Innovation *for* Society

How innovation is driven towards societal desirability through innovation policies

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1. Executive Summary

Three major definitions of Responsible Research and Innovation (RRI) make reference to positive outcomes or impacts. Rene von Schomberg (2013: 63) includes *societal desirability* amongst the three building blocks of RRI. The definition used within Horizon 2020 notes that the *outcomes* of responsible innovation must be aligned better with the *values, needs and expectations* of European society. And Richard Owen et. al.'s prominent framework for Responsible Innovation poses questions about the purposes and motivations for innovation.

How can positive outcomes from research and innovation be achieved? How can research and innovation be driven towards products and services that align with needs, values and expectations? How can the purposes of research and innovation be steered to take the interests of the whole of society into account?

Fig 1 - Positive Outcomes of R&I

Our previous report (*Innovation* for *Society - Funder Reports*) described and analysed how research funding can drive innovation towards positive outcomes. Here, we ask whether, and if so how, **national innovation policies** can be related to RRI, especially societal desirability. In itself, this would be an unmanageable task, as the innovation policies of **Australia, China, Germany, India, Japan, South Africa, the United Kingdom, and the United States** (which we examine) are highly different and, more importantly, the definition of societal desirability is contested. However, defining societal desirability as tackling Grand Challenges allows a comparison and a glimpse of how RRI could become a global framework where the attempt to guide innovation towards resolving humanity's challenges functions as a common denominator.

For each of the above eight countries, which cover all continents, country-specific context can be found in the main text below. A matrix mapping Grand Challenges onto innovation policies onto RRI, will be published with ProGReSS Deliverable 5.3. Here, we summarize the main commonalities that appear when analysing innovation policies with respect to societal desirability.[2]

<u>Grand Challenges</u>

To begin with, every country has a particular view of what constitutes a societal Grand Challenge to which innovation policies are expected to contribute solutions. Hence, **the vocabulary of Grand Challenges is common and therefore suitable for a global dialogue on RRI**. In Europe there is a common understanding that the Grand Challenges identified in the 2009 *Lund Declaration* (i.e. global warming, tightening supplies of energy, water and food, ageing societies, public health, pandemics and security) affect all European societies. Nevertheless, individual European countries also add tailored challenges. For instance, the German Government has identified the Grand

[2] An analysis with regard to ethical acceptability and sustainability can also be found for each country in the main text.

Challenges of climate/energy; health/nutrition; mobility; security and communication. Here, the added challenge of mobility[3] differs from the *Lund Declaration*.

Outside of Europe, Grand Challenges differ considerably in focus and shape. For instance the Grand Challenges identified by the Chinese Government (wealth distribution; poverty; education; ageing societies, and rural-urban inequalities) are very different from the Australian ones (environment; resources; security; communities; health; food; energy, and competitive industries), or those of India (energy independence; health-care for all; efficient water management; food security, and mitigating effects of climate change). This is not surprising given the socio-economic differences between the three countries.

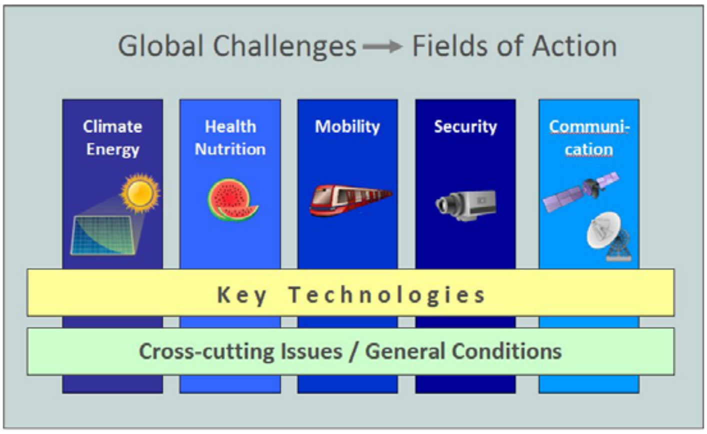

Fig. 2 Grand Challenges in Germany

Societal Desirability in Innovation Policies

Societal desirability is not defined in any of the national innovation programmes that were analysed, neither is a reference made to aligning values and needs with the outcomes and processes of innovation, nor a discussion undertaken of the purposes of science and innovation. However, as noted above, we overcame this shortcoming by equating those initiatives that tackle identified Grand Challenges with societal desirability. To give a prominent example, where innovation policies were framed to address climate change it should be fairly uncontested that this would benefit all of society, in fact all of humanity. But it is important to note that there was rarely direct input from society at large about what the Grand Challenges are and how they should be tackled.

One could draw a tentative conclusion from the description of national innovation policies that achieving societal desirability is the aim of many programmes, but its actual implementation is far from being concrete and understandable. There are no standard implementation methodologies or measurements of societal desirability aspects, neither is there any considerable engagement with the public, nor measurements of the impact of engagement initiatives that do occur.

Inclusive Innovation

China, India and South Africa all include in their Grand Challenges ways of overcoming not only poverty, but also the considerable gaps between the rich and the poor. All three countries use the concept of "inclusive innovation" to capture the efforts of using science and technology to uplift

[3] Based on the assumption of a strong increase of road traffic, priorities in this field of action include the development of fuel cells, battery technologies, intelligent traffic control and the completion of Galileo (a satellite navigation system).

the poor and create a more inclusive society with increased economic particicpation. "Science, technology and innovation for the people" is the new Indian paradigm pushing *inclusive growth*, which means ensuring access, availability and affordability of innovative scientific and technological solutions to as large a population base as possible.

In China, the concept of inclusive innovation puts emphasis on empowering the poor from being passive receivers of innovation to active participants in innovation. In South Africa, the 2011 *National Development Plan* aims at promoting mutual respect, inclusiveness and cohesion by acting on the constitutional imperative that South Africa belongs to all who live in it.

China, India and South Africa are the three largest emerging economies globally (with the exception of Brazil). **Global discussions of RRI should not exclude a concept of such prominence as inclusive innovation.**

On the other hand, RRI is more than just the focus on positive outcomes for society in terms of access to the fruits of science and technology. We therefore also looked at how ethical acceptability and sustainability are represented in innovation policies across the eight countries examined, and finally at public engagement.

<u>Ethical Acceptability in Innovation Policies</u>
The role of ethics in innovation and its incorporation in national policies is clearer than the role of other RRI components. Our Funder Reports showed that clear procedures are available globally to ensure ethical acceptability in funding programs. However, how compliance to these procedures is monitored and enforced remains a major challenge. Similarly, in the description of national innovation policies we see ethical acceptability as a key prerequisite for the success of relevant programmes. And again, similarly, the operationalisation of ethical acceptability in innovation policies poses significant challenges.

Ethical debates are often triggered by specific technological developments in each region. Perhaps the most common occurrence relate to debates in the area of biotechnology and its applications in medicine, food and agriculture. Also nanotechnology and synthetic biology are given as examples of case studies where ethical acceptability is directly described in national innovation policies. The ability to operationalise ethics is nevertheless uncertain. While most countries have specialized expert committees to discuss and provide opinions on ethical issues, these are not necessarily considered in the policy decision making process. Similarly, there are few established routes for public engagement in ethical discussions to show that ethical acceptability is indeed promoted successfully.

Despite the lack of official routes of incorporation of ethical issues in innovation policies, one can still argue that ethical acceptability is the most advanced aspect of RRI. It is discussed directly in the description of policies; it often leads to the establishment of specific advisory bodies, and it provides the main argument for wider consultation exercises.

Sustainability in Innovation Policies

In most innovation policies sustainability is associated mainly with the protection of the environment, but it is also used as an all-encompassing term to describe actions that benefit society in the long term. For instance agricultural biotechnology in India aims at “sustainable” food production, while that of Germany deals with “sustainable” biodiversity.

A good example of applying sustainability in innovation is that of regulating nanotechnology. Most countries have a nanotechnology strategy that includes guidelines for measuring its impact on health and the environment, while there are approval processes that are based on both ethical and environmental criteria.

Public Engagement

From the preliminary analysis of the innovation policy reports, one could note the following: to arrive at a global understanding of RRI, **public engagement has to be understood in a wider sense** than discussions with concerned consumers about new technologies, or the co-development of products with end-users. For instance, in China, the concept of "inclusive innovation" is used to achieve sustainable and inclusive economic growth. Programmes to engage the rural poor in innovation activities have proven successful in building local capabilities and instigating long-term development. This has therefore been a successful way of engaging the public in innovation.

One could conclude therefore that in almost every case the countries reported on have national innovation policies that take account of societal desirability as this relates to their own particular “Grand Challenges”. The only exception where this appears not be the case is the US.

However, we would like to finish with some of the words of the Japanese vision for 2030:

People are feeling that their standard of life is maintained and improving and a sustainable and dynamic society is realized ... An environment where women and young people can fully display their capabilities will have been established. People are enjoying healthy, wealthy, and happy lives. In particular, the elderly are active and have a comfortable life. There will be no health inequalities ... The whole country is enveloped with reassurance, and everyone is planning their life looking toward a bright future.

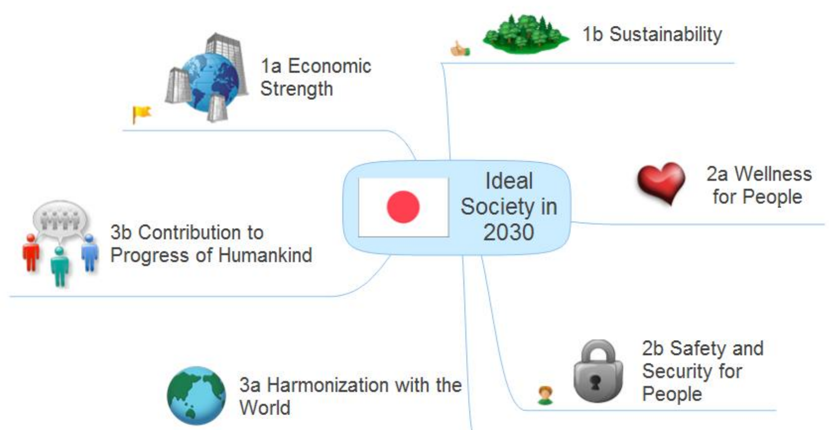

Fig. 3 Japanese Vision of the Ideal Society in 2030

2. Introduction

Three major definitions of Responsible Research and Innovation (RRI) make reference to positive outcomes or impacts. Rene von Schomberg (2013: 63) makes this point most strongly when he lists ethical acceptability, sustainability and *societal desirability* as the building blocks of RRI.[4] The definition used within Horizon 2020, the flagship funding initiative that accompanies Europe 2020, is also strong on outcomes. It notes that the *outcomes* of responsible innovation must be aligned better with the *values, needs and expectations* of European society.[5] Whilst a restricted reading of this statement could mean no more than that the outcomes of innovation must be acceptable to the public, i.e. not rejected as irresponsible, it is more likely to include the demand that the outcomes of research and innovation must be positively desired (e.g. innovative solutions to combat climate change). Richard Owen et. al.'s (2013: 36) prominent definition of Responsible Innovation (*Responsible innovation is a collective commitment of care for the future through responsive stewardship of science and innovation in the present*) can be presented in conjunction with questions about the purposes and motivations for innovation, questions such as:

> "Why do it? Who might benefit and how? Will such benefits be equitable? Will it confer burdens to some or many? In whose interests is it being undertaken and what are the motivations of those involved? Do we (as a society) want it? .... A framework for responsible innovation must then not just include consideration of products, but also purposes, not just what we do not want science and innovation to do, but what do we want them to do." (Owen et. al. 2013, 34)

How can positive outcomes from research and innovation be achieved? How can research and innovation be driven towards products and services that align with needs, values and expectations? How can the purposes of research and innovation be steered to take the interests of the whole of society into account?

