advisory Board was established under the auspices of the Ministry of Mines and representatives of industry and commerce. This was the first attempt in South Africa at public support for industrial and academic research at a time when recommendations to this effect were being prepared in the wake of a conference of scientific and technical associations. The establishment of the Scientific and Technical Committee was a secondary development to undertake and coordinate all industrial research undertaken in the country.

As the coordination function of the Industry Advisory Board and the Scientific and Technical Committee presented problems, the South African government decided on the amalgamation of the two bodies. As a result, the Advisory Board for Industry and Science was established in 1918. After World War I, a period of economic decline followed. These circumstances increasingly inhibited the work of the Board and it was disbanded in 1923. A very important outcome of the Board's work was the appointment of a Technical and Scientific Advisor[96].

The appointment of the first Scientific and Technical Advisor to Government in 1919 represents one of the most important developments in the first decade of formal science and technology policy development. Prime Minister Jan Smuts appointed Dr H.J. van der Bijl, at that time involved in research in the field of electronic

[95] This section was contributed by Dr. Sara S. Grobbelaar.
[96] H.C. Marais, H.C, *Perspectives on Science Policy in South Africa*. Network publishers, Menlo Park, 1999.

engineering in the United States, to become his scientific advisor. Dr van der Bijl set out to ensure South Africa's future independence in techno-scientific areas by developing a strategy to resolve research priorities. Although the Hertzog government did not implement many of his recommendations, a number of Dr van der Bijl's views are noteworthy, viz.

- He stressed the importance of research support for industrial development in view of increasing international competition.
- The establishment of a comprehensive government research institute in line with what was being established in Commonwealth countries and in the UK. (South Africa had to wait until 1945 before this idea would become a reality).
- The identification of strategic research priority areas for the country.

The more immediate effective contribution of Dr van der Bijl was the role he played in the establishment of ESKOM (responsible for electricity production, founded in 1923), ISCOR (Iron and Steel Corporation) and the IDC (Industrial Development Corporation, founded in 1940). All of these corporations contributed significantly to the industrial development of South Africa.

4.2.2 Strategic science (1940's to 1970's)

As World War II broke out, the South African economy had to substitute many of its imported products, including oil. The country also had to supply armies in Africa as well as the Middle East, with products ranging from vaccines to food. During this period, South Africa was required to develop manufacturing abilities to produce spare parts for aircraft, boats and other equipment and to start manufacturing armaments such as rifles, bombs, armoured vehicles and precision equipment, including radar. At the same time, the search for minerals such as titanium, vanadium, chromium and uranium received a new boost. The outbreak of World War II also resulted in South Africa experiencing its first industrial revolution, from which it would not revert back to a purely primary economy[97].

In 1945 the South African Prime Minister, General Jan Smuts, appointed Dr Basil Schönland as scientific advisor to the Prime Minister. The scientific advisor's major objective was to formulate a strategy for establishing a body to advise the South African government on the best methods to co-ordinate scientific research in the national interest and for developing the country's natural resources to the full. The proposals Schönland put forward adopted the Canadian and Australian research councils as the most appropriate models. The Scientific Research Council Act was subsequently passed in June 1945, and few months later a state research laboratory, the CSIR, was established[98].

The CSIR continued to play the role of initiator for projects with strategic significance for the future. In 1952, the CSIR was placed under the Department of Economics'

[97] CENIS, *Science in South Africa: History institutions and statistics,* University of Stellenbosch, 2000.

[98] H.C. Marais, *Perspectives on Science Policy in South Africa*. Network publishers, Menlo Park, 1999.

control, which led to the loss of the CSIR's inter-ministerial status and its ability for arbitration. The president of the CSIR was also no longer the Scientific Advisor to the Prime Minister.

Other research institutes slowly started to emerge independently from the CSIR. A number of other councils were established, including the South African Bureau of Standards (SABS), the Atomic Energy Corporation (AEC), the Council on Minerals Technology (later MINTEK), the Medical Research Council (MRC), the Human Sciences Research Council (HSRC), the Council on Geosciences and the Foundation for Research Development (FRD, now the NRF). Although the main functions of the science councils were research and development in their areas of interest, many were also in one way or another involved in producing science advice.

Even though South Africa lagged behind other commonwealth countries in terms of the establishment of science councils, the organisational space became densely populated after the 1960s[99]. The 1960s and 1970s were characterised by tight government control of the science councils and the council presidents were all ministerial appointments[100].

The wide involvement of state departments, science councils and universities in R&D led to the introduction of the Scientific Advisory Council of the Prime Minister in 1962, with the Scientific Advisor to the Prime Minister as chairman. The main task of the Science Advisory Council was meaningful advice from the scientific community to the authorities, the coordination of the state funded research effort and informed input regarding the allocation of funds. It was the scientific advisor's responsibility to advise government on research priorities – for this reason the council devoted its energies primarily to the formulation of a national science policy[101].

4.2.3 The 1980s and early 1990s

In 1980, the Office of the Scientific Advisor was converted to the Science Planning Branch, followed by the abandonment of the scientific advisor's position. The renamed Scientific Advisory Council no longer advised the Prime Minister directly, but reported to the Minister of Constitutional Development and Planning until 1985 and after that to the Minister of National Education. These changes not only extended the science advisory channels to the highest authorities, but also placed the final authority for science coordination in the hands of the respective ministers, who served as the political heads of government departments of South Africa.

A major function of the Scientific Advisory Council (SAC) was to coordinate the annual financial proposals of the then five statutory research bodies (CSIR, HSRC, MRC, Mintek and the SABS), negotiate the budget with Treasury and advise Treasury on the distribution on the final Treasury award among these bodies. An

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[99] H.C. Marais, *Perspectives on Science Policy in South Africa*, Network Publishers, 1999.

[100] CENIS, *Science in South Africa: History, instutions and statistics*, University of Stellenbosch, 2000.

[101] C. Garbers, "South African science planning: Western-styled to Africa-specific", in *Worldwide science and technology advice to the highest levels of government* by W.T. Golden (ed), Pergamon Press, New York, 1991, pp. 393-402.

example of advice that was given by the SAC was when the Science Planning group created a document which, with the support of the members of the SAC, was submitted to government and resulted in the appointment of a Minister of Economic Affairs and Technology and in the establishment of an Advisory Council for Technology[102]. The Advisory Council for Technology was responsible to the Minister of Trade and Industry and its executive arm, the Directorate: Technology Promotion. The Council (established in 1987) had a total membership of eleven, which included the heads of the CSIR and Mintek. The Scientific Advisory Council was however criticised for a lack of transparency, limited oversight of the system and the composition of its membership[103].

A significant development was the establishment of the National Science and Technology Forum (NSTF), a broad consultative forum where a variety of role players share their views on S&T-related matters. A notable event was the IDRC investigation into the science system in 1993, which gave significant direction to S&T policy and system post-1994.

4.2.4 Major developments in the South African S&T system after 1994

Following the 1994-elections, the new ANC government reviewed public policies and developed numerous new policy imperatives, thereby setting the country on a course where all citizens could benefit from and contribute to economic growth and social development. The socio-economic development of previously disadvantaged individuals was a priority for the new South African government.

The creation of the Department of Art, Culture, Science and Technology (DACST) in 1994 was a step towards creating a vehicle for government to focus its role in developing a science and technology system that would respond to the government's priorities. One of the first major initiatives of the DACST was the development of the White Paper on Science and Technology in 1996, described in more detail elsewhere in this report.

4.3 The National Advisory Council on Innovation (NACI)

In this section the National Advisory Council on Innovation (NACI) is discussed in some detail. Not only is NACI currently on of the major role players in providing science advice to government, but it was mainly a recommendation from NACI that the entire structure that provides science advice to government be reviewed (including the role of NACI itself) that prompted this report.

[102] F.R.N. Nabarro, "George Campbell Lecture: The Organisation of Science and Technology in South Africa", University of Natal Press, 1990.
[103] C. Garbers, "South African science planning: Western-styled to Africa-specific", in *Worldwide science and technology advice to the highest levels of government* by W.T. Golden (ed), Pergamon Press, New York, 1991, pp. 393-402.

4.3.1 NACI as anticipated in the White Paper on Science and Technology (1996)

The White Paper on Science and Technology recognised the need for structured science advice and an associated advisory body, and subsequently anticipated the establishment of a National Advisory Council on Innovation (NACI). The White Paper comments as follows,

> "Government has a constant need for informed advice about the problems and opportunities facing our country, and in no area is this more true than in the concern for the stimulation of innovation in the pursuit of our national vision. Accordingly, a National Advisory Council on Innovation (NACI) will be created by legislation. The Council will be charged with carrying out enquiries, studies and consultations with respect to the functioning of our national system of innovation, as requested by the Minister.
>
> The Council will
> - consist of up to 22 individuals, appointed in their own capacities by the Minister, and drawn from the many different stakeholder groups in our national system of innovation
> - conduct enquiries, studies and consultations consistent with its legislated mandate and initiated on the request of the Minister
> - take steps to ensure that the subjects and terms of reference of its activities are made public
> - be provided with a small independent secretariat and a budget administered by DACST, with which to commission relevant activities, including policy research, in support of its programme of work.
> - play an advisory rather than an operational role.
>
> DACST will be mandated to provide NACI with terms of reference for studies relating to outstanding issues raised in the Green Paper[104], in consultation with other relevant government departments. In addition, NACI will be invited to advise DACST on an overall framework for the proposed reviews of government-financed SETIs and will have a continuing role in providing commentary on completed reviews to DACST.
>
> The establishment of NACI will not reduce the important role of the National Science and Technology Forum (NSTF). Although the NSTF has a strong government sector within it, it is essentially a non-governmental body which has full powers to decide on its own role and functions. Government will look forward to continuing the pattern of dialogue with the NSTF which has developed in recent years."

[104] Department of Arts, Culture, Technology and Science. The *Green Paper on Science and Technology*, which preceded the White Paper on Science and Technology.

It is important to note that the necessity of providing science advice to government was in principle, recognised and endorsed in the White Paper. The fact that a council populated by external experts was proposed, implies that the principle of independent advice was similarly recognised and endorsed. Moreover, it was recognised that the Minister of Science and Technology should have an input to the matters on which advice should be rendered. The White Paper did not, however, foresee that NACI would advise the Minister but rather the DACST.

4.3.2 The establishment of NACI and the NACI Act

NACI was subsequently established with the promulgation of the NACI Act in 1997 (the National Advisory Council on Innovation Act, Act 55 of 1997 published in Government Gazette 18425 on 14 November 1997). The NACI Act is given in Appendix A of this report. It is useful, however, to highlight a number of the salient features here.

The NACI Act defines the “Department” as the “Department of Arts, Culture, Science and Technology” (DACST). It was noted earlier in this report that DACST was “unbundled” in July 2002, when two separate Departments were created, viz. the Department of Science and Technology (DST) and the Department of Arts and Culture (DAC), each with its own Minister. After the unbundling it was implicitly assumed that NACI would advise the Minister of Science and Technology and that the “Department” would be the DST.

According to the Act, the de jure and certainly the de facto role of NACI is to *advise* the *Minister*, and through the Minister the Ministers Committee and the Cabinet. This is in contrast to the White Paper, which recommended that NACI will advise the DACST. The relationship between NACI and the DST (as well as DACST preceding the DST) is an important issue with regard to the functioning and effectiveness of NACI, and must be explicitly addressed. It is important to note that in its “definitions”, the Act designates the Director-General of the Department as the chief executive officer (CEO) of NACI. Section 11 of the Act deals with the CEO and staff of NACI, where it is stipulated that “Work incidental to the performance of NACI’s functions shall be performed by the chief executive officer of NACI and officers appointed in terms of the Public Service Act...”. The relationship between NACI and the DST is explored further in Section 4.3.8 of this report.

It is important to note that NACI is an *advisory* structure. The White Paper also stressed that NACI must play an advisory rather than an operational role. NACI was never intended as an agency that would execute policy or perform other operational functions, but rather to advise on what should (or should not) be done. If, for example, NACI felt that a broader public understanding of science and technology was required, it should advise the Minister so, rather than attempting to organise science fairs itself as NACI. Furthermore, it is not NACI’s brief to advise other bodies (including the Presidency, cabinet, other ministers and departments or the Parliament) *directly*. It delivers its advice to the Minister of Science and Technology, who will then decide how the advice should be dealt with. This can include a referral to other Ministers, the Ministers Committee on Science and Technology or the Cabinet.

There was a period when gathering of data for the national R&D indicators was NACI's responsibility. It was soon realised, however, that this was not an appropriate arrangement, and the function was moved back to the DST. NACI does, however, have a group to interpret the data, which is necessary for its ability to render advice.

NACI's objectives

NACI's objectives are set out in Section 3 of the Act (referred to at the "objects"). It is stipulated that NACI shall advise the Minister and through the Minister, the Ministers Committee and the Cabinet, on the role and contribution of science, mathematics, innovation and technology (including indigenous technologies) in the promotion and achievement of national objectives, namely to

  - Improve and sustain the quality of life of all South Africans
  - Develop human resources for S&T
  - Build the economy
  - Strengthen the country's competitiveness in the international sphere

NACI's functions

The NACI Act stipulates in Section 4 that in order to achieve the objectives listed above, NACI may or shall on request of the Minister, advise on:

- The coordination and stimulation of the National System of Innovation (NSI)
- The promotion of co-operation within the NSI
- The development and maintenance of human resources for innovation through selective support for education, training and R&D in the higher education sector and at science councils, science and technology institutions (SETIs) and private institutions
- Strategies for the promotion of technology innovation, development, acquisition, transfer and implementation in all sectors
- International liaison and co-operation in the fields of science, technology and innovation
- Co-ordination of S&T policy and strategies with policies and strategies within other environments
- The structuring, governance and co-ordination of the S&T system
- The identification of R&D priorities in consultation with provincial departments and interested parties, and their incorporation in the process of government funding of R&D
- The funding of the S&T system in respect of its contributions to innovation, including:
  - A framework for national and government expenditure on R&D
  - The building and maintenance of S&T capacity by way of selective funding of training and R&D
  - The distribution of funds allocated to science councils
  - The funding of R&D in all sectors
  - The funding of national facilities utilised for research
- The establishment, phasing out, rationalisation and management of
  - Science councils
  - National facilities utilised for research
  - National R&D programmes conducted by research councils
  - S&T institutions with the NSI

  - The promotion of mathematics, the natural sciences and technology in the education sector in consultation with the Minister of Education and the Minister of Labour
- Strategies for
  - The promotion and dissemination and accessibility of scientific knowledge and technology
  - The promotion of the public understanding of S&T and their understanding and their supportive role in innovation for development and progress
- The establishment and maintenance of IT systems to support
  - The monitoring and evaluation of the overall management and functioning of the S&T system and the NSI
  - The continuous revision of S&T policy to address changing and new circumstances
- Developments in the fields of science, technology and innovation which may require new legislation
- Any other matter relating to science, mathematics, innovation and technology including indigenous technologies, which the Minister may refer to NACI, or in respect of which NACI may deem it necessary to advise the Minister.

Composition of NACI and criteria for membership

The NACI Act stipulates in Section 5 that NACI shall be composed as follows:

- A chairperson appointed by the Minister
- 16 to 20 members appointed by the Minister (after consultation with the Ministers Committee and after submission to the Cabinet for notification)
- A CEO (Director-General (DG) of the Department)
- An officer of the Department of Trade and Industry (appointed by the Minister with the concurrence of the Minister of Trade and Industry)

Apart from the two government officials, the other members (including the chairperson) of NACI are appointed in their personal capacities and serve on a part-time basis. These members are typically appointed for a period of four years, although they are reappointable.

The Act stipulates in Section 6 that the members, other than the two government officials who serve in their official capacity, shall be persons who have:

- Achieved distinction in any field of science and technology in their own right or in the context of innovation
- Special knowledge or experience in relation to the management of science and technology or innovation
- Special insight into the role and contribution of innovation in promoting and achieving national and provincial objectives; or
- Special knowledge and experience of the functioning of the NSI within the science and technology system or any other aspect of NACI's domain of responsibility.

Section 6 of the Act further stipulates that NACI must be broadly representative of all sectors and be constituted in a manner that will ensure a spread of expertise regarding:

- National and provincial interests
- Scientific and technological disciplines

- Innovation
- Needs and opportunities in different socio-economic fields
- Research and development in all sectors.

The Council is the members. It is important to note that all the members of NACI (including the chairperson) except the two government officials (the DG of the DST who is also the CEO of NACI and the representative of the Department of Trade and Industry) participate in NACI on a part-time basis. They typically participate in three or four plenary meetings per year. Most of them are also active in the task groups and subcommittees. A few also serve on NACI's Executive Committee (regulated by Section 8 of the Act). The part-time nature of the NACI members has a definite impact on the level of their participation and involvement. In order for NACI to make an effective contribution, it is essential that NACI be served with a competent Secretariat. The Secretariat must not only provide secretarial services for NACI and its meetings and project management for its research projects, but also have an adequate policy analysis capability. The shortage of capable policy analysts in the country puts an additional and unrealistic burden on the NACI Councillors themselves and may also result in inadequate policy advice. This can happen because all Councillors are not necessarily trained in or adept at policy analysis, or because there is just an all round lack of capacity in this regard.

Access to the Minister
Section 4(2) of the NACI Act determines that "The chairperson of NACI shall have direct access to the Minister and members of the Ministers Committee to submit and discuss any report of NACI, any minutes of a meeting of NACI or any other matter relating to the functioning of NACI".

4.3.3 The "First" and "Second" NACI Councils

NACI assumed its operations soon after its establishment, with Dr Sibusiso Sibisi appointed by then Minister Ben Ngubane as the first chairperson of NACI. He was succeeded as chairperson by Dr Roy Marcus, who also acted as the Minister's advisor. Four years after NACI assumed operations, the time came for the reappointment of members and the appointment of new members by the Minister.