Fig 4 - Positive Outcomes of R&I

One obvious answer can be given for publicly funded research and innovation, namely funding criteria. Our previous report (*Innovation* for *Society - Funder Reports*[6]) described and analysed whether, and if so how, Australia, Brazil, China, Germany, India, Japan, South Africa, the United Kingdom, and the United States steer their research funding towards specific goals. This first report covered primarily publicly funded research and innovation (even though some funding resources were subject to public-private partnerships, see, for instance, Linkage Grants, Australian Research Council).

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[4] RRI is a transparent, interactive process by which societal actors and innovators mutually respond to each other with a view to the (ethical) acceptability, sustainability and societal desirability of the innovation process and its marketable products.

[5] Science with and for Society unit: http://ec.europa.eu/programmes/horizon2020/en/h2020-section/science-and-society.

[6] http://www.progressproject.eu/wp-content/uploads/2013/05/Progress-Deliverable-3.1.pdf.

This report covers *all* research and innovation and its emphasis is on **national innovation policies**, which - by definition - covers all researchers and innovators, independent of their source of funding. We assess whether, and if so how, innovation policies can be related to RRI, especially societal desirability. In itself, this would be an unmanageable task, as the innovation policies of Australia, China, Germany, India, Japan, South Africa, the UK, and the United States are highly different and, more importantly, the definition of societal desirability is contested. Hence, one would try to achieve a world-wide assessment on a rapidly moving target. To make sure that our target is fixed enough for an assessment but at the same time allows for regional diversity, we restricted our analysis of societal desirability to tacking Grand Challenges as defined by the relevant nation state. Hence, if innovation policies are designed to tackle or contribute to tackling Grand Challenges, we define them as policies that try to achieve societal desirability.

For each country, we give country-specific context, and list the Grand Challenges as noted by the relevant governments. We then focus on the countries' innovation policies. To map these policies onto RRI, we are particularly interested in societal desirability, but for a full assessment, we also give brief accounts of whether these policies map onto ethical acceptability and sustainability.[7]

[7] Further analysis on the current report will be undertaken with Deliverable 5.3, the *RRI Country Requirements Matrix*.

3. Australia

Australia is currently governed by the conservative Liberal-National coalition headed by Prime Minister Tony Abbott. Mr Abbott was elected in September 2013, after six years of Labor Party rule. The official Head of State in Australia is Queen Elizabeth 11 who is represented by Governor-General Sir Peter Cosgrove (appointed March 2014).


Australian Parliament House, Canberra

3.1 Country-specific context

3.1.1. Economic and political situation

Whilst Australia's economy was relatively resilient after the global financial crisis of 2008/9, like many other high-income countries it has seen declining productivity growth in recent years (with multifactor productivity of negative 1.3 per cent in 2013) (Australian Productivity Commission 2014, p.20). The unemployment rate was 6.1% in July 2014, and has increased over the last 3 years (Australian Bureau of Statistics 2014b). In 2012-13, Australia was ranked 21st in the Global Competitiveness Index of the World Economic Forum, the first time it has not been in the top 20 country rankings (World Economic Forum 2013, pp. 8; 110-11).

In 2010-11, gross expenditure in R&D in Australia was (Aus)$30.8 billion, an historical high. As a percentage of GDP this is 2.2%, placing Australia 11th among OECD countries (Department of Industry 2013, p. 1). In 2014, Australia ranked 17th in the Global Innovation Index (Dutta et al 2014, p. 14).

Some more recent statistics are available by sector:

- **Government spending**: In 2012-13, Australian government organisations spent (Aus)$3,725 million on R&D, an increase of 5% (current price terms) from the previous year, continuing an increase over the past 5 years. As a proportion of GDP, government expenditure on R&D remained stable at 0.24%. Private non-profit organisations spent (Aus)$961 million, an increase of 2% from the previous year. This was 0.06% of GDP, which remained stable from the previous year (Australian Bureau of Statistics 2014c).

- **Business innovation**: In 2011-12, Australian businesses spent (Aus)$18,321 million on R&D. This was an increase of 2% (current price terms) from the previous year, continuing an increase over the past five years. Business expenditure on R&D as a proportion of GDP decreased, however, from 1.28% in 2010-11 to 1.24% in 2011-12 (Australian Bureau of Statistics 2013). In 2012-13, 42% of businesses were counted as innovation-active, a decrease from 46.6% in the previous year (the highest recorded value). The main barriers to innovation by businesses were reported to be lack of funding, and lack of skilled persons (Australian Bureau of Statistics 2014a). Innovation is still primarily undertaken by large businesses (Department of Industry 2013a, p.10).

- **Higher education spending**: In 2012, Australian higher education organisations spent (Aus)$9,610 million on R&D (this includes funds obtained from government competitive grants,

as well as other sources) (Australian Bureau of Statistics 2014d). Australia's share of world publications was 3.44% in 2012, an increase from 2.61% in 2008. The Department of Industry (2013a, p. 11) attributes this increase primarily to international collaboration.

- As noted above, in September 2013 Australia saw a change of Federal Government. The Abbott Government has introduced some thoroughgoing changes in terms of restructuring the machinery of government, and in its 2014-15 Federal Budget. Budget measures aim to improve living standards via a range of economic reforms including reduction of overall government spending. The implementation of some of these Budget measures is still uncertain, as is the overall impact of these changes.

3.1.2. Institutions involved in setting Australia's innovation policies

The following institutions are involved in setting Australian innovation policies:

- **The Department of Industry**: this Federal department, particularly its division AusIndustry, has oversight of many of Australia's innovation policies and initiatives.
- **Innovation Australia**: an independent statutory body which assists with the administration of programs to support industry innovation.
- **The Australian Research Council (ARC)**: a statutory agency which manages the National Competitive Grants Program (a major component of public research funding), and Excellence in Research for Australia (ERA) (a research quality evaluation system). The ARC also provides advice to the Government on research matters.
- **The National Health and Medical Research Council**: an independent statutory agency which promotes the development and maintenance of individual and public health. It administers government research funding grants and provides advice to the government, reporting to the Minister for Health.
- **The Prime Minister's Science, Engineering and Innovation Council**: this Council provides advice on technical, economic, environmental, and social aspects of science and technology. It works to raise community awareness and contributes to work on Australia's research priorities.
- **The Commonwealth, State and Territory Advisory Council on Innovation**: this Council is composed of high-level officials from the Australian and New Zealand Federal Governments, and Australian jurisdictional governments (e.g. Victoria). It enables exchange of information on innovation and science policy, and reports to the Prime Minister's Science, Engineering and Innovation Council.
- **The Coordination Committee on Innovation**: a discussion forum for government departments and other agencies with responsibilities or interests relevant to the innovation system. The Committee has worked on specific issues related to innovation via working groups, and reports to the Minister for Industry.
- **The Department of Education**: This department has oversight of a number of issues related to Australia's innovation system, in particular policies related to the research workforce and training. It also administers the Collaborative Research Network Program, which provides funding to develop the research capacity of smaller and regional universities, and has contributed to developing mechanisms to assess the research impact of Australian Universities, and national research priorities.

3.1.3. Strategy overview

The Australian government released a 10-year innovation reform agenda in 2009, *Powering Ideas: An Innovation Agenda for the 21st Century* (Department of Innovation, Industry, Science and Research, 2009). Although this agenda appears to be endorsed by the current government, it is likely that there will be changes to Australia's innovation strategy in the coming years.

A Senate Inquiry into Australia's innovation system is currently underway. Public consultation for this Inquiry has taken place and the committee is scheduled to report by the first sitting day in July 2015. The report is likely to introduce new innovation policies and/or to alter existing policies. In addition, a new *National Investment and Competitiveness Agenda* is due to be released in the remaining months of 2014, and will contain new innovation policies. An Inquiry into Australia's financial system, due to report to the treasurer in November 2014, and a review of Australia's competition policy, due to report by March 2015, are also underway and are likely to impact on Australia's innovation strategy.

> ***2009 Innovation Strategy***
> *Public research funding supports high-quality research that addresses national challenges.*

2009 Innovation Agenda

The 2009 *Innovation Agenda* provided a 10-year policy framework to guide development of Australia's innovation system. It was developed in response to, and drew on the conclusions of a 2008 review (*Venturous Australia – Building Strength in innovation: Review of the national innovation system*). It provides 7 'National Innovation Priorities':

Priority/Aim	**Specific goal stated**
1. Public research funding supports high-quality research that addresses national challenges and opens up new opportunities.	Increase the number of research groups performing at world class levels, and guided by the National Research Priorities.
2. Australia has a strong base of skilled researchers to support the national research effort in both the public and private sectors.	Increase the number of students completing higher degrees by research.
3. The innovation system fosters industries of the future, securing value from the commercialisation of Australian research and development.	Increase the number of businesses investing in R&D.
4. More effective dissemination of new technologies, processes, and ideas increases innovation across the economy, with a particular focus on small and medium-sized enterprises.	Increase the proportion of businesses engaging in innovation by 25% by 2019.
5. The innovation system encourages a culture of collaboration within the research sector and between researchers and industry.	Double the level of collaboration between businesses, universities, and publicly-funded research agencies by 2019.
6. Australian researchers and businesses are involved in more international collaborations on research and development.	Increase international collaboration in research by Australian universities.
7. The public and community sectors work with others in the innovation system to improve policy development and service delivery.	Improve services to the community with a particular focus on improved efficiency.

As well as establishing some governance arrangements for innovation, the 2009 Innovation Agenda introduced a range of measures which aimed to support and strengthen publicly funded research, business innovation, public sector innovation, research training, and collaboration (particularly between public researchers and private industry). Taking a broad view of the innovation system, it also introduced measures to encourage business environments that are conducive to innovation, and to promote innovation in the government and community sectors.

Some initiatives that were recommended to be continued or established in the agenda included:

- To enhance **governance**:
    - an annual report on Australia's innovation system will be produced,
    - a National Research Infrastructure Committee will be established,
    - there will be expansion of the duties and renaming of the Coordination Council on Innovation (previously the Coordination Committee on Science and Technology),
    - work will be developed to promote consistency and coherence across federal and jurisdictional innovation policies
    - further development of the National Research Priorities.

- To support **university research**:
    - the Education Investment Fund will be established,
    - a new *Sustainable Research Excellence in Universities* initiative to increase support for indirect research costs,
    - development of the Joint Research Engagement Scheme to support collaboration with industry and end-users,
    - the establishment of a Collaborative Research Networks Scheme to support regional and smaller universities to collaborate.
    - Additionally, a range of reforms to university funding via the development of a measure of research quality (the ERA) and changes to indexation on research block grants are planned.

- To support **business innovation**, the Innovation Investment Fund will be set up together with the Commercialising Emerging Technologies (COMET), a portal to enable businesses to access information about innovation support mechanisms.

The current Federal budget announced a number of changes however, that included ceasing, consolidating or replacing some of the above programs. The budget also announced alterations in **tax incentives** for industry research. Australia has had tax incentives to promote industry R&D since 1986, and these have been altered a number of times (including legislative amendments in 1997, 2011, 2013), generally with the aim of focusing funding towards smaller business entities or simplifying administrative arrangements. The budget reduced the refundable and non-refundable tax offsets offered by 1.5%. Currently the R&D tax incentive thus offers a 43.5% refundable tax offset to eligible entities with an aggregated annual turnover of less than (Aus)$20 million, and a non-refundable 38.5% tax offset to eligible larger entities. The R&D incentive is available only to entities with aggregated assessable income of less than (Aus)$20 billion (Department of Industry 2013b; Department of Industry 2014; Senate Economics Legislation Committee 2010; Senate Economics Legislation Committee 2014).

3.1.4. Challenges and outlook

Due to the change of government, Australia's overall direction in terms of innovation policy is not presently clear. Specific programs and policies are likely to alter significantly in the coming few years, and it is possible the overall direction will also change.

It is also currently not clear who has overall oversight for innovation policy. Federally, the Department of Industry, Innovation, Climate Change, Science, Research and Tertiary Education (itself only established six months prior to the 2013 government change) was abolished in September 2013, and its functions were transferred to the Department of Industry, the Department of the Environment, and the Department of Education. Most innovation-related policies appear now to be administered by the Department of Industry. There has been some controversy over the lack of a Minister for Science in the current Abbott government, with responsibilities for science in Australia being shared across portfolios.

> ***Science governance***
> *There has been some controversy over the lack of a Minister for Science in the current Abbott government, with responsibilities for science in Australia being shared across portfolios.*

An issue previously identified with Australia's innovation system is the number of different bodies, programs, schemes, and policies that are relevant to it. The 2009 Agenda identified 110 innovation policies and programs administered by the Federal and jurisdictional governments, commenting on the resulting confusion and lack of cohesion and coordination. This situation continues. Given the number of currently ongoing inquiries and reviews that are relevant to Australia's innovation system, it is likely that further efforts to coordinate innovation-relevant policies and regulations will be needed.

The current climate of government fiscal restraint is also likely to continue for some time in the face of an ageing population with associated expected significant rises in health costs, combined with falling government revenues.

3.2. Grand Challenges

In 2012, in response to a 2011 review of Australia's publicly funded research, the Australian Research Committee (ARCom) was established to provide integrated, strategic advice on investment in research, science, and innovation. The first task of the ARCom was the development of the 2012 *National Research Investment Plan*. Consultations undertaken for this plan identified the following key challenges facing Australia:

- **Environment**: marine, terrestrial, atmospheric;
- **Resources**: minerals, petroleum, fisheries, forestry, water;
- **Security**: biosecurity, cybersecurity, critical infrastructure, disaster management;
- **Communities**: demography, regional, Indigenous, built environment, transport;
- **Health**: disease prevention, treatment, service delivery;
- **Food**: production, technology, processing, security;
- **Energy**: clean technologies, sustainability, distribution;

- **Competitive industries**: business processes/services, innovative technologies, advanced manufacturing (Department of Industry, Innovation, Science, Research and Tertiary Education 2012, p. 51).

The Plan adds that 'megatrends' in Australia and other countries that will drive research during the next ten to twenty years are: "demographic change, health, the environment, natural resource management including energy and food production, technological change and information and communication technologies" (Department of Industry, Innovation, Science, Research and Tertiary Education 2012, p.52). In comparison, the Grand Challenges identified for European countries in the *Lund Declaration* (2009) were "global warming, tightening supplies of energy, water and food, ageing societies, public health, pandemics and security" (Lund Declaration 2009).

To apply the identification of Grand Challenges to guiding investment in publicly funded research, ARCom then developed the *Strategic Research Priorities*. Released in June 2013, these replaced the previous *National Research Priorities*. They identified five broad societal challenges considered to be "of immediate and critical importance to Australia and its place in the world" (Department of Industry, n.d., p. 1). Under each of the challenges are three criteria which are used to assess research proposals with the purpose of focusing publicly funded research:

- **Living in a changing environment**
    - Identify vulnerabilities and boundaries to the adaptability of changing natural and human systems
    - Manage risk and capture opportunities for sustainable natural and human systems
    - Enable societal transformation to enhance sustainability and wellbeing
- **Promoting population health and wellbeing**
    - Optimise effective delivery of health care and related systems and services
    - Maximise social and economic participation in society
    - Improve the health and wellbeing of Aboriginal and Torres Strait Islander people
- **Managing our food and water assets**
    - Optimise food and fibre production using our land and marine resources
    - Develop knowledge of the changing distribution, connectivity, transformation and sustainable use of water in the Australian landscape
    - Maximise the effectiveness of the production value chain from primary to processed food
- **Securing Australia's place in a changing world**
    - Improve cybersecurity for all Australians
    - Manage the flow of goods, information, money and people across our national and international boundaries

Megatrends
Megatrends that will drive research during the next ten to twenty years are: demographic change, health, the environment, natural resource management including energy and food production, technological change and ICT.

- Understand political, cultural, economic and technological change, particularly in our region

- **Lifting productivity and economic growth**
  - Identify the means by which Australia can lift productivity and economic growth
  - Maximise Australia's competitive advantage in critical sectors
  - Deliver skills for the new economy

3.3 Innovation Policies and Grand Challenges

3.3.1. Extracting societal desirability criteria from innovation policies

The *Strategic Research Priorities*, developed specifically to guide research investment towards meeting identified challenges, are quite clearly linked to societally desirable outcomes. For example, to address the challenge of 'living in a changing environment', research is to identify either, "the level of environmental change human and natural systems can tolerate before fundamental ecological processes are irreversibly changed" (first criterion); develop options for "managing change in the linked human and natural environment" (second criterion); and/or "develop options for the change required to mitigate and/or adapt to environmental change" (third criterion) (Department of Industry n.d., p 2).

To meet the challenge of 'managing our food and water assets', research will identify, "ways to make Australian agriculture and food processing more productive, globally competitive and efficient" (first criterion); "study the dynamics of water and its use, patterns of rainfall, water resource distribution, how to retain water in our soils and how to resolve conflicting demands on water resources" (second criterion); and/or "enable effective planning to meet changing needs of consumers while increasing food production" (third criterion) (Department of Industry n.d., p. 3).

Whilst Australia's overall innovation policies are likely to be altered in the near future, there are a number of non-research-focused innovation strategies that are also linked to combating Grand Challenges. Some of these are mentioned in the sustainability criteria section but one of relevance here is the National Broadband Network (NBN). The NBN is a national project which seeks to provide a minimal level of broadband service Australia-wide. It involves progressively upgrading existing internet and phone line infrastructure using a range of technologies to suit the needs of different areas.

The NBN was motivated in part (perhaps primarily) as a means of increasing productivity and efficiency, but it has also been regarded as desirable from an environmental perspective in improving efficiency. Now, however, some of its potential uses for other societally desirable purposes are also being investigated. These include tele-health uses (e.g. video-conferenced doctor's consultations in remote areas; remote monitoring of patients), and education uses (improvements in distance education; opportunities for small regional schools to access specialised teachers), which are particularly useful in Australia (See, e.g., Department of Health 2014; Banks 2011).

3.2. Extracting ethical acceptability criteria from innovation policies

Australia has developed the *National Enabling Technologies Strategy*, which aims to, "provide a responsible framework for the development of enabling technologies such as nanotechnology, biotechnology and other emerging technologies" (Department of Innovation, Industry, Science and Research n.d.).[8] It was developed in 2009 in recognition that innovations have the potential for significant social and economic benefits, but also, "pose new health, safety and environmental risks and have ethical and social impacts". It seeks to promote a nationally coordinated approach to managing such risks and impacts, through supporting regulatory agencies, supporting engagement between such agencies and policy bodies nationally and internationally, and commissioning and conducting research on potential risks and impacts. It will also conduct community consultations, public attitude research and education programs; and seek to support uses of new technologies that will meet recognised societal challenges.

Ethical issues arising from innovative technologies or practices in a non-research context are also sometimes dealt with on a case-by-case basis. An example is the ongoing public discussion and policy developed surrounding government collection of metadata via the National Broadband Network (NBN). The government is requiring companies providing internet access through the NBN to retain customer's details for law enforcement and counter-terrorism purposes, raising privacy and security concerns.

Another example is the recent proposed changes to higher education, including possible fee deregulation, which would impact - critics say - particularly on students from lower socioeconomic backgrounds. Presumably in anticipation of this, the current budget measures include a provision that 20% of additional revenue that universities gain from student fee contributions must be used for scholarships and other support for disadvantaged students. Additional funding will also be provided for regional higher education providers, as their costs are higher. Policies are also in place to increase higher education access for specific groups, including minorities, women, Aboriginal and Torres Strait Islander people, and regional students (for example, students from regional colleges may be required to have a lower Tertiary Entrance for particular courses than students from other colleges).

3.3. Extracting sustainability criteria from innovation policies

The *Australian Code for the Responsible Conduct of Research* includes the principle of respect for the environment, saying that researchers should, "conduct their research so as to minimise adverse effects on the environment". Institutions are expected to train researchers in environmental protection. Risks to the environment from any specific research proposal would be evaluated by institutional research ethics committees, approval from which is required for any research project. It also requires researchers to comply with laws and regulations relevant to sustainability.