Although not mandated by the NACI Act, it had become established practice for science councils and related organisations to be reviewed and evaluated from time to time. An external review of NACI was subsequently performed in 2002, on NACI's own initiative, and a report with findings and recommendations was issued[105]. The members of the audit panel were Prof. Wieland Gevers (senior deputy vice-chancellor of UCT at the time, later with ASSAf), Dr Saleem Badat (CEO of the CHE at the time, now the Vice-Chancellor of Rhodes University), Mr DF Hunt (SA Chamber of Business) and Mr J Mullin (consultant from Canada and project leader of the 1993 IRDC review of the S&T system).

[105] *Audit of the performance of South Africa's National Advisory Council on Innovation*, October 2002.

After the first four years, the terms of some members were extended for a period. New members as well as a new chairperson were subsequently appointed early in 2004. Ms Phumzile Mlambo-Nguca, the then Minister of Minerals and Energy and current Deputy President of South Africa was then the acting Minister of Science and Technology, and in that capacity she appointed the new members. Professor Calie Pistorius, Vice-Chancellor and Principal of the University of Pretoria, was appointed as the new chairperson. This NACI cohort came to be known as the “Second NACI Council”. During the term of the Second Council, NACI was ably assisted by a Secretariat, headed by Dr Bok Marais.

The four-year term of the Second Council expired early in 2008. At that time, the Minister of Science and Technology, Mr Mosibudi Mangena, decided to extend the terms of some members and appoint new ones for an interim period of one year, rather than appoint a new Council (which would have been the “Third NACI Council”) for a four-year term. Dr Steven Lennon of Eskom was appointed as the new chairperson, following Professor Pistorius’ indication that he would prefer to step down as chair, although he was reappointed as a member of NACI for the interim year.

The first Council approved an annual internal, but externally moderated review for the first three years of tenure. This was, however, done inconsistently. An external review was done in the final year of tenure as was mentioned above. The Second NACI Council performed an annual self-assessment, with a major external review being performed in May 2008. The members of this external review panel were Mr Ralph Havenstein (chair), Prof Phuti Ngoepe (University of Limpopo), Professor Susan Couzens (Georgia Institute of Technology) and Dr Per Koch (Norway). This report is being released more or less at the same time as the findings of the 2008 review. This report specifically does not refer to the outcomes and recommendations of the review, to ensure that both the report and the review maintain their objectivity and independence. It should be noted that the author of this report also gave inputs to the review in his capacity as a former chairperson of NACI.

4.3.4 NACI’s subcommittees and task teams

Section 8(4)(a) of the Act determines that NACI “may establish committees to assist it in the performance of its functions, and may designate as members of such committees persons who are not members of NACI….The chairperson of a committee established (a) shall be designated by NACI from amongst the members of NACI”.

By the end of the term of the Second Council, NACI had three standing subcommittees, viz.

- Science, Engineering and Technology for Women (SET4W)
- Indicators Reference Group (IRG)
- National Biotechnology Advisory Committee (NBAC)

4.3.5 The NACI Act and its definitions of science, technology and innovation

In order for NACI to function properly, it must be clear what it should advise the Minister on. In examining NACI's role, particularly within the context a future structure for scientific advice in South Africa, one must investigate NACI's mandate in terms of its role and functions within the definitions of "science", technology" and "innovation" that govern its work. There are three types of indications that can provide guidance in this regard, viz.,

- The Minister of Science and Technology should be advised on all matters that pertain to his/her portfolio. This approach implies that the Minister's portfolio and also the mandate, role and responsibilities of the Department of Science and Technology are well defined and demarcated (including its position vis-à-vis other government departments), including their roles with regard not only to science and technology (including those that specifically pertain to other government departments) but also to innovation, the National System of Innovation and competitiveness.
- The National Advisory Council on Innovation (NACI) should provide advice (to the Minister) on all aspects pertaining to "innovation", since that is what is indicated by its name. Within this context, the definition and interpretation of the term "innovation" become very important.
- NACI must provide advice within and according to the stipulations of the NACI Act. By law, this is NACI's mandate. However, an examination of the broader contexts explored in this report indicate that the provisions of the law are somewhat ambiguous in some cases, and must be interpreted. Furthermore, their meanings may also evolve with time.

4.3.5.1 NACI's mandate determined by the Minister's portfolio and that of the Department of Science and Technology[106]

According to its website, "The DST strives toward introducing measures that put science and technology to work to make an impact on growth and development in a sustainable manner in areas that matter to all the people of South Africa.

This includes focused interventions, networking and acting as a catalyst for change in terms of both productive components of our economy, making it competitive in a globally competitive liberalised environment, and also in respect of the huge development backlog existing among the poorest components of our society. The goal of realising this vision is underpinned by development and resourcing strategies for the formation of science, engineering and technology, human capital, democratisation of state and society, promotion of an information society and ensuring environmental sustainability in development programmes".

The vision of the DST is "To create a prosperous society that derives enduring and equitable benefits from science and technology", and its mission is "To develop, coordinate and manage a national system of innovation that will bring about maximum human capital, sustainable economic growth and improved quality of life".

Science and technology as vehicles through which the DST aims to achieve its goals are prominent in its vision, as they should be. It is not always clear, however, to what

[106] http://www.dst.gov.za/

extent the social sciences and humanities are included in its view of science in this regard. What exactly is meant by the “Science” part in the name of the Department of Science and Technology (DST)? It is interesting to note that the National Research Foundation (NRF), which resorts under the DST and whose function it is, inter alia, to fund research in higher education, does include the humanities and social sciences in its brief.

The National System of Innovation, its development, coordination and management is central to the DST’s mission. Implied therein is a focus on innovation, which immediately begs the question as to what exactly is meant by the term. Various definitions and interpretations of the term “science” were explored in Chapter 3 of this report. It must be emphasised again that the definition is important, because it determines the thrust, scope and boundary conditions of what is to be done, and as such impacts on the mission. From the earlier discussion on innovation and national innovation systems, it is clear that these can typically not be the domain of a single department but maps onto the domains and turf of a number of government departments, including that of the DST. Placing the NSI central in the DST’s mission may therefore lead to overlap, duplication and possible friction between various government departments. Furthermore, it is also possible that important areas are not addressed by any department and fall between the cracks, resulting in possible policy voids. This issue should therefore be treated with considerable sensitivity by all involved.

The same is true for the aim of enhancing the country’s international competitiveness. This too is a domain that spans the responsibilities of a number of government departments. The DST should therefore place considerable focus on the “coordination” aspect mentioned in its mission as well as on cooperation with other departments.

An interesting policy question is whether it is the Minister of Science and Technology’s mandate to involve himself or herself in all matters in which NACI is to render advice. If that was the case, the Minister of Science and Technology would be mandated to make and implement policies with regard to higher education and labour, for example, since NACI is mandated to advise him/her on these. The Act notes however, that the NACI should *consult* with the Minister of Education and the Minister of Labour (Section 4(1)(k) of the Act). NACI’s advice can also be presented to the Minister’s Committee and Cabinet, albeit through the Minister of Science and Technology. One cannot therefore assume that the Minister of Science and Technology must make and execute policies on all the matters in which he is advised by NACI. The implication is rather that, in cases where the advice or aspects thereof fall outside his remit, other Ministers should be consulted or the advice passed on to them. The DST, and by implication the Minister of Science and Technology, do however see it as their mission to develop human resources in science and technology.

4.3.5.2 NACI’s mandate determined in the context of definitions of innovation

Although the NACI Act does not provide a definition of “science and technology” per se, it defines a “science and technology system” as being “all persons who and institutions which are involved in the process of making scientific knowledge available, or which are involved in the process of converting and using scientific knowledge, in order to devise or implement new applications, and which operate within the national system of innovation". The Act is silent on what exactly is meant by the term "scientific knowledge" in this context, particularly whether the intention was to also include knowledge pertaining to the social sciences and humanities, in addition to the natural sciences and technology.

The NACI Act defines the term "innovation" as meaning "the process of transforming an idea, generally generated through research and development, into a new or improved product, process or approach, which relates to the real needs of society and which involves scientific, technological, organisational or commercial activities". The NACI Act takes its cue with regard to the notion of "innovation" from the White Paper on Science and Technology of 1996, where "innovation" is described as "…the application in practice of creative new ideas, which in many cases involves the introduction of inventions into the marketplace". The White Paper further notes that, "In contrast, creativity is the generating and articulating of new ideas. It follows that people can be creative without being innovative. They may have ideas or produce inventions, but may not try to win broad acceptance for them, put them to use, or exploit them by turning their ideas into products and services that other people will buy or use. Similarly, people can be innovative without being creative. For example, if they apply or implement ideas or inventions that were made elsewhere, they are being innovative, even though the inventions or creative ideas were not their own. Some innovations are truly revolutionary, while most represent modest improvements in the way we do things. Competitive companies, for example, are continually introducing incremental innovations to improve the products they sell or the processes they use in production. Only rarely will they introduce something radically new into the market place." The National R&D Strategy refers to "innovation" as the "introduction into a market (economic or social) of new or improved products and services".

Strictly speaking, the definition of innovation in the NACI Act is aligned with the genre of definitions of innovation that considers the invention-component to *not* be part of the innovation process. It seems as if the Act implies that innovation starts after the ideas (research) has been generated. The implication would be that NACI would, again strictly speaking, not be concerned with any elements of research, for example, since its definition of innovation implies that the ideas have already been generated. Hence NACI will focus only on the downstream part of innovation. Yet the Act determines that one of the functions of NACI is to advise the Minister on issues pertaining to "the identification of research and development priorities" and funding of "…a framework for national and governmental expenditure on research and development". This point again illustrates some of the ambiguities that currently exist in the legislation and practice regarding NACI and its operation.

According to the NACI Act, the "national system of innovation" means "all sectors, and institutions within those sectors, which pursue common social and economic goals through innovation", stressing again the importance of clarity of the definition of innovation. This definition seems to imply that the social and human sciences are included. In as far as NACI must advise on issues pertaining to the National System of Innovation, these are then also included.

4.3.5.3 NACI's mandate determined by the content of the Act

The areas in which NACI must advise the Minister are specified in Sections 3 and 4 of the Act, dealing with NACI's objects and functions. They are discussed in Section 4.3.2 of this report as well as given in Appendix A. They are not, however, congruent with the definitions of the Act in all cases as discussed above. The point has been made that definitions, or at least their implications and intentions, are important in the context within which we are dealing here. It would seem that the thrust of the definition of innovation as implied by the NACI Act *excludes*, for example, the creative aspects and processes (including those of research and development). It is not clear whether this was the intention, but it certainly has important implications as to what NACI should advise on and what not. A strong argument can be made, of course, that NACI should advise on research and development issues; and the definition of innovation should certainly include these.

According to the NACI Act, the objects of NACI, are to "advise…on the role and contribution of science, mathematics, innovation and technology, including indigenous technologies, in promoting and achieving national objectives, namely to improve and sustain the quality of life of all South Africans, develop human resources for science and technology, build the economy, and strengthen the country's competitiveness in the international sphere". The fact that "innovation" is grouped together with a number of other issues implies that, on the one hand the Act recognises science, mathematics and technology to be different from innovation per se, but on the other hand that NACI should still advise the Minister on these matters.

4.3.6 Setting NACI's agendas and work programmes

It is important to consider the modes by which NACI's agendas and work programmes are determined, because these in effect ultimately result in the advices to the Minister.

There are in essence two modes in which NACI can decide on the issues on which advice to the Minister is to be provided. Section 4 of the NACI Act states that NACI "...may, or shall on request of the Minister, advise on…". This is interpreted to imply that NACI's agenda for advice is determined by specific requests from the Minister, and also by areas or issues which NACI itself deems important. These must fall within the "menu" specified in Sections 3 and 4 of the Act, noting that Section 4(1)(o) includes "…any other matter relating to science, mathematics, innovation and technology including indigenous technologies, which the Minister may refer to NACI, or in respect of which NACI may deem it necessary to advise the Minister".

It is interesting to note that the White Paper on Science and Technology emphasises the fact that NACI's work programme and the issues on which advice is to be rendered are set by the Minister, rather than to also allow for an option where NACI itself can also determine on which issues the Minister should be advised. A strong case can be made that, in the context of providing science advice to government, independent advice must also include the ability of the advisor to initiate and decide on issues on which advice should be rendered, in addition to those on which advice is specifically requested. This is the case with the NACI Act as it stands.

An examination of the list of possible matters on which NACI can advise the Minister as set out in Section 4.3.2 of this report (and Section 4(1) of the Act), indicate that a very broad range indeed is covered. All of them, in one way or another, relate to the National System of Innovation. Other than what is implied by a narrow interpretation of the definition of innovation, it also includes issues pertaining to research and development. It also includes issues pertaining to human resource development (albeit for science and technology) and the promotion of research in higher education. These are areas which may overlap with the domains of the Department of Education and the Department of Labour.

Given the resources available to NACI, including its budget, the time that the part-time Councillors can spend on NACI-related activities as well as the capacity of NACI's secretariat, it is clear that NACI cannot address all of its functions listed in the Act, and certainly not all at the same time. On the other hand, there is no indication that it was the intention of the Act that this should be the case. It is against this background that NACI developed work plans and agendas to set the framework for those issues on which it would focus. These were typically part of a subset of the functions listed in Section 4 of the Act, or variations on the themes. The work programmes include the requests from the Minister, which are typically obtained via a discussion between the Minister and the Chairperson of NACI. NACI's work programmes are set out in its annual corporate plans, and are discussed with the Minister. They are also discussed with the Parliamentary Portfolio Committee on Science and Technology when NACI reports to the Parliament.

There are a number of concerns with the determination of NACI's work programme as described above. The first refers to the fact that all the functions mentioned in Section 4 of the NACI Act are matters on which external advice should be rendered. The fact that they are taken up in the NACI Act can lead to the assumption that they are indeed addressed by an advisory council (specifically NACI). The case for the necessity of external scientific advice was made earlier in this report, and certainly applies to all NACI's functions. Given that NACI can at most address only a few issues at a time or during any given year, many of the issues listed in Section 4 of the Act may never in fact really become the object of independent external advice. Many policy matters that fall squarely in the definitions of NACI's functions are also routinely addressed by the DST, since they fall within the DST's remit as a government department. The fact that they are not continuously or at all considered by NACI, however, implies that the Minister may not have the benefit of independent external advice on these matters. His/her main source therefore will be the DST.

It can happen that NACI is not alerted by the DST to the fact that a particular issue is under discussion in the DST, and often only at a late stage when advice that could have been generated is too late to influence policy significantly. It is acknowledged that NACI does not advise the DST, and as such the DST is strictly speaking not required to ask or adhere to NACI's advice. Recall that NACI advises the Minister. In order to do so, however, it must be alerted by government departments, and particularly by the DST, on which policy issues that fall within its scope, are being considered. Early warning is important, in order to allow NACI, with its part-time Councillors and subsequent longer lead times, time to develop advice on the issues which the law requires it to advise on. A clause similar to that in the Higher

Education Act that mandates government departments to provide the CHE with information, may assist NACI significantly in this regard.

Another concern with regard to the way in which NACI's work programme is set, is the collegial and consensus seeking nature of a Council such as NACI. Although the national objectives and priorities are known and the DST's can be determined, every Councillor ultimately has his or her own particular areas of interest and expertise, as well as opinions on the issues that NACI should be advising the Minister on. Since NACI cannot advise on every function for which it is mandated in the Act, a small number of thrusts are identified and prioritised for consideration during a given period. Under the circumstances, these tend to typically be aligned with the members' interests, rather than necessarily with the highest and most pressing national issues.

Soon after the appointment of the "Second Council" in August 2004, NACI engaged in an extensive strategic planning exercise. Following the planning session, it decided to form five task teams to guide the components of the advice it would render to the Minister on its own accord, viz.

- Infrastructure for innovation promotion
- Human capital and knowledge base
- Science, technology and innovation for competitiveness
- Social dimensions of innovation
- Position and role of NACI in the NSI

In addition, the Minister's requests were also accommodated. A series of advices were rendered to the Minister during the term 2004 to 2008, as set out in NACI's annual reports for the period.

4.3.7 NACI's public interaction

NACI's mission is to advise the Minister of Science and Technology on various issues pertaining to the National System of Innovation. It is an advisory body with one client, and with no operational functions. It is against this background that NACI's public interaction must be addressed. The issue has a number of dimensions, including NACI's and its Councillors' public profile and interaction, as well as the extent to which NACI's research reports must be put into the public domain.

4.3.7.1 Interaction of NACI and its Councillors with the public

The NACI Councillors must, in terms of the NACI Act, all have a certain stature in the science, technology and innovation field. It is to be expected that they would therefore also have a broader knowledge in this area, which they must bring to bear on NACI's activities and from which the advice given to the Minister must benefit. Even so, not many of the Councillors will be familiar with all the national policy issues that NACI must deal with, nor will many of them have a policy analysis background. Hence it is important that NACI and its Councillors should be exposed on a regular basis to national issues that relate to the STI-policy debates. They must actively ensure that they are constantly familiarised with and informed about those issues that are of concern to NACI, and take proactive measures to stay abreast of these. As such, they must participate actively in appropriate networks, locally and abroad.

It is equally important for NACI to ensure that it maintains a positive public profile, particularly in the STI-community. Even though NACI advises the Minister, it can only do so effectively if there is public trust in the Council and the Councillors and their credibility. Marketing NACI is thus important in this regard.

In order to gather information and evidence to support its research-for policy, which will culminate in advice to the Minister, NACI typically commissions research reports to serve as the evidence for underpinning its advice. From time to time it also hosts workshops and conferences. Although part of the purpose of these are to disseminate information, the major focus is to enable NACI and its Councillors to be better informed about the issues on which they must render advice and also to gauge the buy-in from the relevant reference community. The workshop in July 2007 during which the OECD report on the South African National System of Innovation was discussed, is a good example. At this workshop, the review of the South African National System of Innovation that was performed by the OECD was discussed in a forum where representatives from government, industry and the higher education attended. It will be to NACI's benefit and also positively enhance its ability to render advice to the Minister, to increase the frequency of these workshops and other interactions with the public under the NACI flag, with the purpose of gathering information and stimulating public debate on STI-related matters. NACI must use these events to maintain and enhance its knowledge of the public mood and opinions on aspects pertaining to the NSI.

The public, and specifically the local and international STI-community must hold NACI in high esteem in order for these workshops and conferences to be successful, again underscoring the importance of projecting a positive public image about NACI and its mission.