> ***Carbon Tax***
> *There have been concerns that the repeal of the carbon tax has removed incentives for businesses to develop and adopt innovations towards developing more sustainable business practices.*

[8] See also http://www.industry.gov.au/industry/nanotechnology/NationalEnablingTechnologiesStrategy/Pages/NationalEnablingTechnologiesStrategyPolicy.aspx.

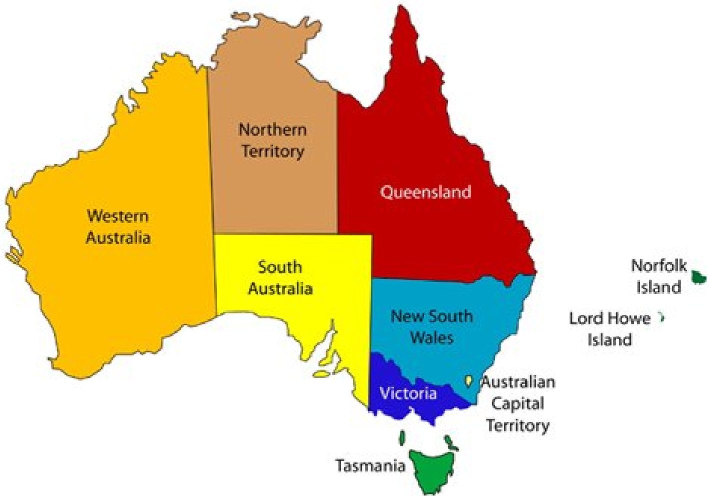
A recent policy change relevant to innovation and sustainability is the July 2014 repeal of Australia's Carbon Tax. This tax operated in 2012-13 and 2013-14, and was a tax on companies operating facilities with direct carbon dioxide emissions exceeding 25,000 tonnes p.a. There were also taxes imposed on other companies via a tax on fuel and levies on synthetic greenhouse gases. It is estimated to have affected around 75,000 businesses, though only 370 were directly liable under the carbon tax itself. The rationale for its removal was to reduce costs for businesses and households, and boost economic growth, jobs, and Australia's international competitiveness. Whilst these aims are in some senses tied to promoting innovation via reduction of business costs overall, there have been concerns that the repeal of the carbon tax has removed incentives for businesses to develop and adopt innovations towards developing more sustainable business practices.

As mentioned previously, various non-research-focused innovation strategies are also linked to combating Grand Challenges. For example, a number of programs were introduced in 2008-09 to support businesses both in achieving more environmentally friendly practices, and to develop innovations that might assist in reducing impacts of activities on the environment (e.g. Clean Business Australia, the Green Car Innovation Fund, the Clean Energy Initiative, the Global Carbon Capture and Storage Institute, and the Climate Change Action Fund.) The Australian Bureau of Statistics (2014a) has begun including measurements of business involvement in innovation to reduce environmental impacts. In 2013, the Government reportedly allocated 3.6% of its R&D budget to the environment, and the growth rate of investment in environmental R&D has been higher in recent years than other R&D investment growth (Department of Industry 2013a, p. 148). The *Australian Innovation System Annual Report* for 2013 includes a special section on 'eco-innovation'.

3.4. Conclusion

Australia is highly active in research and innovation. However, the overall picture could be better. The situation was well summed up recently by Australia's Chief Scientist, Professor Ian Chubb, when he said, "We are one of only three nations in the OECD which lacks a national plan on science, technology, engineering and mathematics", and again, "our science historically has been the victim of on-again, off-again policies, too often short term, too often based on terminating programs; and when they are on, they are not necessarily connected to all the other elements that make science strong" (Chubb 2014). The problem can be seen currently. A new government was elected in late 2013, and one year on, it is unclear what the future research directions will be.

Australia's Chief Scientist:
We are one of only three nations in the OECD which lacks a national plan on science, technology, engineering and mathematics.
Ian Chubb 2014



Since this report was written, the Australian Government has announced new policies on research, innovation and industry (Industry Innovation Competitiveness Agenda, Commonwealth of Australia 2014c). These include (Aus)$188.5 million in funding for five industry growth centres that will be charged with pursuing "global excellence in areas of competitive strength", focusing on food and agribusiness; mining, equipment and technology services; oil, gas and energy resources; medical technology and pharmaceuticals; and advanced manufacturing sectors. These industry-led centres are designed to bring together expertise from business and industry, the scientific and research communities and the university sector.

It has also been announced that a science council will be established, which will advise the government on various areas of policy aimed at further improving links between science, research and industry.

4. China

China is the most populous country in the world (1.35 billion), with the world's fastest-growing economy, and is one of the world's prime exporters. The People's Republic of China was founded in 1949 and the current government is headed by Xi Jinping who came into power in 2012/3. The main focus of his leadership has been economic reform and a fight against corruption.[9]

China has a continuous culture stretching back nearly 4,000 years

China has put more and more emphasis on the necessity of "Socioeconomic Development Oriented Responsible Research and Innovation" in recent years. The report of the 15th sustainable development strategy[10] indicated that sustainable development policies are required to implement the long-term economic development strategy, which aims to achieve development for more people sustainably. To this end, China has established research projects and carried out basic research in key areas such as agriculture, energy, information, resources and environment, population and health, and materials since 1998.

4.1 Country-specific context

4.1.1. Economic and political situation

Investment has stimulated China's economic growth. According to the National Bureau of Statistics, the growth rate for the first half of 2014 is 7.4%.[11]

From 2002 to 2012, the normal growth rate was 25% and in the first half of 2014 the net export was US$102.9 billion. This is despite the global financial crisis triggered by the US subprime mortgage crisis. However, the trend for net exports is now downward and the same applies to the ratio of consumption to GDP; from 57% in 2003, it gradually decreased to a level of about 49% in 2014.

The conference emphasized that the purpose of reform should be to allow more benefits from development to be shared more equally by all people.

One could say that China's economy has quietly entered a new "turning point phase", from a focus on manufacturing and economic growth to structural adjustment and attempts to move towards a knowledge and innovation economy. Responding to this situation, and to secure China's future development, fiscal policy serves as a prime tool for state governance and has begun to adjust to the challenges and opportunities which were emphasized in the Third Plenary Session of the 18th Communist Party of China (CPC) Central Committee in 2013. The conference emphasized that the purpose of reform should be to allow more benefits from development to be shared more equally by all people. The Third Plenary Session of the 18th CPC Central Committee thus produced a communiqué that puts

[9] http://www.bbc.co.uk/news/world-asia-pacific-13017880
[10] http://www.people.com.cn/GB/huanbao/259/7623/7624/20020226/674319.html
[11] http://www.stats.gov.cn/

comprehensive reform of the fiscal and taxation system in place. Focusing on the important role of finance in China aligns with China's aims to push forward significant innovation policies. The funding priority was given to scientific and technological innovation, building independent innovation capacity and new strategic industries.

4.1.2 Institutions involved in setting China's innovation policies

The main government department involved in innovation policy in China is the **State Department of Science and Technology**. Its main job is to study and put forward macro-economic strategies for scientific and technological development as well as policies, laws and regulations to promote economic and social development. In addition, it guides research on major issues of science and technology for economic and social development; determines the priority areas for innovation; promotes and improves the national scientific and technological innovation system; and establishes mechanisms to facilitate innovation.

The Ministry of Education has the important task of ensuring that the citizens of China are sufficiently educated to partake of and participate in innovation. This is particularly difficult in rural areas. The 18th National Congress of the Communist Party of China therefore proposed to promote the equalization of basic public education services, in order to accelerate narrowing the gap in education between urban and rural areas, and ensure that every citizen can obtain a good education.[12]

The State Information Center was established in 1987 and is China's well-known soft science[13] institution, under the framework of the National Development and Reform Commission. In terms of innovation policies, the Center has co-authored a report with the World Bank entitled *Promoting Inclusive Innovation to Achieve Sustainable and Inclusive Growth In China.*[14]

The Chinese Academy of Social Sciences (CASS) is China's elite academic research organization in the social sciences and a national centre for comprehensive studies. CASS has been creatively carrying on theoretical exploration and policy studies which promote China's reform and further opening-up globally, whilst aiming for socialist modernization. CASS research projects include those on urbanization, social welfare reform and social innovation.[15]

4.1.3 Strategy overview

The timing of talking about responsible research and innovation (RRI) mirrors the fact that innovation is demanded for further developing the national economy and realizing the welfare of the whole society. This was reflected in discussions at the Party's 18th National Congress.[16] The congress focused on comprehensively deepening reform strategies. It proposed a decision on deepening reform of the science and technology system, including establishing and improving original innovations, integrated innovation (i.e. comprehensive innovation that links innovation

[12] http://www.moe.gov.cn/

[13] Soft science comprehensively uses decision theory, system method and computing technology to generate modern science and technology knowledge.

[14] http://www.sic.gov.cn/

[15] http://cass.cssn.cn/

[16] http://www.xj.xinhuanet.com/2012-11/19/c_113722546.htm

from one sector to another), and importing and absorbing new innovation systems and mechanisms. It was noted that a comprehensive technological innovation mechanism needs support from both the government and the society, and has to take social, ethical and sustainability criteria into consideration. This would guarantee responsible innovation to be carried out at the national level. The following strategic goals were agreed:

- **Adjusting the role of the market:** Perfecting the market-oriented technical innovation mechanism is necessary in China today. The market should also play a guiding role in technology research and development direction, but cannot entirely dominate the route selection of innovation, as development does not happen automatically through the market, given the gaps between those in rural and urban areas.

- **Adjusting the role of government:** the government was able to increase financial support to society through the good growth rates of the last two decades to establish a diversified investment mode. Government support for society includes three aspects:
    a. First, the government provides financial incentives for the development of emerging technology companies and reduces the tax burden on such companies and related services practitioners.
    b. Second, the government tries to establish a diversified mode of technology services investment, which would collect social and individual actors' suggestions on the protection of social welfare during technological innovation.
    c. Third, the government proposes appropriate support policies to improve relevant information platforms to make innovation activity more transparent to the public.

- **Adjusting the role of research and education:** to achieve higher benefits from innovation, the relationship between university education, research and innovation needs to be studied, which is also an important part of founding a national innovation system. Furthermore, science and technology plans and resources need to be better integrated. The related policies include establishing innovation survey and report systems, building open and transparent mechanisms for the funding of national scientific research projects, and perfecting the government support mechanisms for basic, strategic, cutting-edge scientific research and generic technology development. What is even more important is to pass the results of research and innovation to a broader base of people.[17]

4.2 Grand Challenges

Despite the considerable success in poverty reduction in China in recent decades, one of the Grand Challenges that technological innovation and economic growth have brought to Chinese society is the uneven distribution of benefits to people. People from different geographic areas, and from different professional backgrounds and social classes are likely to have different experiences of technological advancements and economic developments. The following table shows how a gap between urban and rural citizens of China increased even in just two years, between 2009 and 2011.

[17] http://opinion.people.com.cn/n/2014/0818/c159301-25481576.html
Access date:2014.09.08

Table 1 Project comparison of urban-rural gap

	2009			2010			2011		
	City	Village	gap	City	Village	Gap	City	Village	Gap
Engel coefficient (%)	36.5	41.0	4.5	35.7	41.1	5.4	36.3	40.4	4.1
Net income per capita (Yuan)	17,175	5,153	12,022	19,109	5,919	13,190	21,810	6,977	14,833
Consumption expenditure per capita (Yuan)	12,265	3,993	8,272	13,471	4,382	9,089	15,161	5,221	9,940
Domestic tourism spending per capita (Yuan)	801	295	506	883	306	577	878	471	407
Ownership of colour TV per hundred households	135.7	108.9	26.8	137.4	111.8	25.6	135.2	115.5	19.7
Ownership of computer per hundred households	65.7	7.5	58.2	71.2	10.4	60.8	81.9	18.0	63.9
Ownership of family car per hundred households	10.89	——	——	13.07	2.75	10.32	18.58	5.51	13.07
Proportion of household spending on education and entertainment (%)	12.0	8.5	3.5	12.1	8.4	3.7	12.2	7.6	4.6
Average living standard of minimum living guarantee (Yuan / month / person)	227.8	100.8	127.0	251.2	117.0	134.2	287.6	143.2	144.4
Health expenditure per capita (Yuan)	2176.6	562.0	1614.6	——	——	——	——	——	——
Number of people who participate in pension insurance (10,000)	23,550	8,691	14,859	25,707	10,300	15,407	——	——	——

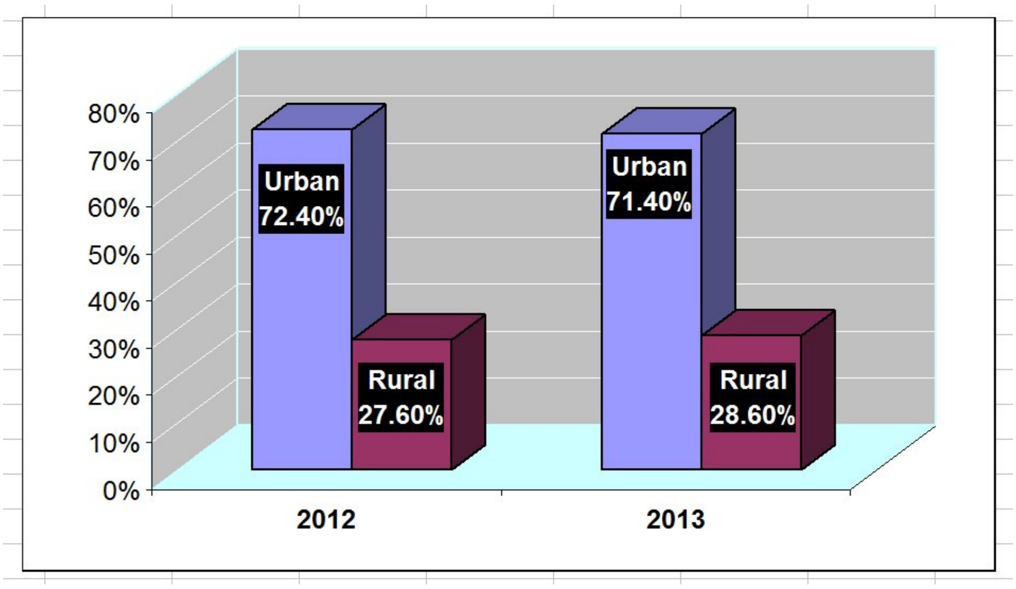
Source of the Table: 2010-2013 China Statistical Yearbook

What are the challenges for overcoming the uneven distribution of the results of technological innovation and economic growth? The following three challenges can be divided into material (instrumental), capability, and institutional level challenges:

- **Uneven Income:** The uneven distribution of educational resources affects the quality of labour resources in certain geographical areas, which means that those living in these areas are likely to have a lower capability of getting a job, or a well-paid job.

- **Uneven Capability:** The uneven distribution of educational opportunities can also lead to fewer chances to *use* the results of technological innovation. This is particularly obvious in terms of those without access to internet resources. Even if the first level problem, namely material shortage (e.g. no paid job), was not an issue, low educational level might still create a capability problem. The following figure shows the percentage of rural versus urban Internet users.

Figure 5: The structure of Internet users in urban and rural areas



Data source: CNNCI China Internet Development Survey, 2013.12

- **Uneven Distribution of Opportunities:** When Deng Xiaoping met a senior American business delegation on 23 October 1985, he said that some areas and some people can get rich, which could stimulate and help other regions, other people, and gradually the whole of society.[18] The economy in urban areas as well as in the eastern region has been developing rapidly. The living standards of the urban population and the eastern region have thereby been greatly improved. This was achieved by an institutional design, which combines market and non-market forces to ensure an even distribution of the right for people to enjoy equally the results of technological innovation and economic growth.

In earlier efforts to combat poverty the focus was on changing uneven income distributions. Yet it has been proven that efforts at the material level alone cannot change the poverty problem fundamentally. Since the 20th century, the way to combat poverty has become better understood: the United Nations introduced the new aid modalities of "technology+capital".[19] To realize long term growth and the fundamental eradication of poverty demands cultivating a growth-capability instead of only supplying those undeveloped areas and people on lower incomes with material support. In development economics, "development" is defined by expanding the connotation of the concept of "growth". It includes not only the expansion of the total economy to cover as comprehensive an area and as many social classes as possible, but also embraces the adjustment of economic structures, modes of development, resource conservation and environmental protection, etc. All these efforts focus on cultivating the capability of eliminating poverty in certain less developed areas and amongst a given group of people.

Last but not least, to address the Grand Challenge of poverty and uneven distribution of income and opportunities, the transformation and reconstruction of the entire economic system requires

[18] http://theory.people.com.cn/GB/49154/49156/4618371.html, Access date: 2014.09.02
[19] http://paper.people.com.cn/rmrb/html/2009-10/28/content_370302.htm, Access date: 2014.09.16

institutional support, such as support for small enterprises and enhancing the educational level of rural labor forces.

4.3 Innovation policies and Grand Challenges

Taking uneven income, uneven capability and uneven institutional rights as the Grand Challenges to be overcome by innovation policies, we now link relevant Chinese policies to the RRI criteria, following von Schomberg.

4.3.1 Extracting societal desirability criteria from innovation policies

What is socially desirable has, for the purposes of this report, been linked to the Grand Challenges identified by a country. If a country tackles a Grand Challenge, it benefits all of society. Hence, tackling poverty and the rich-poor gap in income, education and rights clearly qualifies as a societally desirable government aim. Using research and innovation to do so then brings in the RRI element.

It is noticeable in China that the concepts employed to tackle this Grand Challenge have moved from "growth" to "development" to "innovation", all prefaced with the term "inclusive" to ensure that the rich-poor gap is not widened, but rather reversed. The aim of “inclusive” innovation then is long-lasting development that seeks to remove poverty fundamentally.

> *... the concepts employed to tackle this Grand Challenge have moved from "growth" to "development" to "innovation", all prefaced with the term "inclusive"....*

Theoretically, Prahalad and Hart proposed a Bottom of the Pyramid (BoP) strategy (Avlonas and Nassos, 2014). Those who live at the bottom of the pyramid live below the poverty line, and thus the BoP strategy describes a way to combat poverty which sheds light on our understanding of policy decision making in China. Prahalad and Hart noted that if we want to alleviate and eliminate poverty among those populations, we need to find their internal driving force so that the innovation power of these populations can be released. **Practically**, in order to confront the Grand Challenge of poverty reduction mentioned above，what strategies does the Chinese government employ?

- First, establishing a fair social insurance system ensures a more even distribution of wealth, which reduces the gap between the rich and the poor.
- Second, better education cultivates and enhances the quality of human capital, which in turn increases the innovation potential of the newly educated classes.
- Third, enhancing the fairness of institutional design and policy making ensures that people live in a fair competition environment. The construction of a favourable institutional environment is necessary to realize inclusive and sustainable growth. Only with institutional guarantees can corporations motivated by business interests be induced to offer professional training to less-educated potential workers. Good institutional support would then accelerate the process of social transformation. For example, local governments can increase spending on education, and technical and health care investment. In turn, the local economy will enjoy the longer-term benefits of economic development, if their internal innovative capability can be released by fair institutions.

Thus, material and institutional as well as internal and external factors contribute to combating the uneven distribution of the results of technological innovation and economic growth. However, external and material support on its own will not abolish poverty and social exclusion, since this kind of support is not sustainable. Only if the internal innovation power of all citizens is promoted by a favourable environment, namely better educational and other institutional factors, will it be possible to advocate and ensure equal opportunities for the low-income groups to enjoy the benefits of technological innovation and economic development. If this succeeds, one has achieve inclusive innovation.

Only if the internal innovation power of all citizens is promoted by a favourable environment will it be possible to advocate and ensure equal opportunities for the low-income groups to enjoy the benefits of technological innovation and economic development.

Inclusive Innovation

Innovation strategies in China have gone through four stages in the past.[20] The first, formation stage was from 1949 to 1977. The innovation model in this stage was characterized by "government-oriented innovation". The main target of this phase was to establish various research institutions, formulate national science and technology development plans, and gradually form a national innovation system. During this phase of major innovation the *12 years technology development plan* was established. The main goal of this stage was to maintain national security, and China's high-tech developments were therefore mostly in the area of military research.

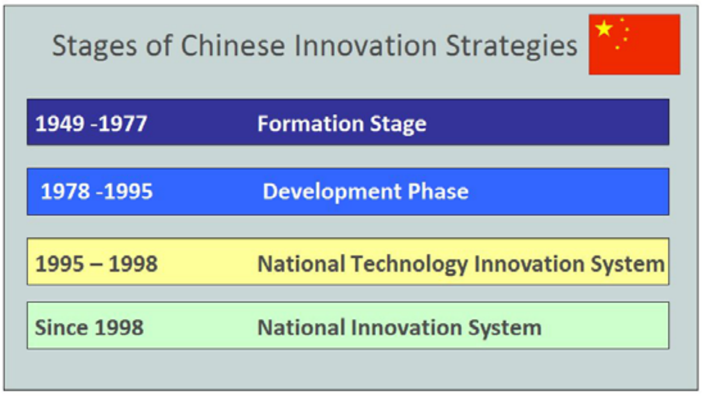


Fig 6 - Stages of Chinese Innovation Strategies

The second stage was the development phase, which lasted from 1978 to 1995. This stage explored the development mode and the innovation policies of the national innovation system. Certain reform policies and measures were carried out during this stage and the innovation mode was "plan-oriented". Competition was introduced through the *National Science and Technology Plan*. The autonomy of state-owned enterprises was expanded, while the regulatory power of the market was growing.