4.3.7.2 NACI's reports in the public domain – a balance between confidentiality and transparency

NACI's major mode of gathering information is by commissioning research reports from experts. Once the reports are received, they are analysed by policy analysts, who then formulate the appropriate draft advice for the Minister. The policy analysts are part of NACI's Secretariat, often the Councillors themselves and external experts from time to time. Each project is typically run under the auspices of one of NACI's task groups. The final advice is approved by the entire Council after extensive debate and deliberation, after which the advice is delivered to the Minister.

The research reports typically form the basis of NACI's evidence-based advice to the Minister. In this regard NACI is careful, however, to interpret the findings and recommendations and to reach its own conclusions on which the ultimate advice is based, as opposed to "putting is own cover on the research reports and forwarding that to the Minister as advice". The background reports that support NACI's advice are usually also included with the advice itself, when the advice is presented to the Minister.

It was noted earlier in this report that NACI's advice must provide decision support for the Minister, taking into account that the Minister makes political decisions about issues pertaining to the National System of Innovation. In addition to science, technology and innovation related matters, these decisions must also account for a number of other issues, including economic, social and environmental. The policy analysis on which the advice is based must take these into account and then weigh various options, alternatives and compromises. It is important to note that there must therefore be a relationship of trust between NACI and the Minister which it advises.

A relationship of trust must necessarily include an element of confidentiality. This encourages robust debate. It also allows the Minister the opportunity to consider the advice in his/her own time, to consider other advices as well and then decide what the next course of action should be. The Minister can accept the advice as is, reject it *in toto*, partially accept the advice or refer it back to the advisor or advisory body for further work. No Minister is bound to the principle of being advised by only one person or body, statutory as they may be. Hence the Minister may also want to test the advice against other sources or combine various pieces of advice from various sources. It may also happen that the Minister has access to information that may not have been available to the advisor, and that such advice may influence the Minister's decision. That is the Minister's prerogative and also the nature of the process of giving advice to government. Ultimately the Minister is responsible for the political decision that is taken.

At the same time, it is also important to remember that Ministers remain accountable to Parliament and the public, and that the advisory bodies, particularly statutory ones, are funded with public funds. As such, the public also has a right to know what the issues are that are being considered. Clearly a balance between confidentiality and public transparency is called for.

In light of the above, it seems appropriate that the Minister should inform the advisory council what he/she has done with the advice delivered to him or her and what the path forward is[107]. This can of course also be done in confidence, and will also allow the advisory body to keep track of the usefulness of its advice and shape its agendas for the future.

One approach towards public transparency is for NACI to consider making the research reports that have been commissioned available to the public after the advice has been delivered to the Minister. In order to put the reports and their findings in context, every report should also include the brief and research question that the report addresses. When such a report is made available to the public, it should clearly indicate that it is a commissioned research report, the purpose of which is to assist NACI to formulate advice to the Minister. It should be very clear that the report itself is not necessarily the Minister's or NACI's opinion and that NACI does not necessarily endorse the report, its findings and recommendations and that the report does not necessarily in itself reflect NACI's advice to the Minister. Usually NACI also retains the copyright of the reports, implying that the service providers cannot publish the reports without NACI's approval[108].

[107] If the Minister of Education decides not to accept the Council on Higher Education's advice s/he must give reasons in writing to the Council.
[108] This report was funded by the University of Pretoria and offered to NACI, rather than having been commissioned and funded by NACI.

In order to allow the Minister space to make his/her decisions, the reports should not be released to the public after the Minister has received the advice and the report. There can either be a time limit for release, i.e. default delay, or alternatively the Minister can indicate when the report can be released. The release can be on NACI's website, which will ensure wide distribution.

Another approach will be to make the report available to the public before NACI formulates its advice. This can be a mechanism to subject the report to peer review, and to gather further inputs, criticisms and comments on the report and the topic under discussion. After receiving the public's comments on the report, NACI can then formulate a more informed advice to the Minister. The advantage of this approach is that it will introduce a much needed peer review mechanism and broaden the base of expertise that is brought to bear. This mechanism will, however, imply that the issue and particularly the way in which the advice may go, will be in the pubic domain before the Minister has seen the report. The advantages of this mechanism may outweigh the disadvantages.

It may be of interest to note the practices of three American advisory bodies, viz, the National Academies, Congressional Research Service (CRS) and PCAST, in this regard.

> The National Academies were established by President Abraham Lincoln in 1863 to serve "whenever called upon by any department of he Government…to investigate, examine, experiment, and report upon any subject of science or art".[109] Federal agencies are the main financial sponsors of the National Academies' work. The National Academies provide independent advice, and the external sponsors have no control over the conduct of a study once its has been initiated and the budget finalised.
>
> The National Academies produce more or less 600 reports, roundtables and workshops per year, of which 200-300 are reports. Some of these are commissioned by the Congress, others by various other parts of the administration and some by the National Research Foundation (an element of the National Academies). The reports are all peer reviewed. Very soon after the report has been delivered to the client (a day or so), the National Academies will, as a rule, make the report public. Sponsors are not given the opportunity to respond to suggest changes to the reports. The reports can typically be purchased from the National Academies Press and is also available on its website.
>
> The CRS serves the USA Congress with advice. Most of the CRS' work is in response to quick requests for factual information. All requests for information to the CRS are confidential. If repeated requests are made for the same information, the CRS will make a report available to Congressional staff via its website. Its reports are generally not available to the public, but can be

[109] Henry Kelly et al, *Flying Blind: The rise, fall and possible resurrection of science policy advice in the United States*, Federation of American Scientists, Occasional Paper No. 2, December 2004.

requested via Congressional Representatives and Senators. A number of the reports have made their way onto the internet, but this is not the general case.

The President's Council of Advisors on Science and Technology (PCAST) advises the President of the USA. It was established to enable the President to receive advice from the private sector and academic community on technology, scientific research priorities as well as math and science education. The council members are distinguished individuals who are appointed by the President. They are drawn from industry, education and research institutions and other nongovernmental organizations. PCAST's reports are generally available on its website.[110]

4.3.8 NACI's role vis-à-vis the DST

The White Paper envisaged a NACI that would advise the DACST, i.e. the Department mandated to deal with science and technology. Perhaps the intention of the White Paper was to thereby indicate that the DACST should have an external advisory function. At the time of writing of this report, the DST has no advisory structure of a nature similar to NACI. The NACI Act mandates that NACI should advise the Minister of Science and Technology (and through the Minister, the Ministers Committee and the Cabinet), rather than the Department.

To put the discussion into context, the difference between a Ministry and a Department must be acknowledged. The Minister is a member of the Cabinet, and has a portfolio that s/he is responsible for. As such, the Minister is a politician, as opposed to being a civil servant. The Ministry is in effect the Minister's office, of which the Deputy Minister (if there is one) forms part. Very often there are also advisors in the Ministry. Their function is to advise the Minister (and Deputy Minister where appropriate). If the advisors are attached to the Minister or Ministry, they render their advice to the Minister independently of the Department, although the advice will necessarily relate to policies and issues that are the concern of the Department. This gives the Minister the opportunity to access advice external and independently from the internal and in-house expertise of the Department.

The Department of Science and Technology, like other national government departments, is a governmental bureaucracy staffed by civil servants. The Director-General (DG) is the managerial and administrative head of the Department, and reports to the Minister. The role and responsibility of the Department is to execute the government's policies in its area of responsibility. The policy itself is typically a political decision for which the Minister is politically accountable. The Department will, however, usually also be involved in the development of these policies. Hence the need for the Minister to have access to advice independent from the Department. It is of course also possible that a Department can also have its own advisory structures, other than those that advise the Minister. This need not be a standing committee (such as NACI), but can include a range of other types of advisory bodies as discussed in Section 3.3.3.3.

[110] http://www.ostp.gov/cs/pcast

NACI's particular organisational arrangements and logistics, as determined and implied by the NACI Act, has been the subject of many discussions since its inception. NACI has, by virtue of the NACI Act, since its establishment been very close to the DST (and its predecessor, the DACST). By law, the DG of the DST is NACI's CEO. NACI's secretariat is appointed as employees of the DST. Section 11 of the Act determines that "Work incidental to the performance of NACI's functions shall be performed by the chief executive officer of NACI and officers appointed in terms of the Public Service Act, 1994…". Although the Act does not stipulate that the officers (the Secretariat) should be appointed in the DST, it has always been the practice. Section 10(1) of the Act determines that "Expenditure incidental to the performance of the functions of NACI shall be defrayed from money voted to Parliament as part of the appropriation of the Department". NACI's budget is therefore administered by the DST. This is a different arrangement from the Council on Higher Education (CHE) that advises the Minister of Education, for example. The CHE is a juristic person, and its budget is not administered by the Department of Education[111].

It can happen that developments relating the issues listed as NACI's objectives in Section 3 of the Act, occur during a year in which they are not on NACI's work plan for that specific year. Many of these issues will obviously originate in the DST. If NACI is not alerted to these issues and do not consider them for advice, the Minister will not have the benefit of NACI's independent external advice on these particular matters. It is therefore essential for the DST to proactively alert NACI to issues under its consideration, particularly if they fall within NACI's brief, i.e. an area of which NACI is required by law to advise the Minister on. The DST should proactively provide NACI with enough information to allow NACI to render timely advice to the Minister. This could typically be done via the DG of the DST that is an ex officio member of NACI, or by regular briefings from the DST to NACI. NACI could then plan its programme so that enough capacity is conserved to deal with such issues as they arise. A rule similar to that on which the CHE relies for information (see box below), will serve NACI well.

It is useful to compare NACI with other similar statutory advisory bodies that advise other ministers. The Council on Higher Education (CHE) that advises the Minister of Education, and the Law Commission that advises the Minister of Justice are discussed below as examples.

The Council on Higher Education (CHE)

The Council on Higher Education (CHE) advises the Minister of Education, and is regulated by Chapter 2 of the Higher Education Act (Act 101 of 1997). It is noticeable that the organisational arrangements of NACI, which advises the Minister of Science and Technology, are quite different from those of the CHE.

The first and very important difference between NACI and the CHE is that the CHE was established as a juristic person. This is not the case with NACI, and is the major reason why NACI's administration is controlled by the DST.

[111] See also H.C. Marais. *Perspectives on Science Policy in South Africa* where the NACI Act and the Higher Education Act as it pertains to the CHE are compared.

The Higher Education Act also stipulates that "Every national and provincial department of state, every publicly funded science, research and professional council and every higher education institution must provide the CHE with such information as the CHE may reasonably require for the performance of its functions". Through the application of this stipulation, the CHE can ensure that it is regularly briefed on issues of concern, including those pertaining to the Department of Education.

Being a juristic person, the CHE appoints its own staff, and must "with concurrence of the Minister and the Minister of Finance, determine the conditions of service of the executive officer and the other employees of the CHE". The CHE appoints its own CEO, which is not the DG of the Department of Education. The funds of the CHE consist of money appropriated by Parliament, donations, contributions and other income from other sources as well as moneys paid for services delivered. The CHE's annual statement of estimated income and expenditure is approved by the Minister, and its books of account and financial statements are audited by the Auditor-General.

It is also interesting to note that the Minister of Education must consider the advice of the CHE and provide the CHE with reasons in writing if the Minister does not accept the CHE's advice.

It is evident that, although the CHE advises the Minister of Education in a manner very similar to which NACI advises the Minister of Science and Technology, the CHE has a very different organisational dispensation than NACI.

The Law Commission

The Law Commission is regulated by the South African Law Reform Commission Act (Act 19 of 1973, substituted by Act 55 of 2002), and advises the Minister of Justice.

The object of the Law Commission is "to perform research with reference to all branches of the law of the Republic and to study and to investigate all such branches of the law in order to make recommendations for the development, improvement, modernizations or reform thereof…". The Law Commission prepares a full report "in regard of any matter investigated by it, to the Minister for consideration".

The Commission appoints the secretary and staff of the Law Commission in terms of the Public Service Act (as are those of NACI). It is also interesting to note that the Commission may also employ full-time Commissioners, albeit not more than three.

The Law Commission must, from time to time, draw up a programme "in which the various matters which in its opinion require consideration are included in order of preference, and shall submit such programme to the Minister for approval". In contrast, both NACI and the CHE may decide on issues that their respective Ministers should be advised on, without the Minister's approval of these issues.

The comparison of NACI with the CHE and the Law Commission indicates that both the CHE and the Law Commission enjoy far greater autonomy from the associated departments (Education and Justice respectively) than NACI enjoys from the DST.

It should be noted that the current Director-General of DST recognises the dangers that departmental control may bring to NACI's autonomy and independence of advice, and has taken a position to emphasize that the DST should be involved in NACI's administration only and not in the policy matters that NACI addresses. The DG sees himself as accountable with regards to the budget, human resources and other administrative matters regarding NACI, but not in the role of influencing NACI's agendas for advice to the Minister. This is a commendable position and is highly appreciated in NACI.

Nonetheless, it remains difficult for NACI to extricate it from the DST, given that the DST provides an administrative home for NACI, the fact that the NACI secretariat are appointed as DST employees and the DST's control of NACI's budget The perception of NACI's independence is also compromised by the close relation that it must maintain with the DST. Attempts have been made to increase the arms length relation between the DST and NACI, as per the CHE model for example, but these have not been very successful. The Cabinet and Parliament's apparent reluctance to establish such independent bodies are usually given as the reason for their reluctance to do so. The complexities of providing a separate budget, appointment of staff and compliance with the Public Finance and Management Act (PFMA) are all referred as problematic in this regard.

In order for NACI to maintain its ability to provide independent advice to the Minister, it is also necessary that the Chairperson of NACI continues to exercise the right of direct access to the Minister provided for in Section 4(2) of the NACI Act.

4.3.9 Re-examining NACI's role

The focus on the "Position and role of NACI in the NSI" identified as one of the task groups mentioned in the previous section, followed from a realisation that already existed in August 2004, namely that the scientific advisory structure in the country needed to be reviewed. This included NACI, its role and mandate[112].

After almost fifteen years of democracy, South Africa is widely accepted into the international science community and has established relationships with organisations such as the OECD in science, engineering and innovation domains. Since the conception and establishment of NACI more than ten years ago, the science, technology and innovation environment within South Africa and also with regard to its external relations and the globally, has been very dynamic. Many of the policy instruments and initiatives that were foreseen in the White Paper on Science and Technology (*Preparing for the 21st Century,* 1996), have been put to the test of time. Whereas the establishment of the Department of Arts, Culture, Science and

[112] Calie Pistorius, "How NACI interprets its brief", *Proceedings of the ASSAf Double Symposium on Evidence-based practice: Problems, possibilities and politics*, Pretoria, 3 March 2006.

Technology (DACST) was in itself a new and welcome development in South Africa, its subsequent unbundling led to the establishment of the Department of Science and Technology (DST). This paved the way for more focused national science, technology and innovation strategies. There have also been substantial learning from experience of NACI itself as well as from international best practices, regarding the nature of providing science advise to government as well as the nature and structure of such advisory bodies. Learned societies such as the *Academy of Science of South Africa* (ASSAf) and the *South African Academy of Engineering* (SAAE) were established long after NACI was established, for example. These types of bodies render valuable advice in other countries, and they should form part of a more comprehensive science advice structure in South Africa.

The Second NACI Council therefore considered its strategic planning session of August 2004 an opportune time to revisit its mandate, role and structure. A subsequent advice on NACI's role and mandate was given to the Minister late in 2006. The broad recommendations and findings regarding NACI's role that were delivered as part of the 2006-advice are incorporated in this report where appropriate. It was obvious, however, that the science-government space is a vast one, and that a constellation of advisory bodies and entities are required to serve the needs of a modern National System of Innovation in this regard. A broader study on national scientific advisory structures was called for. This report is a response to that recommendation. The recommendations of this report are set out in the last chapter. The major external review of NACI in May 2008 was mentioned earlier.

4.4 Other advisory structures in South Africa

In addition to NACI, there are many other structures that provide and can be called upon to provide "science advice to government". The list below is not intended to be an exhaustive one, but is rather intended to gives examples of the types of advisory bodies currently providing science advice to government in South Africa.

4.4.1 The Presidency[113]

The President of South Africa and the Presidency is advised by a number of bodies. Many of these are consultative in nature. The Presidency's website mentions that "The President holds a number of discussions and interactions with a cross-section of representatives from a range of interest groups that assist in informing him of the needs, problems and challenges of civil society. This includes commercial agriculture, education, business, trade unions, religious groups and the youth. There exist a selection of consultative forums through which these engagements are facilitated. These forums are used as a key mechanism for interest groups and communities to inform Government policy"[114].

[113] Personal discussion with Mr Trevor Fowler, the Chief Operations Officer of the Presidency, May 2008; http://www.thepresidency.gov.za/
[114] http://www.thepresidency.gov.za/main.asp?include=president/pcforums.html

Working Groups
The Presidential Working Groups were established in 1999, and provide the President and Government with the opportunity to interface and engage with key segments in society. The Presidential Working Group on Higher Education (PWGHE) is one such group, where the President, a number of Cabinet Ministers and other officials meet with the vice-chancellors of the universities and universities of technology.

The Economic Sector Working Groups must "lay the basis for the development of an agreed and common agenda for economic growth and social development". The four Economic Sector Working Groups are Trade Unions, Commercial Agriculture, Big Business and Black Business).

Advisory groups
The Presidency is also served by a number of advisory groups, including

- *The International Investment Council Advisory Group*
  This group consists of prominent international business leaders, who advise the Presidency on issues pertaining to economic growth and development.
- *The Information Communications and Technology (ICT) Advisory Group*
  This group advises the President on strategies to overcome the digital divide and the government's policy framework for the development of ICT. ICT is seen as having a key potential as a driver of economic growth.
- *The Presidential International Advisory Council on Information and Society and Development (PIACISD)*.
- *Izimbizo*
  The Izimbizo "brings the Government and people together to interact with one another on matters of common interest and/or concern. The purpose of the Izimbizo is to build partnerships between Government and the South African public in the process of social change".

The Presidency also has, as part of its organisational structure, the "Policy Co-ordination and Advisory Services" (PCAS). According to the Presidency's website[115], PCAS "facilitates integrated and strategic policy formulation by Government as a whole, ensuring continuous monitoring and evaluation of the implementation of the Government's Programme of Action. The sub-programme is also responsible for advising the Principals in The Presidency on matters requiring their attention. The PCAS works directly with Director General Clusters, Ministries and Departments, providing administrative support to FOSAD, advisory structures like the International Investment Council (IIC), the Presidential International Advisory Council on Information Society and Development (PIACISD) and the Presidential Working Groups.

The PCAS is responsible for ensuring alignment between the National Spatial Development Framework and Provincial Growth and Development Strategies and IDPs, updating the Medium-term Strategic Framework and contributing to the review of the organization and capacity of the state. Working with relevant Clusters and departments, the PCAS also contributes to the development of proposals on raising

[115] http://www.info.gov.za/view/DownloadFileAction?id=72539

the country's economic growth trajectory to higher levels as well as the analysis of policy implications of the Macro-Social Report".

4.4.2 Department of Science and Technology

The Department of Science and Technology (DST) has no formal standing committees that are mandated to act as advisory committees. The Department will, from time to time, convene ad hoc groups and solicit opinions from interested parties on major initiatives and bills.

The Minister of Science and Technology is advised by the National Advisory Council on Innovation (NACI). NACI is discussed in some detail in Section 4.3. The Minister can also be advised by forums, such as the NSTF, and personal advisors. Although the current Minister, Mr Mosibudi Mangena, chooses not to have personal advisors, a former Minister, Dr Ben Ngubane, chose to do so.

National Science and Technology Forum[116]
The National Science and Technology Forum (NSTF) was established in 1995[117]. It is strictly speaking not an advisory body and has no formal mandate to provide advice. The NSTF does, however, from time to time also offer opinions and advice. These are often in the form of policy papers. The Minister of Science and Technology is the mentor and patron of the NSTF.

According to its website[118], the NSTF "…is a South African not-for-profit organisation. It is a broad-based Science, Engineering and Technology (SET) forum whose main purpose is that of consultation about, and addressing of SET issues within the broad SET community. The NSTF performs a powerful consultative and lobbying role on general SET policy matters, and runs the National Science and Technology Awards…. has a proud history of involvement with SET policy issues and the promotion of discussion about SET matters…

The NSTF acts as a constructive watchdog and sounding board in relation to SET policies; promotes communication and co-operation amongst its members and the community; acts as a communication channel to and from Government; seeks common understanding among its stakeholders on SET issues; advances, promotes and protects the common interests of its members relating to science and technology; supports the development of an integrated science and technology system which reflects the principles inherent in a free and democratic South Africa; promotes excellence and encourages good practice through the annual National Science and Technology Awards".

The vision of the NSTF is "to promote and build a society which is informed and aware about SET and related issues, where such issues can be discussed and debated freely, where knowledge and information are readily accessible, and are

[116] An interview was held with the Chairperson of the NSTF, Professor Brenda Wingfield.
[117] Originally started in 1993 as the *S&T initiative*; see H.C Marais, *Perspectives on Science Policy in South Africa.*
[118] http://www.nstf.org.za/

applied innovatively to improve living conditions in South Africa, and promote our country's economic growth and global competitiveness".

The mission of the NSTF is "co-ordinate, facilitate, catalyse and contribute to the implementation of SET initiatives, activities and projects which will make a significant contribution to the economic, human and social development needs of South Africa, whilst maintaining environmental sustainability. The NSTF strives to be inclusive of all national stakeholders and yet capable of reaching common understandings effectively."

It is interesting to note that the White Paper on Science and Technology (1996) stated that "The establishment of NACI will not reduce the important role of the National Science and Technology Forum (NSTF). Although the NSTF has a strong government sector within it, it is essentially a non-governmental body, which has full powers to decide on its own role and functions. Government will look forward to continuing the pattern of dialogue with the NSTF which has developed in recent years".

4.4.3 Department of Agriculture[119]

The Directorate: Research and Technology Development is the central coordinating body for research in the Department of Agriculture and provides:

- Science advice on research projects in the Department, for example annual reports and status report on projects in general
- Consults with other science bodies or departments, such as the DST and NSTF. It also assists in the development of mechanisms for management, as monitoring and evaluation of science councils, such as the Agricultural Research Council (ARC)

It also manages the National Agricultural Research Forum (NARF), which provides policy advice.

The National Agricultural Research Forum

"The National Agricultural Research Forum (NARF) is constituted on the basis of broad representation of key R&D stakeholders in the agriculture sector under the memorandum of understanding. Its main objective is to facilitate consensus and integrate co-ordination in research, development and technology transfer to agriculture in order to enhance national economic growth, social welfare and environmental sustainability and seeks to advise government through the Minister of Agriculture and Land Affairs on all matters pertaining to agricultural research, development and technology transfer." [120]

[120] http://www.nda.agric.za/docs/RD_Strategy.pdf

4.4.4 Department of Education

The Minister of Education is advised by the Council on Higher Education [121]. The Council on Higher Education (CHE) is "an independent statutory body with the responsibility to advise the Minister of Education on all matters related to higher education policy issues and quality assurance within higher education and training". The CHE was established in 1997 through legislation and started its operation in 1998. The NACI Act stipulates that NACI can also consult with the Minister of Education regarding advice dealing with the promotion of mathematics, the natural sciences and technology in the education sector.

4.4.5 Department of Environmental Affairs and Tourism

National Environmental Advisory Forum (NEAF) [122]
"The National Environmental Management Act (NEMA) recognises the establishment of NEAF as the National Environmental Advisory Forum that is established to advise the Minister on any matter concerning environmental management and governance, specifically the setting and achievement of objectives and priorities for environmental governance, and appropriate methods of monitoring compliance with the principles set out in section 2 of the Act. The Forum will also inform the Minister of the views of the stakeholders regarding the application of the principles set out in section 2 of the Act."

It was reported in the press on 15 June 2008 that the Minister of Environmental Affairs and Tourism, Mr Marthinus van Schalkwyk, has abolished the NEAF[123]. According to the press report, "NEAF members accused Van Schalkwyk of closing down the only compulsory forum involving himself and civil society. Although the NEAF is obligatory in terms of the National Environmental Management Act, Van Schalkwyk intends tabling amendments to the Act, allowing him sole discretion on when to convene such a forum…Environmental groups say that while scrapping the NEAF may be intended to streamline public consultation around the environmental impacts, it will ultimately further erode public trust in government policy". The newspaper further reports that the Environmental Affairs spokesperson confirmed that the NEAF would be dissolved at the end of June 2008, but that "…government would still have a statutory obligation to consult 'on major policy and legislative issues' and would do so through existing forums or through new ones appointed on an ad hoc basis".

[121] CHE, 2008. http://www.che.ac.za. An interview was held with Dr Lis Lange acting CEO of the CHE at the time.
[122] http://www.environment.gov.za/Branches/COO/neaf_2005/neaf_2005.php
[123] Bobby Jordan "Minister gives environmental forum the chop", Sunday Times, 15 June 2008.

4.4.6 Department of Trade and Industry (dti)[124]

The Department of Trade and Industry (the dti) does not have a dedicated body that provides it with science advice. Instead, the dti determines the research that is required for addressing a specific policy question and then outsources the required research to an external party.

The dti has a cooperation agreement with the CSIR which provides for a CSIR/dti Bilateral which meets four times a year and discusses and identifies research projects to be carried out by the CSIR for the dti. The dti also has a university research network, which consists of support for research and student support. The dti funds its research through the Research Committee of the Economics Research and Policy Coordination Unit (ERPC).

4.4.7 Department of Minerals and Energy[125]

The Mine Health and Safety Inspectorate[126] "aims to reduce mining-related deaths, injuries and diseases through the establishment of national policy, legislation and systems to regulate and enforce health and safety, and support training in the mining industry. The main functions of the Mine Health and Safety Inspectorate are:

- Providing policy inputs for the establishment and application of mine safety standards at mining operations, and promote their application;
- Providing policy inputs for the establishment and application of mine equipment safety standards at mining operations, and promote their application;
- Providing policy inputs for the establishment and application of mine health standards at mining operations, and promote their application; and
- Ensuring an effective support and inspection service."

The *Mining Health and Safety Council* (MHSC) oversees three permanent committees of the Council, viz

- *Safety in Mines Research Advisory Committee* (SIMRAC) reviews occupational health and safety (OHS) risks and establishes the need for OHS research projects; establishes criteria for determining the funding of health and safety research; evaluates research proposals and oversees the research programme and technology transfer of research outcomes
- *Mining Regulation Advisory Committee* (MRAC) is responsible for advising the Council on proposed regulatory changes, guidelines for codes of practice; and on national standards approved by the South African Bureau if Standards;
- *Mining Occupational Health Advisory Committee* (MOHAC) is responsible for advising the Council on health policies, standards, systems and procedures related to occupational health risks; health regulations, health research and health data.

[124] An interview was held with Dr Johannes Potgieter, Chief Director: Innovation and Technology at the Department of Trade and Industry. He is also a member of NACI.
[125] An interview was held with Ms Zungu, Deputy Director General at the DME.
[126] http://www.dme.gov.za/mhs/home.stm

4.4.8 The national academies

4.4.8.1 The Academy of Science of South Africa[127]

The Academy of Science of South Africa Act, Act 67 of 2001, came into operation on 15 May 2002. ASSAf is the official national Academy of Science of South Africa, recognised by Government and represents South Africa in the international community of science academies.

A core role of the Academy of Science of South Africa (ASSAf) is evidence-based advice to government. This is also reflected in ASSAf's budget of R9.5 million, of which roughly 75% is spent on science advisory related activities. ASSAf focuses on any policy field and in theory will engage with any problem from any policy area.

4.4.8.2 The South African Academy of Engineering[128]

Currently the South African Academy of Engineering (SAAE) is a non-statutory permanent body. The SAAE Draft Bill has been finalized in meetings between SAAE and DST, but the bill is yet be enacted into law. This is generally viewed as a very positive development.

According to the OECD report on South Africa's National System of Innovation (2007), neither ASSAf nor the SAAE appears to have a significant influence on government policy[129]. This position may have changed in the mean time.

4.4.9 Science councils and institutions of higher learning

There are a number of science councils in South Africa. Although their primary mission is to perform basic and applied research in their areas of expertise, they can also be called upon to deliver science advice to government. The science councils are the CSIR, HSRC, Mintek, NRF, ARC, MRC, SABS and the Council on Geosciences.

There are 23 institutions of higher learning in the country, consisting of universities, universities of technology (former technikons) and comprehensive institutions (institutions where universities and technikons were merged). In addition to the individual experts in these institutions that can contribute, a number of the institutions also have dedicated research institutes and units that can contribute towards providing science advice to government.

The individual experts in the science councils and institutions of higher learning that can contribute towards providing science advice to government can, of course, also make their contributions through structures other than the institutions themselves as well. These include standing committees such as NACI and the academies (Academy of Science of South Africa (ASSAf) and the South African Academy of Engineering (SAAE)).

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[127] Interviews were held with Professor Robin Crewe (President) and Professor Wieland Gevers.
[128] An interview was held with Dr Bingle Kruger (President).
[129] OECD, "OECD Reviews of Innovation Policy: South Africa", 2007.

4.5 Aspects of national scientific advice structures, vis-à-vis the portfolio of the decision makers and departments

One of the major points of departure in considering the nature of structures to provide scientific advice to government, is whether a country has a dedicated Department of Science (and Technology), as is the case in South Africa. In such cases there will typically also be a Minister for Science. The Minister of Science, being a politician will typically not be the Science Advisor to government. Even though the Minister may be a renowned scientist in own right, s/he will not have the time nor necessarily the expertise in all the necessary areas of STI. The principle of independent and autonomous external advice also precludes an executive to be his/her own advisor.

It is argued elsewhere that the Minister of Science must have an advisory structure that advises him or her. Associated with this, is the question of what aspects of innovation (in addition to science and technology) should also be included in this advice. The larger question though, is whether the President or Cabinet should also have a scientific advisory body, and to what extent this body should also address issues of innovation. If the Minister has an advisory body on science and technology (and aspects of innovation) and the President and/or Cabinet also has such a body, the question immediately arises to possible duplication, cross-lines or antagonism between the bodies.

4.5.1 International trends

International trends with regard to government structures in science and technology are discussed in the supplementary report *A review of the international bodies that provide science advice to government*[130]. Table 3.1(from the same supplementary report) below lists examples of foreign Ministries that show permutations of portfolios of science, technology, innovation, universities (higher education) and related areas. Note that there are several examples that combine science and higher education. Some countries have Ministers and Departments of Science and Technology. In other countries, there are Departments of Research to name but two. A trend that is gaining momentum, is to have a national Department of Innovation (and associated Minister). This notion is discussed below in further detail. Very often a Department of Innovation is grouped with other areas, such as Higher Education and Skills. There are also many countries, such as the United States, that do not have a Ministry or Department of Science and Technology at all.

[130] Sara S. Grobbelaar, *A review of the international bodies that provide science advice to government*, University of Pretoria, 2008.

Country	Name of Ministry
Austria	Ministry of Science and Research
Denmark	Ministry of Science, Technology and Innovation
France	Ministry of Higher Education and Research
Germany	Two separate ministries: Ministry of Education and Research and a Ministry of Economics and Technology
Ireland	Ministry of Education and Science
Italy	Ministry of Universities and Research
Netherlands	Ministry of Education, Culture and Science
Portugal	Ministry of Science, Technology and Higher Education
Slovenia	Ministry of Higher Education, Science and Technology
Spain	Ministry of Education and Science
Sweden	Ministry of Education and Research
UK	Ministry of Innovation, Universities and Skills
Australia	Ministry of Innovation, Industry, Science and Research
India	Ministry of Science and Technology
Japan	Ministry of Education, Culture, Sports, Science and Technology
New Zealand	Ministry of Research, Science and Technology

Table 3.1: Examples of foreign government portfolios that include science, technology, innovation and higher education

4.5.2 Cross-cutting issues

As was stated above, the government must be served with solid science advice – where the term science must be interpreted very broadly. It includes the natural sciences and engineering, life and biological sciences, technology – and also innovation. The distinction between "science and technology" and "innovation" is often blurred, but it was shown in a previous section why it is important to be clear about the distinctions. On the organisational level and specifically also on the national level, "innovation" would normally be interpreted to have a much broader scope than "science and technology". As an illustrative example, consider NACI's brief (set out in Appendix A of this document). Recent NACI studies subsequently focused on aspects of education for example, which would normally fall within the remit of the Ministers of Education and Labour. Recall that the Act makes provision for consultation with these two ministers.

Other advices may deal with the energy crisis, telecommunications, tax credits for R&D and health matters. The application of science and technology towards the alleviation of poverty and other social issues could also very well be interpreted within the innovation domain. The issues mentioned above all have science and technology aspects to a more or lesser degree, but all of them also fall within the remit of government Ministers and Departments other than the DST. In the cases mentioned above, those would include the Departments of Education, Minerals and Energy, Finance, Health and Social Development. Part of NACI's (and the Minister of Science and Technology's) dilemma, is that although NACI's advice is innovation-related, the application and impact is much broader than science and technology and ways must be found to "transfer" the advice to other Ministers and Departments. The NACI Act in fact determines that NACI must advise the Minister of Science and Technology but also that it must also advise the Ministers Committee and Cabinet through the Minister of Science and Technology.

A further complication is also that almost all government departments will have some aspect of science and technology that impact on them. The question is to what extent NACI should address issues that clearly fall in the remit of other government departments but are also science and technology related. This includes innovation, which can also be in the domain of a number of government departments, depending on how innovation is defined and interpreted. It is therefore important to develop, accept and implement a well-founded definition of “innovation”. This point refers to some governments’ decisions to establish departments of innovation, as mentioned above.

It must be stressed again that it is necessary for the government to have internal and in-house expertise on STI. It is, however, also essential that there is adequate external, autonomous and independent advice on science given to the government. This advice must be structured, so that all branches and levels of the government are served with regard to all the required aspects of science.

4.5.3 Science advice to the President

It is essential that the head of state, the President in the case of South Africa, be served by a well-functioning advisory function, including one that deals not only with science and technology but also with innovation and competitiveness. It must be clearly understood, however, that science and technology specific advice must be clear and present. The Presidency currently has a number of advisory and consultative structures that it turns to, as described elsewhere in this report. This includes the International Investment Committee and the ICT Advisory Group. A strong case can be made, however that the President and Presidency must be served by a Council that focuses on Science, Technology and Innovation. In this body, STI must be interpreted very broadly. It must account for the contribution of STI to economic growth, the country’s competitiveness as well as the social well-being and quality of life as well as the international dimensions. These issues are cross-cutting amongst many government departments, and hence must be elevated one level for coordination and advice.

If a country has a science minister, that minister can be the source (through his advisory structures) and funnel of scientific advice to the Presidency and cabinet. One model would be for the science minister to have an extensive science advisory structure, and that s/he can be the conduit for science advice to the Presidency and Cabinet. In such a case it is essential to ensure that the Minister is served by an adequate independent external advisory body, and does not rely on the in-house expertise of the Department of Science and Technology alone. Since the Minister is also a member of the Cabinet, one should guard against the Minister acting as his/her own advisor,

Another model will be for the Presidency (and Cabinet) to have its own innovation (or scientific) advisory structure. This is the model in which Sir David King operated in the British Government until very recently, having been appointed as the Chief Scientific Advisor. The model also has some dangers, in that it may be possible for the “Presidential advisory group” to come into conflict in some way or another with the science minister and his/her advisory group(s), politics being what they are.

Whatever model is followed, however, it is essential that the head of state has access to well-founded and independent science advice in the broadest term. Furthermore, there should be mechanisms to deal with the advice once it has been delivered. This problem is of course not unique to STI, but applies to many governmental issues.

4.5.4 Science advice to the Minister of Science and Technology

Irrespective of whether the Presidency has its own innovation or scientific advisory structure, it is essential that the Science Minister (if there is one) should also have a scientific advisory structure. This can be a combination of the following:

- An individual Science Advisor or advisors
- A structured body (such as the current NACI), of which the members are appointed by the Minister. Under a previous Minister, the Minister's advisor was also the chair of NACI. This practice was deemed inappropriate at the time and discontinued. However, its merits should be reconsidered.
- Use of ad hoc groups that focus on specific problems, or the ad hoc use of existing organisations such as the Academy of Science of South Africa (ASSAf), the South African Academy of Engineers (SAAE) or the Royal Society of South Africa, for example.