The third stage was the *National Technology Innovation System* phase from 1995 to 1998. This phase focused on the country's technological innovation model, which made this phase a distinctive one and established market economy goals.

The fourth stage is the current *National Innovation System* (1998 - present) period. In this phase, the national innovation system is further defined as a knowledge innovation system, a

[20] http://www.most.gov.cn/mostinfo/xinxifenlei/gjkjgh/200811/t20081129_65774.htm

technological innovation system, a knowledge dissemination system and a knowledge application system.

Given that the national innovation system in China is now fully developed, recent years have witnessed an emphasis on inclusive innovation and inclusive growth. It is hoped that inclusive innovation will serve as an important complement to China's national innovation system, as this bottom-up model for innovation could supply sustainable development.

Inclusive innovation aims to expand the group of beneficiaries of technological innovation to the bottom of the pyramid and to stimulate grassroots innovation. Inclusive innovation pursues rapid progress of science and technology so that those at the bottom of the pyramid, for instance farmers living in remote areas, or disabled people, can get better access to and benefits from the results of scientific and technological innovation.

At the same time, inclusive innovation will not only enable access to the fruits of science and technology but also allow disadvantaged groups to participate in innovation activities and to help solve the people's production and life problems locally, to achieve "grassroots" innovation. Not only do the poor currently only rarely enjoy the benefits of globalization, innovation and economic growth, they also bear a disproportionate burden of environmental deterioration, famine and various other adverse consequences.

Inclusive innovation will not only enable access to the fruits of science and technology but also allow disadvantaged groups to participate in innovation activities and to help solve the people's production and life problems locally, to achieve "grassroots" innovation.

The concept of inclusive innovation puts emphasis on shifting poor people from passive receivers of innovation to active participants in innovation. Passive recipients of innovation cannot maintain their welfare in the long run, but active participants of innovation can. The latter could create wealth by transferring their innovative capability (Cozzens and Sutz, 2012) to wealth, which ensures long-lasting benefits. The enhanced capability of innovation among the grassroots people could also remove a financial burden from governments. In other words, inclusive innovation moves the pattern of passive development to the pattern of active development, ideally with the result of improving all citizens' quality of life and eliminating poverty.

At the same time, inclusive innovation offers opportunities to explore potential new markets. Those people who are at the bottom of the economic and social pyramid have long been excluded from the formal market economy. In this sense, the bottom also contains commercial potentiality. This low-income group could be transferred into an emerging market.

The way of empowering the poor is the channel of education, especially professional education that directly transfers innovation knowledge to the poor and cultivates their innovation capability. Once the poor are effectively educated, the next step is to transfer their capability of innovation to wealth. A well-structured labour force market is therefore also one of the necessary channels to relieve poverty.

4.3.2 Extracting ethical acceptability criteria from innovation policies

An example where the uneven distribution of resources leads to problems that require ethical solutions relates to the fact of ageing societies. As in affluent nations, the ageing process in China is accelerating whilst the number of children who could look after their parents is declining due to the former one child policy. By contrast with many affluent countries however, China is experiencing an "old before getting rich" process. The ageing process is accelerated whilst income is still at a relatively low level. Medical technology and services in China have advanced significantly. Yet, access to medical services is not distributed evenly. There is also a regional disparity of Chinese medical resources as rural areas have fewer resources available compared to urban areas, but also a misdistribution of resources between the younger and the older, with older people having less reliable access to health care.

This unbalanced distribution of medical resources creates an ethical challenge, and access to health care is considered to be one of the most complex problems that Chinese society faces. In order to seek a more harmonious society and sustainable development, there is an urgent demand to deal with the problem of the disparity of medical resources. Large resources have been poured in to improve the medical conditions of older people and those living in rural areas, but sustainable solutions are yet to be found.

4.3.3 Extracting sustainability criteria from innovation policies sustainability criteria from innovation policies

The Twelfth National Five-Year Plan on Environmental Protection (File No. [2011] 42) was issued on Dec. 15, 2011 by the State Council in China with the target of building an environmentally sustainable society.[21]

Through the "Twelfth Five Year Plan", science and innovation have been tasked to reduce major pollutants significantly. For instance, speeding up the innovation of environmental management mechanisms in Beijing, Tianjin, Hebei, Yangtze River Delta and Pearl River Delta regions, in order to control complex air pollution, has been planned.

An Opinion of the State Council on Strengthening the Key Tasks of Environmental Protection (File No. [2011] 35)[22] is another significant document delivered recently. The Opinion demands a historical transformation of the former development strategy, namely to include the protection of the environment *during* the process of development. Reform and innovation are seen as the driving forces to realize sustainable development.

4.4 Conclusion

One of the Grand Challenges in China is continuing poverty at the same time as the widening gap between the wealthy and the poor. The Chinese government has delivered a series of policies and involved many actors in order to transfer the growth pattern to a sustainable one that achieves fair growth. Traditionally, narrowing the gap between the poor and the wealthy was done through monetary influx into rural areas and funding transfers for those on low incomes. Yet, this kind of

[21] http://www.gov.cn/zwgk/2011-12/20/content_2024895.htm, access date: 2014.11.18.
[22] http://www.gov.cn/zwgk/2011-10/20/content_1974306.htm, access date: 2014.11.18.

measure to fight poverty is not sustainable. The aim of inclusive innovation is to tackle the challenge of poverty *and* unfair distribution of wealth in a sustainable manner. Furthermore, sustainability also means that the development strategy should be environmentally friendly, which means that neither the health of people today nor the rights of future generations are harmed.

The aim of inclusive innovation is to tackle the challenge of poverty and unfair distribution of wealth in a sustainable manner.

5. Germany[23]

Germany is the most populous country within the European Union and its economy is Europe's largest, followed by France. The country is ruled by a grand coalition of conservatives and social democrats, led by Germany's first female Head of State, Angela Merkel. Merkel was re-elected into a third term in 2013. Both Angela Merkel and Germany's current president Joachim Gauck grew up in the communist part of Germany.

5.1 Country-specific context - Germany

5.1.1 Economic and political situation

Having experienced a sharp downturn in GDP in 2009, the German economy returned to reasonable growth in the following years, however at diminishing rates. The unemployment rate stands at around 5% in 2014. Public investment in R&D sharply increased after 2009 whereas private investment remained stable in 2009, and increased in 2010, reaching about 2.9% of GDP in 2012 (Bundesministerium für Bildung und Forschung, 2012a)[24].

Glass dome of the German Parliament building in Berlin

5.1.2 Institutions involved in setting Germany's innovation policies

Public support of research and innovation in Germany is a joint task of federal and regional institutions. The following summarizes the main federal institutions:

- The BMBF (Federal Ministry of Education and Research) is the institution in Germany with primary responsibility for science and technology policy. It also implements instruments such as grant-based project funding and institutional funding for public research organisations (e.g. Fraunhofer, Max Planck).
- The BMWi (Federal Ministry of Economics and Technology) is responsible for the implementation of industry related research programmes, as well as higher education and industry collaborations with the potential to move from basic research to commercialisation.
- The German Research Foundation (DFG) administers research programmes and provides grants for academic research projects and infrastructure.
- The KfW (German Development Bank) provides financial support for Start-ups and SMEs to support research and innovation (e.g. High-Tech start-up Fund).

5.1.3 Strategy overview

Research and technology policy in Germany goes back to the 1960s. However, the first national strategy was only launched in 2006, entitled the *High-Tech-Strategy* (*HTS*) (Bundesministerium für Bildung und Forschung, 2012a). The *HTS* aimed to link all relevant topics and stakeholders involved

[23] Parts of this German section are repeated from Deliverable 2.1.

[24] See also: http://data.worldbank.org/indicator/GB.XPD.RSDV.GD.ZS.

in the innovation process in one shared concept and vision. Stakeholders included higher education institutions, public research institutions and industry, as well as the government and various ministries at the federal level. The strategy also aimed to create an innovation-friendly economic environment, and the proposed activities concentrated on pooling the innovative power of science and industry, the improvement of conditions for SMEs and start-ups, fostering technology dissemination, strengthening international cooperation, and investment in human capital. The overall strategy priorities remain:

- To keep pace with global technological trends
- To provide funding for cutting-edge public and private research and innovation
- To reform the education system in order to tackle demographic change, and
- To improve the link between industry and science

(see Bundesministerium für Bildung und Forschung, 2012a)

Key technologies (medical technologies, transportation technologies, nanotechnologies, biotechnologies, material sciences and environmental technologies) were identified as either being able to contribute significantly to the realization of policy aims, or as drivers of innovation for other technology fields.

The successor to *HTS 2006* (*HTS 2020*, Bundesministerium für Bildung und Forschung, 2012b) is discussed in the next section, as it is built around Grand Challenges. What is worth noting here is that *HTS 2020* identified the importance of cross-cutting issues and general conditions for the success of innovation. For example, a positive innovation climate (see Innovationskraftwerk, 2011) and planning security, better conditions for setting up businesses (including guidance and funding for spin-offs), and progressive participation in standard setting. At the educational level, the introduction of entrepreneurial training as part of the curricula at schools, vocational schools and HEIs is aimed at.

After the federal elections in autumn 2013, the government further developed the previous two editions of the *HTS*. The *New Hightech-Strategy* (*Die Neue Hightech-Strategie*, Bundesministerium für Bildung und Forschung, 2014) now brings together two earlier approaches focussing on the market potential of certain technologies (*HTS 2006*), and the tackling of societal needs with innovation (HTS 2010). This results in five pillars:

1. Setting priorities in technology fields of great growth potential.
2. Creating better networks of science and economy at the regional, national and international levels.
3. Increasing innovation dynamics by supporting especially SMEs (see also below).
4. Improving the regulatory framework for securing a qualified work force, financing of innovations and other prerequisites for innovation power.
5. Strengthening the dialogue with society as a whole by improving the general openness towards technology, citizen participation and support for social innovations.