There should also be a very clear distinction between the Minister and the Ministry on the one hand, and the Department on the other. This has a serious impact on the independence of the advice. It is necessary for the Minister and Ministry to have access to independent advice. This also implies independence from the department for which the Minister is responsible. Although the Department can also access advice through some of the channels mentioned in previous paragraph, it is essential that the Minister must have access to external advice that is independent from the line department.

4.5.5 Science advice to the Department of Science and Technology

In order to construct a national science advisory system, it is therefore necessary to be very clear about the role and mandate of the Department of Science and Technology. There must be clarity whether the term "science" refers to the nation's research capacity, public and private, if the social and sciences are included, or whether it is limited to the natural sciences. A further issue is the way in which science and technologies that also fall within the remit of other departments (such as energy, telecommunications, defence, health and environment) are shared and dealt with by the DST (with regard to policy, regulation, legislation and budget). Furthermore, it is also necessary to define "innovation" and how various government departments take responsibility for their part and contribution to the National System of Innovation. The DST currently views itself as a major custodian, with an oversight function, of the National System of Innovation. Although a nodal point for coordination is useful, there are obviously many other role players, including other government departments, who must contribute and participate. The question that must be addressed in the context of this study, is where and how bodies that give advice on science, technology and innovation should be located, what the scope of advice is, and to whom it should be rendered.

4.5.6 Science advice to other government departments

Every government department should have an advisory structure that addresses the science and technology issues in that department. This is particularly relevant in government departments that also have their own research budgets. The Department of Science and Technology, in particular, should have such a mechanism.

4.5.7 Science advice to Parliament

During NACI's recent interactions with the Parliament, it was evident that there was a need for the Parliament, and the Parliament's Portfolio Committee on Science and Technology in particular, to also have access to a scientific advisory body (such as NACI). During the discussions, it was pointed out that NACI's remit according to the NACI Act, is to serve the Minister of Science and Technology and not the Parliament per se, even though NACI (as a publicly funded entity) will also report to the Parliament regarding its activities.

There are many examples where countries' legislative bodies have scientific advisory bodies, or advice bodies that can produce innovation, science and technology related advice. In the USA, for example, the *Congressional Research Service* (CRS) performs this function as did the (now defunct) *Office of Technology Assessment* (OTA). The *Institute for Prospective Technological Studies* (IPTS) that served the European Union is also an interesting organisation in this regard.

It is recommended that the establishment of a science advisory structure or function that can serve the Parliament also be considered.

Chapter 5
Conclusions and Recommendations

The purpose of this report is to offer proposals that can contribute towards the development of an enhanced structure to provide science advice to government in South Africa.

The South African government has, through its policy papers and actions, indicated that it recognises the importance and value of the provision of science advice to government. The point was made in the White Paper on Science and Technology of 1996. The establishment of NACI and the recognition of the national academies are further examples of this. Since the publication of the White Paper on Science and Technology in 1996, the environment in which science and technology policy impacts, has changed dramatically. There has been a steady advancement of the country's standing in the international arena, an evolvement of the Government's national policies as well as significant changes in the national and international science, technology and innovation domains. Whereas the establishment of the Department of Arts, Culture, Science and Technology (DACST) was in itself a new and welcome development in South Africa, its subsequent unbundling led to the establishment of the Department of Science and Technology (DST). This paved the way for a more focused national science, technology and innovation strategy. There have also been significant developments with regard to best practices in respect of providing science advice to government, internationally as well as locally. This has contributed to substantial learning from experience of NACI itself as well as from international best practices regarding the nature of providing science advice to government as well as the nature and structure of such advisory bodies.

The circumstances within which NACI was conceived and established have clearly changed since its conception and establishment almost a decade ago. At the time of NACI's planning meeting in August 2004, there was general agreement, including amongst the members of NACI itself, that it is necessary to revisit NACI's mandate and role. NACI subsequently initiated such a study and provided advice in this regard to the Minister of Science and Technology late in 2006. It was evident from that study that the repositioning of NACI by itself would offer a suboptimum, necessary but not sufficient solution. What was required was a review of the entire system of providing science advice to government as an essential element of the National System of Innovation, and to define a more focused structure that could serve the country's future needs in a coordinated and synergistic manner. NACI's future role should be defined as a role player in such a system, together with others.

This report captures the research, and subsequent findings and recommendations, that was undertaken at the University of Pretoria to address the question and issues surrounding a structure that can provide South Africa's future needs regarding the provision of "science advice to government". The report was prompted by NACI's need in this regard and as such is made available to NACI, who can use it to inform its advice to the Minister of Science and Technology. The report will also be distributed to other stakeholders who have an interest.

The study has shown that the topic of providing “science advice to government” is one that is receiving significant attention globally. Not only is it a topic about which an extensive body of literature as well as knowledge exists, but also one, which is very current in policy circles.

The study included an extensive review of international practices, including discussions with officials and advisory structures in and from the United States, Australia, Singapore, Finland, the United Kingdom and the OECD as well as South Africa. A review of the literature, interviews and discussions were conducted with officials from various advisory structures in South Africa, including the Presidency, government departments, the national academies, science councils and universities as well as other advisory structures.

Given the nature of the topic and the current contexts in South Africa, this report will best serve its purpose by highlighting the importance and the major topical issues that surround the provision of “science advice to government” and to suggest options as to how they may be applied in a future structure in South Africa, rather than to present rigid “best answer” directives. As in many complex problems, there is no single right answer. The “best” solution is very dependant on the larger contexts, the interaction with other elements in the system and, in the case of advice, also the preferences of the policy makers to whom the advice is to be delivered. Hence the positioning of this report as a discussion document, culminating in a discussion of various options.

The options are issues on which decisions should be made. Often they are not mutually exclusive, and very often the differences are subtle. However, often these subtle differences lead to flawed science advice to government and problematic policy down the line. As part of the conclusions and recommendations given below, options are pointed out, with the implication that they need to be resolved in order to establish a robust future structure to provide “science advice to government”.

5.1 Importance of Science, Technology and Innovation

There can be little dispute as to the importance of science, technology and innovation (STI) with regard to their contributions to economic growth, competitiveness of the nation as well as the social well-being and quality of life of its citizens. This point is well recognised in South Africa, but should continuously be emphasised, in word and deed. Without a robust and well functioning science, technology and innovation capability, the country will find it difficult to attain its national goals and aspirations. It is important that that there is also a cohesive thrust to enhance the nation’s competitiveness.

It will be beneficial for government to reconfirm its acknowledgement of the importance of science, technology and innovation as necessary contributors towards economic growth and prosperity, competitiveness, quality and life and the social well-being of all the citizens. It is also important to acknowledge the importance of competitiveness and the government’s commitment towards ensuring that the country improves its international competitiveness.

5.1.1 Defining Science, Technology and Innovation

In order to arrive at a structure that can provide science advice to government, its is necessary to be clear about the definitions, meanings and interpretations of the terms “science”, “technology” and “innovation”. This is not merely a semantical indulgence, but lies at the heart of the challenge. If there is ambiguity, misunderstanding or confusion about these terms, it can result in ambiguous advice and may ultimately lead to flawed or unstable policy.

The problems that can arise include an attempt by more than one government department to address the same challenge or, alternatively leave some issues that are not addressed by anyone and thereby create an advice or policy void. Many of the issues in the STI arena are cross-cutting and are not limited to the domain of one government department. Although the Department of Science and Technology (DST) is obviously a major player, practically all the other departments are also involved in STI in one way or another. Consultation and coordination therefore becomes a very important matter, albeit one that brings its own challenges in government, specifically when it also involves provincial and local authorities. The principle of co-operative government is an important one, and is in fact encapsulated in the South African Constitution. Ultimately it is necessary that the nation and all the branches of government on all levels share the same vision, and that there is a coherent and coordinated national policy. This also applies to science, technology and innovation.

There are a number of different interpretations to the term “science”. They are not necessarily mutually exclusive, but it is exactly this subtlety that can create the types of problems mentioned above. The issues that must be resolved include the following:

- Do we mean by “science” the natural sciences (which can include the engineering, biological and life sciences) or does it rather refer to the body of knowledge organised in a systematic manner, implying the use of the scientific method as the research vehicle? Does the term refer to a body of knowledge (that is constantly expanding) in the natural sciences, or does it pertain to the nation’s processes of generating new knowledge (which will include the disciplines in the humanities and social sciences)?

  From a national policy viewpoint, the first approach will typically include the second, but only as far as the natural sciences are concerned. These pertain to “the systematic study of the nature and behaviour of the material and physical universe based on observation, experiment and measurement, and the formulation of laws to describe these facts in general terms”. In addition to research in science (which in this case will imply the natural sciences), there are a number of other non-research issues that are also implied, particularly with regard to science advice to government. These include advice on science councils, science education, new legislation and so on. The second viewpoint is more slanted towards the process of research, and will impact on the national research policy and strategy. It will, as such, include the social sciences and humanities, as well as the natural sciences, engineering and the life sciences (including veterinary science). The concept is illustrated in Figure 5.1.

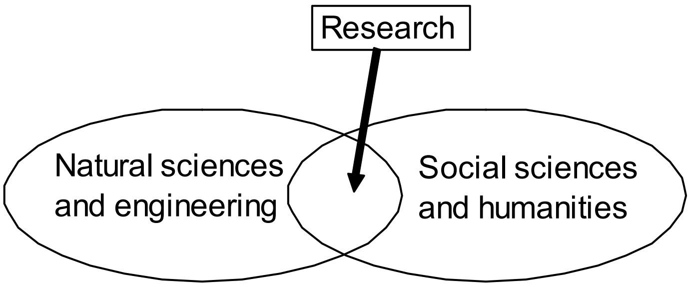

Figure 5.1: Interaction between natural sciences and engineering, social sciences and humanities, and research as the interface

An interesting vignette is to consider the transformation of the Foundation for Research Development (FRD) into the National Research Foundation (NRF). The FRD was a science council in South Africa, resorting under the DACST, and was tasked primarily to fund research and research development at institutions of higher learning in South Africa, specifically in the natural sciences and engineering. At the time concomitant funding for research in the social sciences and the humanities was done by the Centre for Science Development in the Human Sciences Research Council (HSRC) and research in medicine and the life sciences by the Medical Research Council (MRC). Through the consolidation that accompanied the establishment of the NRF, one of the fundamental shifts was in effect to move from the interpretation of “science” as pertaining only to the natural sciences (and engineering in this case), to the interpretation that focuses more on the quest for new knowledge through the application of the scientific method, and as such also embracing the social sciences and humanities.

The NRF was formed by a merger between the functions of FRD and the funding agency of the HSRC referred to above. The NRF therefore currently funds research in the natural sciences and engineering as well as the social sciences and the humanities, in universities and universities of technology. The NRF also rates and funds researchers in the medical field. The MRC also has agency function that funds academic research, although it funds units. Many of the other science councils, including the CSIR and the Agricultural Research Council (ARC), also fund research at universities, but typically as contract research rather than grant funding as in the case of the NRF.

- To what extent does the term “science” also imply, for purposes of policy and the associated advice, the concepts pertaining to “technology”? This is more applicable to the natural sciences interpretation of the term science referred to above.

- To what extent is “innovation” also included in the term “science” in the context of providing science advice to government? In Section 3.3.1.4 of the report it is explained that “innovation” is a process that, in principle, is a very broad one. Although the term is often used, specifically in the policy domain, to refer to scientific and technological innovations there are many other types of innovations other than scientific and technological innovations. These include marketing innovations, organisational innovations, financial innovations, fashion innovations, service innovations and an almost infinite number of other types of innovations. One of the issues that must be clarified is to what extend the national advisory structures on innovation also deal with these innovations.

Although a first take will be to indicate “innovation” to refer to scientific and technological innovations, it is important to realise that there are many dangers, from a policy viewpoint, in adopting a definition that is too narrow. Even scientific and technological innovations often rely heavily on the social sciences and humanities for success. Very often there are elements of natural sciences and the social sciences that combine to contribute towards an innovation. The success of the sewing machine, for example, was attributed to the mechanical invention of the machine as well as the financial innovation of the forerunners of “hire purchase”. The latter enabled households who did not have sufficient money to buy a machine outright, to still acquire one and pay for it in instalments. This ensured the widespread adoption and diffusion of the invention, thereby turning it into a successful innovation.

- There is also a debate as to whether the term “innovation” should include the concept of “invention” (which can again include the notions of discovery, research, creativity and other forms of knowledge generation), development and manufacturing as well as commercialisation (which can include marketing, diffusion and adoption). It is suggested that a useful working definition of innovation is

  innovation = invention + market exploitation

- It is important to caution against the perils and pitfalls of the “linear model” of innovation. In its simple form, this model implies that the “first step” is science (produced by research), followed by development that leads to technology, manufacturing and finally marketing that leads to commercialisation. It is generally acknowledged that innovation is a much more complex process, and certainly not, in general, a linear one. There are many iterative and feedback loops. Also, technology does not necessarily follow science. There are many cases where it is actually the other way around. At the same time, it should also be recognised that the process of innovation contains many steps and sub-processes. The inclusion of these (such as in the equation above or in Figure 3.3 conceptually depicting the government-science space) does not necessarily imply a linear causal relationship, but merely indicates the elements that are included.

  An implicit and sometimes (false) intuitive application and acceptance of the linear model often finds it embedded in organisations, processes and policies. These may include the design of engineering curricula (see Appendix B), the layout of factories, and the decisions of what the portfolios of government departments should be or how decisions that fund research at agencies that fund education in higher education, for example, are made.

In South Africa, current government departments include the Department of Science and Technology (DST), the Department of Education (DoE) and the Department of Trade and Industry (dti). Other countries have found it useful to have different configurations, which in a sense also reflect different interpretations of the innovation model. In Australia, for example, there is a Department of Innovation, Industry, Science and Research and the UK a Ministry of Innovation, Universities and Skills. In many countries the emphasis in the configuration of government departments is not so much on science and technology per se, but rather on research and innovation. Following this line of argument in other countries, higher education is often grouped in the research cluster, rather than in the same cluster with primary and secondary education.

5.1.2 The importance of competitiveness

It has been said that the difference between invention and innovation is that whereas invention creates new knowledge, innovation creates new wealth. Hence the importance of focusing on innovation as the ultimate goal, rather than on invention. In a similar manner the importance of competitiveness cannot be over-emphasised[131].

The importance of competitiveness is recognised in a number of South African policy documents and declarations. The NACI Act also refers to one of NACI's objects as inter alia advising the Minister on "strengthening the country's competitiveness in the international sphere". The Act refers to competitiveness as a national objective. There is certainly a tight link between competitiveness and innovation. Whereas a strong public policy on innovation is essential, ultimately it is competitiveness that counts. Innovation is necessary but not sufficient condition for competitiveness.

It is therefore important that competitiveness, in own right, be recognised as an important national objective, and that this importance is reflected in its treatment in public policy, organisational structures (including portfolios of government departments) as well as appropriate advisory structures.

5.1.3 National STI policies

The government executes its mandate through policies. The differences in the definitions of science, technology and innovation (STI) have policy implications, in the sense that, depending on the definition, the science policy will be different from the technology policy, which will in turn be different from the innovation policy and competitiveness policy.

[131] C.W.I. Pistorius, "South Africa's Competitiveness Trap", *South African Journal of Science*, Vol 97, January/February 2001, pp. 9-15.

One way to conceptualise these policies is to view the national science policy as dealing with the nation's research system (natural sciences, engineering, social sciences, humanities and health sciences). The technology policy will deal with the technology aspects and can encompass the science policy although there may be many issues that are addressed by the technology policy that may not necessarily be part of the science policy. In a similar manner, the innovation policy deals with the National System of Innovation and how it will promote innovation in the country. It will encompass the technology policy (and hence also the science policy), but also address a number of issues that do not necessarily form part of the technology policy (and thus also the science policy). Ultimately there should be a national competitiveness policy.

5.2 The importance of providing science advice to government

It is generally accepted that a well functioning structure that provides science advice to government is an essential component of any modern national system of innovation. This is certainly also true for South Africa.

Given the importance of STI towards economic growth, social well-being and quality of life, much of which is manifested in a nation's competitiveness, the government must ensure that it has adequate internal in-house expertise with regard to science, technology and innovation. It is, however, important that the national policies regarding science, technology, innovation and competitiveness must also all be the subject of independent and autonomous external advisory structures that provide "science advice to government".

Before different advisory structures are discussed, it is important to acknowledge the difference between the concepts of advice, consultation and coordination. Advice is typically given by either an independent external body (committee or individual) or an internal or in-house body (committee or individual), and is in essence recommendations as to an appropriate course of action. In this context, advice is delivered to government, as manifested in the executive branch (President and Presidency, Cabinet and individual ministers, government departments), legislature (Parliament) and the judiciary all on the national level, as well as similar structures on the provincial and local levels.

Consultation refers to discussions and interactions between decision makers and other stakeholders, which can include advisors. The aim of the consultations can, for example, be to inform, to reach consensus and/or to arrive at a decision. Where the decision maker who must be advised partakes in the consultation, it can strictly speaking not be independent advice anymore, since a decision maker cannot advise him or herself.

Coordination refers to actions that are aimed at aligning and harmonising different actors or policies with an aim of all contributing in an effective and efficient manner to the same goal. In order to coordinate successfully, advice may be required and such may be an element of the coordination activity.

The government must acknowledge the importance of the provision of independent and autonomous science advice to government, and ensure that the government-science space is adequately addressed in this regard.

5.3 Providing science advice to government

5.3.1 The National System of Innovation

The National System of Innovation (NSI) is a very useful policy concept, and a vehicle through which all levels of innovation can be promoted and coordinated, be they on the institutional or national level. The concept of the NSI acknowledges not only all the components of the innovation process, but also that there are a large number of role players nationally who must contribute in order to have a successful NSI. It is a manifestation of the dictum that the whole is larger than the sum of the parts. The networks and linkages between the different role players are very important.

Coordination of the NSI and its elements is an important aspect of national policy, and forms the basis of national innovation policies. The surge of such policies across the world, on the national, regional and local levels, is evidence of the general recognition of the importance of this concept. Given the broad spectrum of role players and activities that are all part of the NSI, the responsibility for coordinating the NSI is a policy challenge. The DST, by virtue of its mission, currently accepts significant responsibility for this coordination. The NSI also features very prominently in the NACI Act with regard to issues on which NACI must advise the Minister of Science and Technology.

The question remains, though, whether a single government department can effectively coordinate the entire National System of Innovation, particularly if the Department's main focus is on the science and technology components of the system. The notion that the NSI should be coordinated on a higher level should be considered. Irrespective of the organisational arrangements, it is essential that an advisory structure addresses the National System of Innovation.

When conceptualising structures to provide science advice to government, it is important to distinguish between the concepts of advice, consultation and coordination as briefly discussed above. Given the broad span of STI, it is essential that appropriate mechanisms be created to coordinate STI across all elements of the government. Science and technology is pervasive in all government departments, even though its application may be specific to a given department (such as agriculture, health or the environment, for example). Innovation as it manifests in the National System of Innovation, however, is a cross-cutting process, that affects practically all of government. Every department must play its role. To ensure that the NSI functions effectively and efficiently, it is therefore important that it should be coordinated at a level higher than a single government department. A coordination function in the Presidency or at Cabinet level is an appropriate level. A Ministers Committee can also be utilised for this purpose, in which case there must be a clear lead Minister (and associated department) identified, with an articulated role.

An independent external advisory structure should then be established to advise the policy makers responsible for the National System of Innovation, where "innovation" must now be interpreted in its broadest sense. In as far as different government departments do contribute to the NSI, they too should be advised in this regard in their areas of responsibility. This principle also applies to the Department of Science and Technology, which may play a larger role than many other government departments with regard to the NSI.

5.3.2 Science advice to the President

Many countries have advisory bodies that advise the head of state on issues pertaining to science and technology. It was argued in this report that the terms "science and technology" should be interpreted broadly in this regard. A more appropriate approach would perhaps be to advise the head of state on issues regarding the NSI and competitiveness, which must specifically include matters pertaining to science and technology where appropriate. However, STI also contributes to social well-being and quality of life in addition to economic growth and prowess and competitiveness, and these aspects should also be captured.

The President of South Africa currently has a number of advisory, consultation and coordination structures, including advisory bodies dealing with international investment and ICT. Caution should be exercised in merely incorporating advice on the NSI and competitiveness into one of these existing bodies. The thrust and importance of the NSI and competitiveness justify consultation and coordination bodies in own right, together with the associated advisory bodies. A standing committee of some sort (conceptually a "super NACI") would be an appropriate advisory structure in this case, as is the case in many other countries.

5.3.3 Science advice to Ministers

Ministers all have departments that execute the policies of their portfolios. Every department is headed by a Director-General. Even though the departments execute the policies, they are usually also involved in planning and policy formulation. Ultimately, it is the Minister, however, who is accountable for the political decisions and policies. It is therefore important to emphasise the difference between the Minister and the Ministry (which can include the Deputy Minister(s) if any) on the one hand and the associated Department on the other hand.

It is a healthy governance principle for the Minister to have an autonomous external advisory function that is independent of his/her Department. The advisory function must be attached to the Minister and Ministry, rather than the Department (which does not preclude the Department of having its own advisory functions of course). This provides, from the Minister's viewpoint, a check and balance on the advice and proposals originating in the Department. The Minister's advisory structure can typically include:

- One or more individuals
- A standing committee, where the Minister will appoint specific individuals for a term

- Ad hoc advice, which can come from a variety of sources. These include the national academies, science councils, universities and public opinion (through forums or electronic solicitation of inputs, for example).

It was argued in the report that advice that is presented to the Minister must adhere to a number of criteria, described elsewhere. In essence though, the advice must support the Minister’s decision-making ability. As such it must account not only for the technical matters, but also the social, economic, environmental and a host of related issues. Impacts must be assessed. Given the political nature of the Minister’s decisions, the advice must specifically also account for the political aspects and implications. Hence the advice must be the product of policy analysis. In order to be useful to the Minister, the format of the advice must also be aligned to the Minister’s preferences.

An argument can therefore be made that the Minister should be served at least by a standing committee as contemplated above. This committee must have a secretariat that can perform the secretarial duties associated with a committee, have the ability to manage the projects associated with outsourced contract research and also have an adequate policy analysis capability. The existence of such a committee does not exclude the use of other forms of advice to the Minister but can rather facilitate and enhance the usefulness of other forms of advice, particularly with regard to aspects of policy analysis, formatting and enhancing the Minister’s decision-making capability.

It is suggested that a new minister should have the right to appoint his/her own members of his/her advisory board (including the chairperson), irrespective of whether the term of office of the members appointed by the previous Minister has run out. A new Minister should have the same prerogative as his/her predecessor and not necessarily have to work with the same council appointed by his/her predecessor. Councils such as NACI, which can have up to 22 members, may not be required in all cases. Smaller committees or individuals (Science advisors to the Minister) may be appropriate for many Ministers.

5.3.4 Science advice to the Minister of Science and Technology

In the case of the Minister of Science and Technology, NACI provides an advisory function. If a higher level advisory body is created to advise the President and Cabinet on issues pertaining to the National System of Innovation, it may be useful to change NACI’s name to something more appropriate and aligned with its mission of advising the Minister of Science and Technology. Specific proposals regarding NACI, its mandate, positioning and operations are made elsewhere in the report.

It is, however, strongly suggested that the Minister retains a standing committee comprised of external members that can serve him/her with independent advice regarding matters of science and technology. This body should have a demonstrable independence from the DST. Currently, that body is NACI. This does not preclude the Minister from using other sources of advice as well, as was discussed in a previous section.

5.3.5 Science advice to government departments

The point was made that science and technology are very pervasive in government, and that they affect practically all government departments. Given the necessity of providing and accepting science advice to government, one would expect that departments will have mechanisms to also acquire external advice on science and technology that pertain to their areas of responsibilities.

5.3.5.1 The Department of Science and Technology

The Department of Science and Technology (DST), as it is currently configured, has a coordination and oversight role where it is responsible for national strategies regarding science, technology and innovation and the NSI. At the same time it also executes its own STI mandate, funded by a budget allocation to the Department. The DST's and other government departments' involvement with the NSI, and subsequent advisory needs, were addressed above. In as far as the DST's science and technology mission (as opposed to the broader innovation mission) is concerned, it must also draw on external advice. This need not necessarily be in the form of a standing committee (such as NACI) but can comprise of a range of other advisory modes. These include ad hoc committees, inputs from the national academies, science councils and universities as well as the solicitation of inputs from the public. The latter can be via workshops or invited comments on position papers and bills.

It is very important that the DST has a close liaison link with NACI, to ensure that NACI is informed and in a position to pro-actively advise the Minister of Science and Technology. The DST can also consider establishing a forum where the science advisory boards of different government departments meet and coordinate.

5.3.5.2 Other government departments

Science and technology play an important role in most other government departments. The same sort of advisory structures proposed for the DST above can also be utilised by them. Where science and technology is not a department's main mission, but plays an important role, the role of science advisor can also be utilised. Other departments may also defer to the DST for advice on their science and technology issues, given the DST's mandate and coordination role.

5.3.6 A new portfolio configuration?

In the discussions above a scenario was sketched where the STI portfolio can be divided amongst government departments in different configurations. Such an arrangement implies a different view and interpretation of the innovation model, and certainly does not underscore the linear model. Different innovation models and the subsequent way in which they can underpin different configurations of the portfolios of government departments should be interrogated.

Many governments do not have departments of "science and technology", including the United States. This does not (necessarily) mean that they underestimate the values and contributions of science and technology. Given the pervasive nature of science and technology, STI are often addressed in other configurations with specific coordination mechanisms on a high level. The arguments behind these configurations would be the synergies behind the national research system and higher education, as well as the notion that the ultimate goal is successful innovation and competitiveness rather than just science and technology per se. Both the Australian and UK governments have positions of the equivalent of a Chief Scientific Advisor to the government, with the appropriate infrastructure. This function provides not only advice, but also participates in coordination and consultative bodies that serve the government.

Whatever the configuration, it is essential that appropriate independent external structures exist that provide adequate advice on science and technology matters per se to government (as opposed to the broader innovation and competitiveness issues).

5.3.7 Science advice to Parliament

Parliament very often passes legislation with science, technology and innovation related contents. In order to execute its oversight role, it may also require knowledge and interpretation on aspects regarding science and technology. This is particularly true for the Portfolio Committee on Science and Technology.

It is very evident that Parliament also requires a structure that can advise it on matters of science and technology specifically, but also on other issues pertaining to the National System of Innovation. There are many examples of legislative bodies in other countries that have access to such advisory bodies[132]. The (now defunct) *Office of Technology Assessment* and the *Congressional Research Service* that serve the USA Congress are good examples.

In discussions between NACI and the Parliamentary Portfolio Committee on Science and Technology, it became evident that the South African Parliament will also benefit significantly from an advisory structure that serves it with advice on science and technology. As in the case of the Minister, such a function may consist of individuals, a standing committee and/or ad hoc advisory inputs. The latter may, for example, be from the national academies, science councils, universities and solicitations from the public through a variety of mechanisms. Many Parliaments, including that of South Africa, also use public hearings to gather information and advice. This can be a very useful mode, and certainly one that can also be applied to science and technology. As in the case of the Minister, it will, however, be useful to have some sort of a standing committee with a small secretariat to coordinate the advice, particularly with regard to the required policy analysis.

[132] Sara S. Grobbelaar, *A review of the international bodies that provide science advice to government*, University of Pretoria, 2008.

5.3.8 Science advice to the Judiciary

The judiciary often finds itself in a position where sophisticated matters regarding science and technology are put before it. The NACI Act, for example, charges NACI inter alia with advising the Minister of Science and Technology on “developments in the fields of science, technology and innovation which might require new legislation”. It is contemplated here that developments in science and technology may from time to time require new legislation. Hence one can anticipate that the judiciary will also need advice on matters of science and technology.

Even though the judiciary may not require a standing committee to advise it, it can draw on external, independent advice from other sources as well. This advice should be distinguished from expert witnesses that may testify on behalf of litigants. The external independent advice to the judiciary may be delivered by individuals as well as the other bodies mentioned elsewhere in the report.

5.3.9 Science advice to provincial and local governments

In exactly the same manner in which the national government and its executive, legislative and judicial branches require independent external advice on matters pertaining to science and technology, so will the provincial and local authorities. Recall the vignette on the (almost) embarrassing legislation that was almost passed in the State of Indiana in the USA regarding the physical constant π.

5.4 Advice and advisors

5.4.1 The nature of advice

There are a number of actors who can provide science advice to government. These include individuals, standing committees, ad hoc committees, public and private organisations such as science councils, universities and non-governmental organisations (NGO), national academies (such as the *Academy of Science of South Africa* (ASSAf), the *South African Academy of Engineering* (SAAE), the *Royal Society of South Africa* (RSSAf) and other learned societies and professional bodies, public forums (such as the NSTF), labour organisations, advocacy and lobby groups as well as various international organisations. It is also important to identify international organisations that can be used to provide science advice to the government in South Africa.

It is generally acknowledged that a constellation of role players is in fact required to serve the government with advice, including advice on issues pertaining to science and technology. It is essential that, in addition to internal and in-house expertise, the government also has access to and uses external, autonomous and independent advice. The government-science space must be populated and covered with a well functioning system of bodies that can provide independent, external advice. This principle is clearly reflected in international practice.

It is, however, important to also acknowledge that the value of the advice and hence also its usefulness, particularly as an instrument of decision support, depends significantly on a number of factors and characteristics. In addition to the scientific integrity, characteristics such as an absence of bias and timeliness are all important. The independence of the advice reflects upon the absence of a conflict of interest.

In order to be useful for political decision makers, the advice must account for the political decisions, impacts and consequences, in additional to the STI, economic, social and environmental aspects. The advice must, ideally, consider various options and their consequences, be they direct or indirect, intended or unintended, immediate or delayed. The quality of policy analysis that can be brought to bear on the advice is just as important as the technical quality of the advice.

Much of the discourse on providing science advice to government focuses on the delivery of the advice. It is, however, also necessary that attention should be paid to the notion of receiving advice. Policy and decision makers must be empowered to utilise the science advise they receive.

5.4.2 Transparency

There will always be a tension between confidentiality between an advisory body and the decision maker that it advises on the one hand, and transparency on the other. Like many things in life, an appropriate balance is required.

Very often the underlying research that informs science advice to government is publicly funded. More often than not, this research does not contain sensitive information that prevents it from being put in the public domain. One approach may therefore be for the advisory body that commissioned the research, to make it available for public scrutiny, comment and criticism before the advice itself is formulated. This will introduce an element of peer review as well as the attraction of additional information, which can all be subjected to the policy analysis process before the advice is formulated. It should be stated clearly, however, that such research, although commissioned by the advisory body, reflects the opinions of the authors and does not necessarily represent the views of the advisory body nor the decision maker whom the body advises. It should also be clear that the report does not constitute advice to the policy maker.

Alternatively, the report can be released to the policy maker who is being advised first, together with the advice itself. The report can then, at a later stage, after the policy maker has had the time to consider the report and advice, be put in the public domain.

A case can be made that the actual advice that is rendered to the decision maker should be done so in confidence, and that it is the prerogative of the decision maker to decide whether all or part of the advice should be put in the public domain. Unless there is a good reason not to do so, that would be the preferable route. An appropriate time delay can also be introduced as a default option. A related argument is that the debates regarding the formulation of the advice themselves are usually also best conducted in private, since that encourages robust and frank discussions. This does not, of course, exclude additional public debate on the matters.

Transparency is important in the process of providing science advice to government. It defrays unnecessary suspicions and biases. Equally important is the stimulation of public debate on matters of science and technology, as is the process of enhancing the public understanding of science and technology. Hence the need to conduct much of the business of providing science advice to government in the public domain.

5.4.3 The national academies

The national academies in South Africa, particularly the *Academy of Science of South Africa* (ASSAf), the *South African Academy of Engineering* (SAAE) and the *Royal Society of South Africa* (RSSAf), can play a special role with regard to the provision of science advice to government as important elements in the broader constellation of bodies that can render science advise to government. As a “free agent” the societies can claim a high degree of independence, they can muster experts that may not always be present in other standing advisory committees, and their advice can serve a multitude of clients. These are the same characteristics that distinguish similar academies in other countries, notably the National Academies in the USA.

The academies’ advice can be offered in an unsolicited mode, i.e. on the academies’ own initiative, or in response to a request from a decision maker or body. Such request can come directly from the decision maker (a Minister for example) or via the decision maker’s own advisory structure (such as NACI).

5.5 National capacity for science advice and policy analysis

The case for the necessity to provide science advice to government has been made. It was also argued that good science advice must be supported by good policy advice in order to be useful as decision support.

One of the problems that South Africa faces, is a shortage of scientists and engineers. This includes a shortage of enough scientists to provide in all the science advisory needs, given the requirements of independence, transparency and such like, and the number of advisory structures that need to be populated. An even greater and direr need in the current context though, is the national shortage of policy analysts, particularly in the fields of science, technology and innovation.

It is recommended that a programme or programmes be initiated and supported where such policy analysts can be trained and where policy research can be done. Research institutes and units at universities (preferably more than one) are ideally placed to do this. In addition to training analysts and producing research on policy analysis, these institutes will also be able to contribute policy analysis functions to various bodies that provide science advice to the various elements of government, including the Presidency, Cabinet, Ministers, Departments and the Parliament.

It may also be useful to establish research institutes that focus on impact assessment, in a manner similar to the (now defunct) *Office of Technology Assessment* in the USA or the *Institute for Prospective Technological Studies* (IPTS) in the European Union. In a similar fashion, there may also be a need for an institute to focus on aspects of South Africa's competitiveness in a manner similar to the *Council on Competitiveness* in the USA.

It must be acknowledged that the fields of science, technology and innovation policies are vast, and the bodies of knowledge and best practices pertaining to providing science advice to government similarly so. It is recommended that a separate study be undertaken to focus specifically on best practices regarding the advice, rather than the organisations through which it can be rendered.

5.6 Recommendations pertaining to NACI

Advice was delivered to the Minister of Science and Technology in 2006 pertaining to NACI as such, rather than on broader science advisory structures. The advice was in response to a brief, initiated by NACI itself, to investigate NACI's mandate and position, rather than its position in a future structure to provide science advice to government. For the sake of completeness, those main features of that advice, supplemented by the author of this report's views, are presented here.

A role for NACI

5.6.1 In as much as NACI already exists in the role of advising the Minister of Science and Technology as an independent council appointed by the Minister, it is recommended that NACI (or similar renamed body) should continue to do so, taking into account the other recommendations in this report. If the Minister chooses to have a personal advisor (or advisors), such an advisor's role vis-à-vis NACI and the Department should be clearly articulated.

NACI's functions

5.6.2 The current NACI Act defines an extremely broad range of topics on which NACI is to advise the Minister. These should be re-evaluated in terms of the Minister's requirements and portfolio. Resource allocations prevent NACI from attending to all the issues mentioned, and therefore it must prioritise its work plan for a given year or period. This prioritisation may result in the fact that a number of the issues are not subjected to external advice during a given period.

The DST and other governments should inform NACI proactively if they include any of these issues, as well as other not listed, in their planning programmes, in order to enable NACI enough time to prepare advice to the Minister, as the NACI Act requires.

5.6.3 NACI should develop a range of advisory modes. These should include:

- Evidence-based advice, based on comprehensive policy analysis and research. These advices are typically longer-term studies.

- Concise advices that are more frequent. These advices offer a mechanism of responding in a timely manner to events and issues.
- Pro-active advices, alerting the Minister to future trends in an anticipatory manner. These advices will act as a heads-up and early warning system.