A further major focus for German strategic innovation policies are SMEs, given their outstanding importance for the German economy. Strategic

A major focus for German strategic innovation policies are SMEs, given their outstanding importance for the German economy.

measures to promote the **future success of SMEs** are funding support (Innovation vouchers, High-Tech Start-up Fund, loan programs; Central Innovation Programme for SMEs (ZIM)); access and availability of venture capital; workforce recruitment measures (e.g. *Qualification Initiative for Germany*, 2008); access to knowledge and knowledge protection; pre-market support of research (IGF); commercialisation (e.g. trade fair support (Bundesministerium für Wirtschaft und Technologie, 2013a)), as well as easier access to public R&D programmes (e.g. *KMU-innovativ (SME-innovative)).*

In the German context, it is also important to note that apart from the federal government, all 16 federal states have developed their own state-level strategy and policy, for instance Sachsen-Anhalt (Landesregierung des Landes Sachsen-Anhalt, 2013) and the Saarland (Landesregierung des Saarlandes, 2007), focus their efforts on the respective presence of industrial sectors and research areas. To give an example for Sachsen-Anhalt: the state is home to a strong automotive components supplier industry which therefore features heavily in the innovation strategy of the state government. In providing support for the establishment of an automotive related R&D centre, the state government tries to help interested firms to develop new and more refined products. The Saarland state, by comparison, has defined three main sectors (Bio/Nanotechnology, IT/consulting, knowledge industries) for specific attention, and fosters the establishment of clusters around these industries. Measures include the strengthening of industry-university relations, the provision of a qualified work force, improvements of general investment conditions and improvements of infrastructure.

5.1.4 Challenges and outlook

Even though spending on R&D remained stable during the financial crisis of 2008/09 and increased afterwards, financial market turmoil still posed a major threat, especially to SMEs and start-ups (Rammer, 2011). The venture capital market is still weak in Germany, despite several attempts to improve the situation (see e.g., Poeverlein, 2013). The shortage of qualified labour due to demographic developments already poses a problem to the innovative power of Germany. Immigration restrictions for the highly qualified are still a problem, as is the relatively low number of tertiary education graduates (Rammer, 2011). In the wake of the initiative of the German *Energiewende* (the transition by Germany to an energy portfolio dominated by renewable energy, energy efficiency and sustainable development), energy costs, energy storage and availability are becoming ever more important.[25] The energy strategy for moving the German energy system towards full sustainability was strengthened after the federal elections in autumn 2013.

5.2 Grand Challenges

In 2010, the German government published the *High Technology Strategy 2020* (Bundesministerium für Bildung und Forschung, 2012b), which was based on *HTS 2006*, but refined and augmented by social dialogue.[26] It covered five fields of action (see Fig. 7) and focused on early interaction between potential users and developers of new technologies. The fields are based on the main Global Challenges, as defined by the German government, which create a demand for innovative solutions, and thus market potential.

[25] See: http://www.bmwi.de/DE/Themen/Energie/energiewende.html

[26] E.g. *Dialog der Bundeskanzlerin* (The Federal Chancelor, 2012), and Bürgerdialoge (Bundesministerium für Bildung und Forschung, 2012c).

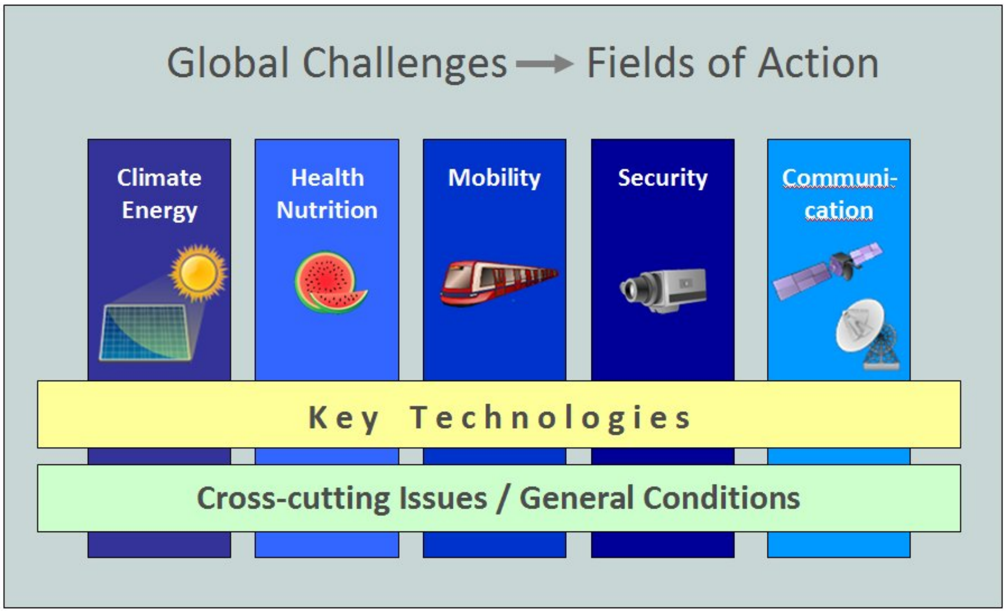


Fig. 7: *Global Challenges and fields of action of the* HTS 2020*;* diagram based on *Bundesministerium für Bildung und Forschung, 2012a.*

Climate and Energy

This field of action is motivated by climate change and the depletion of fossil fuels. Its activities include: further support for cooperation between industry and the financial sector to develop better instruments to support climate protection; intensification of international cooperation; the promotion of energy efficiency measures, and the increased use of renewable energy.

After the Fukushima accident in Japan, the German government decided - relatively swiftly - and with broad support from society, to endeavour to shut down all nuclear reactors within a given timeframe. This **transition of the energy system** towards clean and renewable energy supply (*Energiewende*) is a big issue in Germany, which is observed closely by its neighbours and from further afield. *The Energy Transition* serves also as a double-strategy response to the challenge of climate change, namely by aiming at the reduction of greenhouse gas emissions, as well as the generation of competitive benefits in "green tech" innovation.

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Health and Nutrition

The focus of this field of action is on peoples' needs in view of the demographic changes Germany faces. It involves the development of a new strategy for individualized medicine, support for company health management mechanisms (especially for SMEs), and the advancement of telemedicine to tackle a shortage of doctors.

Mobility

Based on the assumption of a strong increase in transport needs and therefore also of road traffic, priorities in this field of action include the development of fuel cells, battery technologies, intelligent traffic control and the completion of Galileo (a satellite navigation system).

Security

The protection of society and infrastructure from sabotage, organized crime, terrorism and other threats are key to this field of action. Included here is the aim to develop Germany into a lead market for civil security solutions.

Communication

As ICT is the basis for modern industry, the focus in this field of action is on technological and legal advancement of internet-related developments, global standardisations and a roadmap for embedded systems.

Ageing societies

A very serious challenge in Germany, but which is not part of the *HTS 2020* immediate fields of action is the **problem of ageing societies.** Although this is a general challenge for all OECD countries, the situation is worse in Germany than in many others as the German population has a relatively high mean statistical age compared to other countries, see Figure 8.

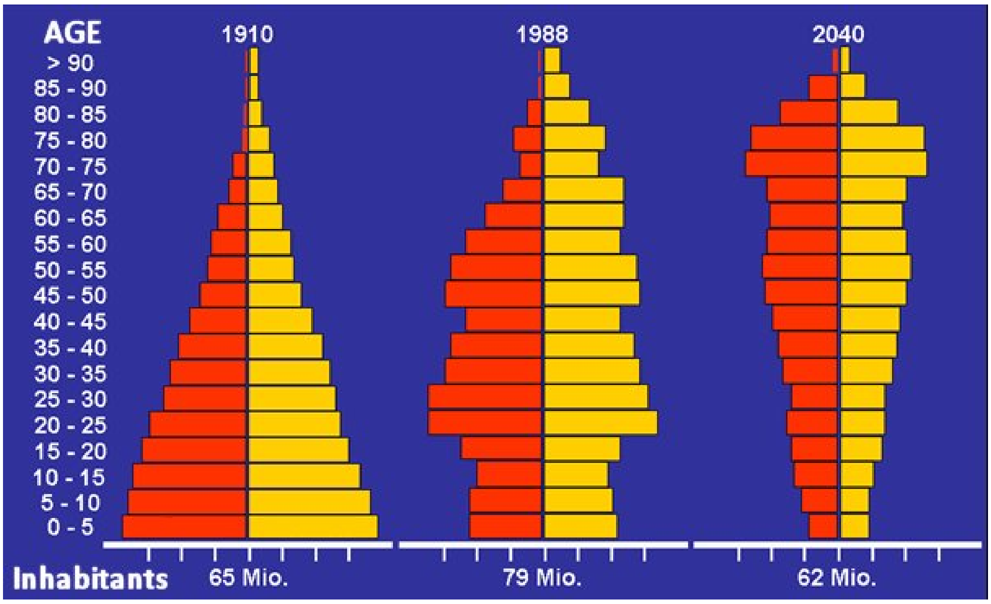

***Fig. 8:** Age distribution in absolute numbers in Germany 1910, 1988, and projected for 2040,* adapted from: http://www.ohg-giessen.de/veranstaltungen/vortraege/2010/7848.html

The different "greying trends"[27] in Germany[28] mean that the country is already facing the problems which are only projected to start in the USA in 2050.[29] In addition (as can be seen in the

[27] Germany's overall greying trends result from good public health support, and support for birth control, as well as relatively restrictive immigration policies since the 1960s.

figure above), Germany will also undergo a significant population loss within the next decades, which does not apply to the US. The demographic change seems therefore comparatively critical in Germany.

The imbalance between the growing number of retired citizens and the decreasing numbers of workers will challenge the national health and social care systems as well as the public pension scheme, thus possibly leading to a rationing of social services in the future.

In summary, *HTS 2020* seems to be influenced by the *Lund Declaration* (2009), which explicates specific issues as major societal challenges of our times, and thus as core action fields for the European member states. The following Grand Challenges match up with most of those which were formulated by the German Government, namely:

- Tightening supplies of energy, water and food
- Pandemics
- Ageing societies
- Global warming
- Public health
- Security

5.3 Innovation Policies and Grand Challenges

Given that the *High Technology Strategy 2020* introduced above links innovation policies onto Grand Challenges, to introduce this section we shall look at the remaining Grand Challenge of ageing populations.

To date, effective and comprehensive counter-balancing measures to address the challenge of ageing populations are lacking. However, some national policies point in the right direction: The *German demography strategy* (Die Bundesregierung, n.d.) describes a policy bundle which includes, amongst others:

- Measures to increase German family sizes (e.g. increasing the availability of day care for children, introducing family-oriented working hours, supporting housekeeping services for working couples with children, support for fertility measures);
- Measures to allow an integration of retirement with part-time working activities beyond the retirement age;
- Measures to increase possibilities for volunteering, both for elderly citizens themselves and those who are able to support them;
- Enabling the immigration of well-educated foreigners, and
- Providing a range of public health and care measures to enable higher quality of life in the last years.

[28] https://www.destatis.de/DE/ZahlenFakten/GesellschaftStaat/Bevoelkerung/Bevoelkerungsstand/Tabellen_/lrbev01.html;jsessionid=4F83192F125916F9DD3ADFAAFB7EF22F.cae2
[29] http://www.berlin-institut.org/newsletter/Ausgabe_28.10.2011.html.html

The re-adjustment of the legally-fixed retirement age from 65 to 67 years had been already decided – however, exceptional case regulations have been recently formulated which partly diminish the balancing effects of this instrument.