NACI Councillors

5.6.4 The broad scope of activities that fall within NACI's domain, also impact on the expectations of the councillors, chairperson and secretariat. The chairperson and councillors as well as the CEO of the NACI (the DG of DST) and the representative of the DTI, all serve NACI in a part-time capacity, and hence the time that they have available to do so (in the current dispensation), is limited. This time and effort should be put to the best possible use. In order for NACI to be effective, it therefore necessary to have a strong, efficient and effective secretariat with a substantial professional, technical and analysis (as opposed to a mere administrative) capability. In addition to taking care of administrative aspects, the secretariat should have a strong ability to support the Council on the technical matters of its deliberations, including policy analysis and development, management of contract research and report writing. In this regard, the position and role of the Head of the Secretariat is very important, as discussed below.

5.6.5 The role of the chairperson of NACI and also what is and can be expected from that person, should be clearly articulated. The chairperson should provide the intellectual leadership, take ownership of NACI's strategic plans and intent and ensure that NACI ultimately provides useful and timely advice to the Minister, as opposed to someone who merely chairs the meetings. The chairperson of NACI will also chair the executive committee, where many of the operational day-to-day issues are decided. As such, the chairperson will play a leading role in directing the operational aspects of NACI, the execution of which will be the responsibility of the Head of the secretariat. The chairperson, being a part-time external member, will be subjected to severe time constraints, which must be accounted for. In addition to supporting the Council, the secretariat should also provide adequate support to the chairperson to fulfil these additional duties. It should be recognised that the role of chairperson of NACI as foreseen here, is a very time consuming one. The issue of availability should be accounted for in the selection of a chairperson.

5.6.6 NACI currently has 16 to 20 members as well as a chairperson and two government representatives. The large number of members allows one to ensure that there is adequate representation from different sectors (business sector, government sector, higher education sector, non-profit sector) as well as balanced representation along racial and gender lines. However, the large number of members also lead to practical and logistical problems that hamper the Council's work. It proves to be extremely difficult to find dates where all members can be present, for example. The time that councillors spend on NACI's activities is also not evenly distributed. In some cases councillors make major contributions with regard to time, specifically those chairing the subcommittees and leading research initiatives, some attend the four planetary meetings and make their inputs there, whereas the attendance of others can sometimes be irregular. Consideration should be given to what the optimal number of Councillors is, and what is expected of them.

5.6.7 It is recommended that Councillors -

- Be chosen on the basis of exceptional stature, experience and qualification (where appropriate) as well as their demonstrable ability to contribute and add value to NACI's work.
- Be dedicated towards NACI's work and commit towards conscientious attendance of meetings and contributions on the workgroups. Before accepting the appointment on the Council, prospective councillors should be briefed on the expectation for their contributions. They must explicitly agree to fulfil these before accepting an appointment on NACI.

5.6.8 NACI's mission is to advise the Minister of Science and Technology on issues pertaining to the NSI. It is an advisory rather than an executing agency. If, for example NACI is of the opinion that a public understanding of science and technology is important, it should advise the Minister as to what should be done in this regard rather than mounting its own campaign to promote the public awareness of science and technology. However, in order for NACI to be effective, its members should be aware of national and international trends, events and developments, and as such they should have access to these. This should be attainable due to the prerequisite that NACI members should in their own right have the appropriate stature. At the same time, it is necessary that NACI as an organisation also enjoys stature in the NSI, including the executive and legislative branches of government, the public and private sectors, the higher education sector, the non-profit sector as well as the diplomatic corps and the international community. It is necessary therefore that NACI's visibility and stature are enhanced and that its marketing and communication efforts are directed towards these ends.

The link between NACI and the DST

5.6.9 In order to entrench NACI's ability to render autonomous and independent external advice to the Minister, it is necessary to establish a clearer arms-length relationship between NACI and the DST. The CHE may provide a useful model in this regard. As the NACI Act stands, the director-general (DG) of the DST is the CEO of NACI. There is general agreement in NACI as well as an external opinion that this is not a desirable situation and that it should be addressed. Apart from the fact that it detracts from NACI's independence (and perception thereof), it can lead to role confusion between the DG, Head of Secretariat and chairperson.

NACI's secretariat

5.6.10 It is an arguable point whether NACI should have a CEO as such, or whether there should be a strong Head of the Secretariat. The latter is preferable, specifically in NACI's current format. In a corporate setting, the appointment of a CEO indicates a structure where the council is in a governance and oversight role relative to the executive (in this case the secretariat) who "manages" the operations. This structure is found in companies and universities, for examples. As an advisory board, NACI has a different role and therefore requires a different structure. NACI is the councillors – its members. The Council itself is the reason for NACI's existence, and provides the ultimate advice to the Minister. Hence the view that the Council should be supported by a strong and able secretariat, rather than the Council having a governance or oversight role over a secretariat that provides the advice. The position of Head of Secretariat is therefore preferable to that of CEO (although this is an arguable point).

Changes to the NACI Act

5.6.11 Consideration should be given towards affecting the necessary changes to the NACI Act to accommodate the recommendations above, as well as to account for the change from DACST to DST.

Appendix A

The NACI Act

REPUBLIC OF SOUTH AFRICA

GOVERNMENT GAZETTE

STAATSKOERANT

VAN DIE REPUBLIEK VAN SUID-AFRIKA

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PRESIDENT'S OFFICE

No. 1512. 14 November 1997

It is hereby notified that the President has assented to the following Act which is hereby published for general information:—

No. 55 of 1997: National Advisory Council on Innovation Act, 1997

KANTOOR VAN DIE PRESIDENT

No. 1512. 14 November 1997

Hierby word bekend gemaak dat die President sy goedkeuring geheg het aan die onderstaande Wet wat hierby ter algemene inligting gepubliseer word:—

No. 55 van 1997: Wet op die Nasionale Adviesraad vir Innovering, 1997.

ACT

To establish a national advisory council on innovation; to determine its composition and objects and functions; to regulate financial and staff matters; and to provide for matters connected therewith.

(English text signed by the President.)
(Assented to 6 November 1997.)

BE IT ENACTED by the Parliament of the Republic of South Africa as follows:—

Definitions

1. (1) In this Act, unless the context indicates otherwise—

(i) "business sector" means all persons who and institutions which conduct business for gain; (xiii) '

(ii) "chief executive officer" means the Director-General of the Department; (iv)

(iii) "Department" means the Department of Arts, Culture, Science and Technology; (i)

(iv) "government sector" means all organs of state as defined in section 239 of the Constitution, excluding any institution within the higher education sector; (xii)

(v) "higher education sector" means universities, technikons, colleges of education and other institutions which provide tertiary education, whatever their source of finance or legal status; (iii)

(vi) "innovation" means the process of transforming an idea, generally generated through research and development, into a new or improved product, process or approach, which relates to the real needs of society and which involves scientific, technological, organisational or commercial activities; (v)

(vii) "Minister" means the Minister of Arts, Culture, Science and Technology; (vi)

(viii) "Ministers Committee" means the Ministers Committee on Science and Technology established by a decision of the Cabinet and responsible for advice and decision-taking on science and technology matters; (vii)

(ix) "NACI" means the National Advisory Council on Innovation, established by section 2; (viii)

(x) "national facilities" means—

(a) the National Accelerator Centre;

(b) the South African Astronomical Observatory;

(c) the Hartebeesthoek Radio Astronomy Observatory; (ix)

(xi) "national system of innovation" means all sectors, and institutions within those sectors, which pursue common social and economic goals through innovation; (x)

(xii) "non-profit sector" means all private persons who and institutions which act without gain; (xi)

(xiii) "science and technology institution" means any institution established by an Act of Parliament with the practicing of science and technology as a substantial part of its activities; (xv)

(xiv) "science and technology system" means all persons who and institutions which are involved in the process of making scientific knowledge available, or which are involved in the process of converting and using scientific knowledge, in order to devise or implement new applications, and which operate within the national system of innovation; (xvi)

(xv) "science councils" means the—

(a) Human Sciences Research Council established by section 2 of the Human Sciences Research Act, 1968 (Act No. 23 of 1968);

(b) CSIR referred to in section 2 of the Scientific Research Council Act, 1988 (Act No. 46 of 1988);

(c) Council for Mineral Technology referred to in section 2 of the Mineral Technology Act, 1989 (Act No. 30 of 1989);

(d) Foundation for Research Development established by section 2 of the Research Development Act, 1990 (Act No. 75 of 1990);

(e) Agricultural Research Council established by section 2 of the Agricultural Research Act, 1990 (Act No. 86 of 1990);

(f) South African Medical Research Council referred to in section 2 of the South African Medical Research Council Act, 1991 (Act No. 58 of 1991);

(g) South African Bureau of Standards referred to in section 2 of the Standards Act, 1993 (Act No. 29 of 1993);

(h) Council for Geoscience established by section 2 of the Geoscience Act, 1993 (Act No. 100 of 1993); (xvii)

(xvi) "sectors" means the government sector, higher education sector, business sector and non-profit sector; (xiv)

(xvii) "this Act" includes any regulation made under section 13. (ii)

(2) The Minister may, after consultation with NACI, by notice in the *Gazette* amend the definitions of "national facilities" and "science councils" in order to delete or substitute any institution mentioned therein or to add any institution which practises research in the fields of science and technology as a substantial part of its activities.

Establishment of National Advisory Council on Innovation

2. A council which shall be called the National Advisory Council on Innovation is hereby established.

Objects of NACI

3. NACI shall advise the Minister, and through the Minister, the Ministers Committee and the Cabinet, on the role and contribution of science, mathematics, innovation and technology, including indigenous technologies, in promoting and achieving national objectives, namely to improve and sustain the quality of life of all South Africans, develop human resources for science and technology, build the economy, and strengthen the country's competitiveness in the international sphere.

Functions of NACI

4. (1) In order to achieve the objects referred to in section 3, NACI may, or shall on request of the Minister, advise on—

(a) the co-ordination and stimulation of the national system of innovation;

(b) the promotion of co-operation within the national system of innovation;

(c) the development and maintenance of human resources for innovation through selective support for education, training and research and development in the higher education sector and at science councils, science and technology institutions and private institutions;

(d) strategies for the promotion of technology innovation, development, acquisition, transfer and implementation in all sectors;

(e) international liaison and co-operation in the fields of science, technology and innovation;

(f) the co-ordination of science and technology policy and strategies with policies and strategies in other environments;

(g) the structuring, governance and co-ordination of the science and technology system;

(h) the identification of research and development priorities in consultation with provincial departments and interested parties, and their incorporation in the process of government funding of research and development;

(i) the funding of the science and technology system in respect of its contribution to innovation, including—
  (i) a framework for national and government expenditure on research and development;
  (ii) the building and maintenance of science and technology capacity by way of the selective funding of training and research and development:
  (iii) the distribution of funds allocated to science councils;
  (iv) the funding of research and development in all sectors;
  (v) the funding of national facilities utilised for research;

(j) the establishment, phasing out, rationalisation, and management of—
  (i) science councils;
  (ii) national facilities utilised for research;
  (iii) national research and development programmed conducted by science councils;
  (iv) science and technology institutions within the national system of innovation;

(k) the promotion of mathematics, the natural sciences and technology in the education sector in consultation with the Minister of Education and the Minister of Labour;

(l) strategies for—
  (i) the promotion of the dissemination and accessibility of scientific knowledge and technology; and
  (ii) the promotion of the public understanding of science and technology and their supportive role in innovation for development and progress;

(m) the establishment and maintenance of information systems to support—
  (i) the monitoring and evaluation of the overall management and functioning of the science and technology system and the national system of innovation: and
  (ii) the continuous revision of science and technology policy to address changing and new circumstances;

(n) developments in the fields of science. technology and innovation which might require new legislation;

(o) any other matter relating to science. mathematics. innovation and technology. including indigenous technologies. which the Minister may refer to NACI. or in respect of which NACI may deem it necessary to advise the Minister.

(2) The chairperson of NACI shall have direct access to the Minister and members of the Ministers Committee to submit and discuss any report of NACI, any minutes of a meeting of NACI or any other matter relating to the functioning of NACI.

Composition of NACI

5. (1) NACI shall consist of—
(a) a chairperson appointed by the Minister;
(b) 16 to 20 members appointed by the Minister after consultation with the Ministers Committee, and after submission to the Cabinet for notification:
(c) the chief executive officer of NACI;
(d) an officer of the Department of Trade and Industry appointed by the Minister with the concurrence of the Minister of Trade and Industry.

(2) The members of NACI referred to in—
(a) subsection (1)(a) and *(b)* shall be appointed in their personal capacity and serve on a part-time basis;
(b) subsection (1)(c) and *(d)* shall serve or be appointed. as the case may be, in their official capacity.

Criteria for membership of NACI

6. (1) The members of NACI, other than the chief executive officer and the officer of the Department of Trade and Industry, shall all be persons who have—

(a) achieved distinction in any field of science and technology in their own right or in the context of innovation;
(b) special knowledge or experience in relation to the management of science and technology, or innovation;
(c) special insight into the role and contribution of innovation in promoting and achieving national and provincial objectives; or
(d) special knowledge and experience of the functioning of the national system of innovation within which the science and technology system operates, the science and technology system, or any other aspect of NACI'S domain of responsibility.

(2) NACI shall be broadly representative of all sectors and be constituted in a manner that will ensure a spread of expertise and experience regarding—
(a) national and provincial interests;
(b) scientific and technological disciplines;
(c) innovation;
(d) the needs and opportunities in different socio-economic fields; and
(e) research and development in all sectors.

Tenure of office of members of NACI

7. (1) A member of NACI, other than the chief executive officer and the officer of the Department of Trade and Industry, shall hold office for such period, not exceeding four years, as the Minister may determine at the time of his or her appointment.

(2) If for any reason the office of such member becomes vacant the Minister may, subject to section 6, appoint any person as a member of NACI for the unexpired portion of that period of office.

(3) A member whose period of office has expired may be reappointed.

(4) Any member of NACI shall vacate his or her office if—
(a) the member resigns; or
(b) the Minister terminates the membership of the member on grounds of misconduct, incapacity or incompetence.

Executive committee and other committees of NACI

8. (1) Subject to subsection (2), NACI may establish an executive committee to dispose of matters determined by NACI.

(2) NACI shall determine the terms of reference and decision-making power of the executive committee for each matter referred to the executive committee for disposal.

(3) The executive committee shall consist of—
(a) the chairperson of NACI;
(b) the chief executive officer of NACI;
(c) two members designated by NACI; and
(d) the officer appointed by the Minister under section 5(1)(d)

(4) (a) NACI may establish committees to assist it in the performance of its functions, and may designate as members of such committees persons who are not members of NACI.

(b) The chairperson of a committee established under paragraph (a) shall be designated by NACI from among the members of NACI.

Meetings of NACI

9. (1) The first meeting of NACI shall be held at a time and place determined by the chairperson, and thereupon NACI shall meet at such times and places as may be determined by itself.

(2) The chairperson may at any time convene a special meeting of NACI, which shall be held at the time and place determined by the chairperson.

(3) Whenever the chairperson is absent from any meeting of NACI, the members present shall elect a person from amongst themselves to preside at that meeting.

(4) The proceedings of NACI shall not be invalid by reason only of the fact that any vacancy exists on NACI.

(5) NACI may, with the approval of the Minister, make rules relating to the procedure and quorum at its meetings and those of its committees.

Expenditure of NACI and remuneration of members

10. (1) Expenditure incidental to the performance of the functions of NACI shall be defrayed from money voted by Parliament as part of the appropriation of the Department.

(2) Any member of NACI, and any person designated in terms of section 8(4)*(a)* as a member of a committee, who is not in the full-time employment of the State, shall, in respect of services rendered by him or her in connection with the functions of NACI, be paid such remuneration, including reimbursement for traveling, subsistence and other expenses, as the Minister may determine with the concurrence of the Minister of Finance.

Chief executive officer and staff of NACI

11. (1) Work incidental to the performance of NACI's functions shall be performed by the chief executive officer of NACI and officers appointed in terms of the Public Service Act, 1994 (Proclamation No. 103 of 1994).

(2) The Minister may—

(a) at the request of NACI, for a temporary period or for a particular matter which is being investigated by NACI, appoint any person with special knowledge of any matter relating to the functions of NACI, or obtain the services of any body, to advise or to assist NACI in the performance of its functions; and

(b) on recommendation of NACI and with the approval of the Minister of Finance, determine the remuneration, including reimbursement of traveling, subsistence and other expenses, of such person or body.

Annual report

12. **(1)** NACI shall annually submit a report on its activities, including an assessment of the extent to which its objects have been achieved, to the Minister.

(2) The Minister shall cause the report to be tabled in Parliament within 14 days after receipt thereof if Parliament is then in ordinary session or, if Parliament is not then in ordinary session, within 14 days after the commencement of its next ordinary session.

Regulations

13. The Minister may, after consultation with NACI, make regulations with regard to any matter which is necessary or expedient to prescribe in order to achieve the objects of this Act.

Short title and commencement

14. This Act shall be called the National Advisory Council on Innovation Act, 1997, and shall come into operation on a date fixed by the President by proclamation in the *Gazette*.

Appendix B

Excerpt from the paper

"The perils of the linear curriculum"[133]

This paper was presented at a conference on engineering education in 1995, shortly after the 1994-elections in South Africa. It illustrates the problems that can follow when an implicit acceptance of the "linear innovation model" is embedded as a process. The application in this case is a typical undergraduate engineering curriculum at a university. The flaw resulting from the underlying linear model is that it can ultimately lead to engineers that are well trained to "invent" and "design", but do not have a wealth creating mindset and hence a lack of focus on innovation. To illustrate the point, they must understand that wealth is ultimately created by thinking in terms of product development instead of design per se, for example. In a similar way, an imbedded acceptance of the linear model can also flaw other policy issues such as the funding of research, the allocation of portfolios to government departments and the design and implementation of the National System of Innovation.

Abstract
The ability to manage technology, and technological innovation in particular, is becoming increasingly important, both operationally and strategically — not only on the company level, but also on the national level. In order to produce engineers who have a wealth creating mindset, it is necessary that engineering students be exposed to the principles of innovation management in addition to entrepreneurship issues. However, the traditional engineering curricula are not conducive to this approach, because they rely too heavily on the perception of a linear relationship between science and technology — the "linear curriculum paradigm". It is proposed that a parallel stream be instated in the undergraduate engineering curricula in order to expose students to topics that have no natural science base, such as the management of technology, innovation and entrepreneurship.

Introduction
As the new millennium approaches, universities and other institutions of higher learning which train engineers should realize that, in addition to the traditional demands that will be made upon engineers, the engineers of the future — those that are being trained now — will also face new types of challenges. Creating a sustainable environment and better quality of life are issues of growing prominence. It has become abundantly clear that rejuvenating the economy and job creation are issues of high national priority in almost all nations. One of the major trends that have to be accounted for is the escalating global economic battle. As the dust settles in the aftermath of the Cold War, the major military and political East-West tensions are subsiding, but at the same time the existence of a fierce global *economic battle* is becoming increasingly evident. Lester Thurow, renowned world economist and previous dean of MIT's Sloan School of Management, summarizes the position as follows, "Today's rules for the international economic game [GATT and the Bretton-Woods agreements] ... were written after WWII and built upon realities that existed then [dominance of the world

[133] C.W.I. Pistorius and G.P. Hancke, "The perils of the linear curriculum", presented at the *1995 World Conference on Engineering Education*, St. Paul, Minnesota, USA, 15-20 October 1995

economy by the US] ... the system that governed the world economy in the last half of the twentieth century will *not* be the system governing the world economy in the first half of the twenty-first century ... future historians will see the twenty-first century as a century of head-to-head [economic] competition"[134]. In his book "The Japan That Can Say No", Ishihara proclaims that "... superpower military warfare of the twentieth century will be replaced by economic warfare in the twenty-first century ... and Japan will be the winner"[135]. An article in the *Washington Quarterly*, published by the Center for Strategic Studies and the Massachusetts Institute of Technology, states that, "…The global economy is being transformed by a technological revolution that is central to defining what kind of new world order will emerge from the East-West and North-South orientations of the past half century"[136]. As Thurow puts it, "New technologies and new institutions are combining to substantially alter ... traditional sources of competitive advantage... In the twenty-first century man-made comparative advantage, with the emphasis on process technologies, will be the starting point for economic competition"[137]. The realities of GATT have brought with sharp changes in the way many industrializing countries interact in the international arena. A country such as South Africa that has become accustomed to global isolation needs to awake to international competition and competitiveness. Apart from now being able to take on the world's best in the international marketplace, domestic markets must also be defended — not by protective tariffs and such regulatory measures, but rather by out-competing all comers! It is very clear that technology will play an increasingly important role in the growing global economic battle. Countries and companies which have the ability to leverage technology strategically will have tremendous advantages over those that don't. Engineers of the future will have to play a key role in this process, and they must be prepared for that role even during their undergraduate education.

The question at hand is how the institutions that train engineers are going to respond to the new challenges that future engineers will face. It is proposed here that part of the solution may lie in the ability of universities to produce engineers that have *a wealth creating mindset*[138]. To paraphrase President John F. Kennedy, we need engineers who "…ask not for whom they will work, but for whom they can create work". The process of actually training engineers with this mindset, however, is easier said than done. In order to do so, it may be necessary to rethink the structure of traditional engineering curricula. In doing so, one discovers that the "linear curriculum paradigm" is a serious constraint, and that ways to resolve this dilemma must be devised. The linear curriculum paradigm is based on the perception that technology flows causally from science.

The next three sections of the paper discuss the importance of including elements of entrepreneurship, the management of technology and innovation in undergraduate engineering curricula as factors that will contribute towards the creation of the engineer with a *wealth creating mindset*. In the rest of the paper it is then argued that the inclusion of such material in engineering curricula faces an inherent bias, which is reflected in the "linear curriculum paradigm". Many of these elements that need to be incorporated into undergraduate engineering curricula have in common the characteristic that they are not based in the natural sciences, and because of the linear paradigm, the main stream thinking

[134] L. Thurow, *Head to head*, *The coming economic battle among Japan, Europe and America*, Warner Books, 1993.
[135] S. Ishihara, *The Japan that can say No: Why Japan will be first among equals*, Simon & Shuster, 1991.
[136] E.H. Preeg, "Who's benefiting whom? A trade agenda for high-technology industries", *The Washington Quarterly*, Vol 16, No 4, p.14.
[137] L. Thurow *op cit*.
[138] C.W.I. Pistorius and A.P. Botha, "Are we adequately preparing new engineers for the future? — A more formal look at the management of technology and innovation", *Proceedings Africon '92*, Swaziland, 22-24 September 1992, pp. 14-16.

on curricula therefore is biased against the inclusion of such material. In order to rectify this situation, it is necessary to recognize the “linear curriculum paradigm”, the implications that it brings, and then to circumvent this phenomenon in some meaningful manner.

Entrepreneurship — is it enough?

A focus on entrepreneurship is often held up as the way to instil a wealth creating mindset in engineers. For the purpose of this paper, we can define entrepreneurship as essentially the establishment of new business ventures. It is associated with the taking of risk. One should, however, be careful of considering entrepreneurship as the *only* non-technical component that is necessary in the armoury of the wealth creating engineering graduate. It is well known that not everybody has the temperament or psychological make-up to be an entrepreneur in the true sense of the word, i.e. starting a new business venture does not suit everybody's personal risk profile. We should accept that far from all graduating engineers will want to start their own businesses, particularly not soon after graduation. There are other factors that also support this notion, viz. a large number of engineers will still be needed and absorbed by established concerns (be they private or public). Furthermore graduate engineers (like other professions) need a few years practical experience where they work under the supervision of a registered professional engineer before they can themselves register as professional engineers. From a national innovation strategy viewpoint it also necessary to take cognisance of the fact that both large and small industries are needed. Although the establishment of a large number of small entrepreneurial organizations is to be applauded, one should not denigrate the role that is to be played by large industries. Engineers working in such organizations can also make a significant contribution as *intra*preneurs, i.e. entrepreneurs that start new internal business ventures *within* existing companies. Such actions also require the spirit of entrepreneurship, can also create wealth, but require a different type of risk taking. Hence one can conclude that if the creation of engineers with a wealth creating mindset is the goal, then the fostering of entrepreneurship and an entrepreneurial spirit as such is only *part* of the solution.

The management of technology

The fierce global arena in which businesses will henceforth need to compete demands that we strive for higher productivity. In addition, one should also take note of the rise of technology as a basis of competition and its pre-eminence as a determinant in global competitiveness. Technology is increasingly being used as a strategic asset, both on the company and national levels. It is becoming clear that a formal and systematic approach to the management of technology and technological innovation is necessary in order to ride the wave rather than be swept away by it; at the firm as well as the national level. Hence we need engineers who understand not only *how* to do things, but also *why*. We need engineers who can manage technology — engineers who can innovate on a sustained basis. A structured approach to the management of technology and technological innovation is thus also required in order to produce the wealth-creating engineer (in addition to an initiative of kindling an entrepreneurial spirit).

In an effort to produce engineers with a wealth creating mindset, a focus on entrepreneurship is definitely a required component, but should not be the only one, i.e. *a focus on entrepreneurship alone is not enough*! Teaching students entrepreneurship will encourage them to establish business ventures, but there is no guarantee that they will pursue technology related enterprise, or even if they do that they will be successful in doing so. In addition to entrepreneurship it is essential that we also focus on the formal management of technology and specifically technology innovation.

Innovation, creativity and invention— which is which?

The mention of the term *innovation* conjures up different images and concepts with people, some of them slightly off the mark. It is therefore appropriate to consider for a moment a few of the related issues that are sometimes confused with the term *innovation*.

- *Discovery* is when we become aware of something that existed before but which was unknown to us.
- *Creativity* is the process whereby one generates ideas and conceptions. In addition to creativity, there are also many other ways in which to get ideas such as renting them (licensing), stealing them (such as illegal copying), borrowing them (such as reverse engineering), and so on.
- *Invention* is the product of the process of inventing, i.e. creating a new artefact or process. If the invention is new, inventive and useful it can be patented. Note that the criterion for success of an invention is a *technical* one — either it works or it does not.
- *Ingenuity* is the resourceful or clever application of an idea or technique.
- *Innovation*, on the other hand, is a much more encompassing concept and often includes some or all of the other processes mentioned above. Although many definitions of innovation have been proposed, essentially it is the creation of new products, processes and services that are exploited in the market. Innovation thus comprises of two parts, viz. an invention part and an exploitation part. If the innovation is not used and diffused in the market, it is merely an invention. Hence the criterion for success of an innovation is a *commercial* one. Very often one finds that the most successful invention is not necessarily the most successful innovation and *vice versa*.

It is also important to realize that innovation is not merely a technical function. It combines the actions of several other functional areas, including R&D, marketing and manufacturing. All of these have to be organized in a symbiotic manner in order to be successful. One important characteristic of innovation is very relevant here, viz. innovation is *not* a linear process. One step in the innovation chain does not in general follow sequentially on the next. Instead, there are usually many feedback loops and parallel sub-processes as well as iterative and cyclical steps. This notion will be discussed again in the next section, where we claim that the perception of a linear relationship between science and technology lies at the heart of the "linear curriculum paradigm", and as such is the cause for a serious fundamental problem in engineering curriculum.

It is important to realize that innovation is a process. It can be studied, researched and taught — more importantly, however, it can be applied in a systematic and scientific way. Technological innovation can and must be managed, because it then has a much better chance of leading to (average) sustained success. One should also realize, however, that many innovations (or actually attempted innovations) are unsuccessful, even when such innovations are the product of a systematic approach. The alternative to a systematic approach, however, is an ad hoc process with occasional serendipitous success where failures vastly outnumber success and where average sustained success is rare.

Having established the premise that a structured approach to technological innovation is not only possible but also necessary, the question that should now be posed is how such a structured approach to technological innovation can be accommodated in engineering curricula.

Problems with current engineering curricula

Having made the case for the importance of exposing undergraduate engineering students to elements of the management of technology and entrepreneurship, we can now turn to the question of why current engineering curricula often have an inherent resistance towards integrating these concepts. Traditional engineering curricula do very well when it comes to the "unchanging" scientific and technological fundamentals — even how to apply them technically. However, these same curricula fail to address the changing nature of how technical disciplines must interact and also the increasingly important role of integrating technical and business issues in the successful competitive enterprise. It would seem that one of the major underlying problems with the current curricula is their linear nature.

Consider a typical undergraduate engineering curriculum at a university. In the first year students are taught mathematics, chemistry, physics, applied mathematics and some very basic engineering courses like engineering drawing or network theory*. Very often the odd course in “communication”, “introduction to engineering” or something of a similar nature is also included. In the second year the mathematics and some applied mathematics are continued and further basic engineering courses are introduced. As the student progresses, the courses become more “engineering” than “science” oriented. However, in general the engineering courses flow naturally from the science courses, and very often the latter are prerequisites for the former. The structure of the curriculum is often that of different “streams” or “lines”. For example, one often finds that a second year course in systems theory will follow a first year course in mathematics. The second year course in systems theory then leads to further courses in signal processing and control theory. Such courses are also often preceded by a course in statistics and probability. Similarly, it is not uncommon to find a stream where physics and mathematics lead to electromagnetics, which then flows through to microwave theory and electrical machines. This entire curriculum philosophy is thus a linear one in which one of the basic premises (albeit implicitly) is that technology and engineering follow linearly and sequentially from science (and in that order) — which is, of course, not true in general. Although there are many examples that can be quoted to show how technological developments followed the discovery of scientific phenomena, there are also many examples that can be quoted to illustrate cases where technological developments were made first, and the underlying scientific theories followed *ex post facto*. Very often new technological developments act as incentives to new scientific work, including the development of new scientific instruments. Orville and Wilbur Wright - the first men to build and fly an airplane successfully - are not famous for the papers they published in scientific, peer-reviewed journals but rather for having solved the technological problems of flight, culminating in the first successful, powered flight.

Scholars of technological innovation know that there are many different types of innovations. One can, for example, distinguish between radical innovations and incremental innovations. Radical innovations are usually embodied in a completely new approach to a problem, often with orders of magnitude of improvement in some performance characteristic, and often something that no increase in scale or improvement in the old innovation could have achieved. Jet engines (that replaced propeller engines), fibre optics (that replaced copper cables) and transistors (that replaced electronic vacuum tubes) are examples of radical technological innovations. Radical innovations are often based on newly discovered or utilized scientific principles. Incremental innovations, on the other hand, are small and continuous improvements which are made by many contributors who are usually distributed in both time and space. Although the individual improvements may be small, the cumulative effect over a long time is often very significant. The Japanese term “kaizen” refers to the practice of continually making small improvements, and has been described as one of the reasons for the success of Japanese technology-based enterprise[139]. Both types, i.e. radical and incremental innovations are important. One is not “better” than the other, but there is a right time and place to emphasize each. It would be fair to say that the number of incremental innovations far outnumber the number of radical innovations, and furthermore that incremental innovations are usually *not* based on new scientific discoveries or developments. They are, instead, technological refinements.

* These comments are true of undergraduate engineering curricula at typical South African universities. Although curricula in other countries may differ in some respects, the general line of reasoning is probably universal.

[139] M. Imai, *Kaizen,* McGraw-Hill, 1986.

In general then, one should not labour under the illusion that there is a linear relationship between science and technology. There is not a general causal "law" by which technology "follows" science. It is a two-way street. The problem, however, is that many undergraduate engineering curricula are based either explicitly or implicitly on this linear paradigm.

One of the shortcomings of this model is that themes which do *not* have a natural science base or do not follow linearly from science, do subsequently not fit naturally into the curriculum. This includes concepts such as manufacturing, social science related issues such as human resource aspects and labour relations as well as all business related issues and alas also the management of technology — all of which are part of the practice of engineering but to which students are typically not exposed to during their education. We all lament the sad fact that newly graduated engineers are "… not interested in manufacturing". Should we be surprised, however, if we do not expose them to it — within context, mind — not even to speak of arousing enthusiasm? When courses without a scientific base are included in an undergraduate engineering curriculum, they are often added on or are shoe-horned into a slot that has been pried open for that purpose rather than being integrated into the natural flow of the curriculum.

There is a case to be made that our curricula have evolved into schemes for training at most inventors rather than developing innovators. The accreditation boards require a certain component of *synthesis*, and our response is to teach *design*. We should realize however, that there is a big difference between a design (as embodied in technically functional artefact) and a product — it is analogous to the difference between an invention and an innovation. A product of course incorporates a design, but it is something of which the marketing issues have been sorted out (including the position of the product in properly segmented markets, pricing and promotion), it is packaged, the warranties and documentation have been tended to, the distribution and service channels have been developed, to name but a few. Once you have a design, or even a product, you still have to manufacture it. It would seem that one of the consequences of our science-based paradigm, is that we end up concentrating on designs and inventions without following through to products, not even to talk about processes (i.e. manufacturing). We do this at our own peril, since *inventions do not create wealth, innovations do*.

What is to be done?

If one subscribes to the line of thinking that there are many issues which do not have an underlying scientific base but which still need to be included in the engineering curriculum, and furthermore one recognizes the pervasiveness of the linear curriculum paradigm, the question then boils down to ways to replace or circumvent the linear paradigm. One solution is obvious, viz. parallel streams can be created in the curricula in which topics which do not have a scientific base can be addressed from the first year. With regard to the management of technology, for example, first year students can be taught what the role of technology in society is and the importance of technology for economical development and competitiveness. They can be taught that innovation is a process that contains many components which are interrelated in complex ways, as explained above. The students can be exposed to the principles of product development and shown that good technical design is only one of the components that will turn the invention or design into an innovation. At the same time they can also be taught the importance of process (which is interpreted here to imply the manufacturing process) and by doing so the whole issue and importance of manufacturing in particular, can be put in perspective. It should be pointed out that both product and process innovations are important. This approach should be a "curriculum stream" (i.e. a line that is followed through from first through to the fourth year), rather than just a single course or something that warrants a "one-period per week" allocation. By the time the students have progressed to their third year where they are immersed into the details of technical design, they will be able to put their design work in perspective. The concept of “design-for-manufacture” will make sense. Similarly when a field trip to visit a factory is organized, students will be able to place the manufacturing operation in perspective and explore how it ties to the other aspects of the innovation process, rather than view the visit as an unwanted diversion that steals time from more “important” things.

It should be stressed that the plea here is not to belittle science-based courses or to argue that they are not needed. That is definitely not the case — these courses form the heart of engineering education and as such are of course vitally important. The thrust of this paper is rather to point out that the science-based linear curriculum paradigm has some shortcomings. These underlie our neglect to expose undergraduate students to topics that do not have natural science roots. Of course the science-based courses should be retained, however we should also consider a parallel stream in the curriculum that is not rooted in natural science.

Although this paper focuses on suggested changes to undergraduate curricula, a complementary approach is to develop dedicated masters degrees that focus on the management of technology. The last couple of years have seen a significant growth in the number of such programs.

In addition, a “reengineering” of the undergraduate curricula of all the departments that offer undergraduate degrees in engineering (viz. Electrical and Electronic, Mechanical and Aeronautics, Civil, Mining, Metallurgical and Materials, Agriculture, Industrial and Systems, Chemical) are being undertaken with the view of implementing the changes in the 1997 academic year. The current thinking is to add a parallel “engineering” stream as suggested above, and that three one-hour lectures per week will be devoted to this stream from first through fourth year.

(Discussion in the original paper of initiatives at the University of Pretoria deleted here for the purpose of the discussion in this report on science advisory structures)

Conclusions

It would seem that typical undergraduate engineering curricula are very strongly based on an implicit paradigm of a linear relationship between science and technology, and in that order. Subsequently many topics that will contribute towards the education of the engineer with the wealth creating mindset are neglected in the curricula because they are not based in the natural sciences and hence do not fit into the natural “flow” of the curriculum. The management of technology and technological innovation in particular are not addressed, the result being that we are training (at most) inventors rather than innovators. This is particularly troublesome in light of the fact that the ability to manage technology and particularly technological innovation, is becoming increasingly important, both operationally and strategically — not only on the company level, but also on the national level. It is suggested that issues as the management of technological innovation be addressed from the first year and continued in an integrated fashion throughout the student’s education.

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