At the same time, societal ageing provides unique innovation opportunities, especially efforts to enable the elderly to live relatively autonomous lives. Such innovations primarily involve ambient assisted living concepts, which are directed towards the development of technical support systems such as tele-care/tele-health systems, smart home technologies, and tailored ICT and mobility solutions. Non-technical innovation options aim at the social inclusion of the elderly through the application of life-long learning concepts, by fostering elderly competence networks, and by multi-generational homes support.

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5.3.1 Extracting societal desirability criteria from innovation policies

In this report, we take societally desirable innovations and policies to be those that are linked to Grand Challenges. As shown above, both the *HTS 2020* and the *Demography Strategy* provide policies to tackle major societal challenges. Thus, the importance of using science and innovation to tackle Grand Challenges has been recognized by the German government. To illustrate this point further, the following underlying goals of the *Demography Strategy*[30] are instructive:

- The development and utilization of educational potential
- The provision for the economy of a suitably qualified workforce in sufficient numbers
- The strengthening of the innovativeness and competitiveness of the economy

If social desirability is defined as combating Grand Challenges with innovation policy measures, the last point provides a good example. The three goals are to be achieved through a range of measures: for the first two goals, concerning education and a suitable workforce, measures include efforts to reduce the number of school dropouts, an improved integration of migrants, and a faster recognition of foreign degrees. The more general goal of strengthening the innovativeness and competitiveness of the economy is addressed by a number of measures, including:

- The research agenda *Das Alter hat Zukunft*[31] (*The New Future of Old Age*) brings together the research agendas of all federal departments, directing them towards improvement of the quality of life for elderly citizens.
- Initiating a Europe-wide R&D initiative which aims at coordinating the demography focussed R&D agendas of 13 EU countries.
- Encouraging researchers to obtain funds from Horizon 2020, which will further provide significant support for research and innovation, helping to cope with the challenges of demographic change.

[30] http://www.bundesregierung.de/Content/DE/_Anlagen/Demografie/5-wachstum-wohlstand.pdf?__blob=publicationFile&v=2
[31] http://www.das-alter-hat-zukunft.de/en

5.3.2 Extracting ethical acceptability criteria from innovation policies

One of the key technologies listed in *HTS 2020* is biotechnology (Bundesministerium für Wirtschaft und Technologie, 2014). It is often described as the process by which raw materials could be biologically upgraded into socially useful products (Fichter, 2000). On the other hand, it is a technology that might present risks to the environment, health, safety and security of societies. In addition some advances in biotechnology can pose a dual use dilemma, as illustrated in the *in vitro* reconstruction of the Spanish influenza virus of 1918 (Tumpey *et al.*, 2005). These ethical challenges have led to serious public concerns about at least some applications of biotechnology - especially of applications in the area of green biotechnology.

The German government is taking these technology conflicts and corresponding policy alignments into account on different levels. In 2009, the Federal Ministry of Education and Research (BMBF) and the Federal Ministry of Food, Agriculture and Consumer Protection (BMELV) established the Bioeconomy Council as an independent advisory board to the German Federal Government. Its members cover the full spectrum of the bioeconomy, and their recommendations include a continued dialogue with citizens, since the route towards the bioeconomy must be acceptable to society (Bioökonomierat, 2014).

When the Federal Ministry of Education and Research (BMBF) established the *Biotechnologie 2020+* initiative to strengthen broad biotechnological research, a consultation with technology assessment experts took place to discuss the ethical challenges of different applications. The rationale behind this step was to include acceptability questions at a very early step of the strategy process.[32]

5.3.3 Extracting sustainability criteria from innovation policies

Biotechnology as part of the German *High-tech Strategy* is also relevant with respect to sustainability. At the level of bioremediation and sustainable energy resources, the environment could gain from certain applications of biotechnology, yet some genetically modified organisms (GMOs) might pose risks to the environment.

To promote the opportunities whilst limiting the risks of biotechnology applications, the German Government has set up the Bioeconomy Council and the *Biotechnologie 2020+* initiative (see above). In addition, Germany is a signatory to the *Convention on Biological Diversity* (CBD) which aims to conserve biological diversity through sustainable use, and ensure fair and equitable sharing of any benefits arising from its utilization. According to the *Genetic Engineering Act* (*Gentechnikgesetz*), genetically modified organisms that might interfere with nature are limited to contained applications. In addition, Germany complies with European legislation to prevent risks

[32] http://www.biotechnologie2020plus.de/BIO2020/Navigation/DE/root,did=164942.html

to the environment, including the Directive 90/219[33] plus 98/8[34] on contained use, and Directive 2001/18[35] on release of GMOs, as well as the REACH[36] legislation.

5.4 Conclusion

Responsible innovation in Germany responds to specific challenges at different levels:

- It tackles Grand Challenges such as the transition towards a clean and climate-friendly energy supply;
- It supports key technologies such as biotechnological developments which may offer solutions to some of the challenges identified by the German government in *HTS 2020* (e.g. improvement of diagnostics and drugs in pandemics control);
- It is directed towards improving the framework conditions for successful science and innovation, thereby also addressing cross-cutting problems such as demographic change, which is a serious issue in Germany.

[33] http://ec.europa.eu/health/files/eudralex/vol-1/dir_1990_219/dir_1990_219_en.pdf, accessed 8th September 2014

[34] http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:1998:123:0001:0063:en:PDF, accessed 8th September 2014

[35] http://eur-lex.europa.eu/legal-content/EN/ALL/;ELX_SESSIONID=3nnLJNDJghn3nwG0JQ2WZXkDnjTmsy1vXg3g35HgRcv6DrKThYZ2!1936920695?uri=CELEX:32001L0018, accessed 8th September 2014

[36] http://ec.europa.eu/enterprise/sectors/chemicals/reach/index_en.htm, accessed 20th August 2014

6. India

6.1 Country-specific context

6.1.1 Economic and political situation

Before the Indian economy was opened, central planning, extensive regulatory controls, and widespread restrictions on foreign investment were the defining characteristics of the Indian economy (Segal, 2008). India liberalized its economy in 1991 following various structural reforms, and this gave way to an era of accelerated foreign direct investment (FDI), and economic and technical progress. Post-1991, innovation activity in India has increased significantly and the contribution of high-technology to GDP has also increased. However, most of this has occurred in just a few sectors, such as pharmaceuticals, and the importance of FDI in Research & Development (R&D) in these sectors is also evident (Mani 2009).

According to the *Economic Survey 2012-13*, following the slowdown induced by the global financial crisis in 2008-09, the Indian economy responded strongly and achieved a growth rate of 8.6% and 9.3% in 2009-10 and 2010-11 respectively, although the growth slowed to 5.0% in 2012-13. However, despite this slowdown, the compound annual growth rate (CAGR) for gross domestic product (GDP) at factor cost, over the decade ending 2012-13 was 7.9% (Economic Survey, 2013). According to the IMF, the real GDP growth for India is projected to strengthen to 5.4% in 2014-15 and 6.4% in 2015-16, assuming that government efforts to revive investment growth succeed and export growth strengthens after the recent rupee depreciation (IMF, 2014).

According to the London-based economic consultancy Centre for Economic and Business Research (Cebr), India is likely to overtake Japan in 2028 to become the third largest economy in the world after China and the United States (The Economic Times, 2013). In the last five years, India's foreign exchange reserves have increased from US$254,207 million to US$314,952 million (RBI, 2014). India's hi-tech exports have also increased from US$10 billion in 2009 to US$12.4 billion in 2012 (World Bank, 2014). However, in India, the share of medium and high technology manufacturing exports is only 27% of total exports (Economic Survey, 2014).

R&D spending in India is low in comparison to many other countries. *The Twelfth Plan* (2012-2017) proposed to increase R&D expenditure to 2% of GDP. It also intended to increase the number of full-time researchers/scientists from the current level of 154,000 to 250,000, and the volume of publication outputs in basic research from a global share of 3% to 5%. In addition, the plan intended to improve the global publication ranking from 9th to 6th by the end of the Twelfth Plan; it aimed at doubling the number of patents and increasing the commercialization of patent portfolios to 5–6% from a level of less than 2% (GOI, 2012).

There have been positive implications of development in S&T. According to *R&D Statistics 2011-12: At a Glance*, the gross expenditure on R&D (GERD) in the country has been consistently increasing over the years and has doubled to INR 530Bn in 2009-10; India's R&D/GDP has increased significantly from 0.81% in 2004-05 to 0.87% in 2009-10; and India's share in global research publications increased from 2.2% in 2000 to 3.5% in 2010 as per the SCI (Science Citation Index) database. In 2010, India's largest shares of global research publications were in Chemistry (6.5%), Material Science (6.4%), Agricultural Sciences (6.2%), Pharmacology and Toxicology (6.1%), Microbiology (4.9%), Physics (4.6%) and Engineering (4.2%). During 2010-11 a total of 39,400

patents were filed in India, out of which 8,312 (21.1%) were filed by Indians. Patent applications filed in India are dominated by Computer/Electronics, Mechanical and Chemical fields (DST, 2013a).

In the policy agenda, S&T has been identified as a key means to achieving national prosperity, both in terms of economic growth and in terms of social development since the 1950s. *The Scientific Policy Resolution* of 1958 clearly mentioned that:

> [T]he key to national prosperity, apart from the spirit of the people, lies, in the modern age, in the effective combination of three factors, technology, raw materials and capital, of which the first is perhaps the most important, since the creation and adoption of new scientific techniques can, in fact, make up for a deficiency in natural resources, and reduce the demands on capital. (DST, 1958).

Subsequent S&T policies, namely the *Technology Policy Statement* of 1983, the *Science and Technology Policy* of 2003 and the most recent *Science, Technology and Innovation Policy* (STIP) of 2013, have reiterated the broad vision of the former policy while expanding and enriching it further. The latest STIP 2013 states that:

> [S]cience, technology and innovation (STI) have emerged as the major drivers of national development globally. As India aspires for faster, sustainable and inclusive growth, the Indian STI system, with the advantages of a large demographic dividend and the huge talent pool, will need to play a defining role in achieving these national goals. The national STI enterprise must become central to national development. (DST, 2013).

The on-going national *Twelfth Five-Year Plan* (2012-17) also recognizes that the objective of development is broad-based improvement of the economic and social conditions of the people. The broad vision and aspiration which the *Twelfth Plan* seeks to fulfil is *"Faster, Sustainable and More Inclusive Growth".* The simultaneous achievement of each of these elements is critical for the success of the Plan. Accordingly, the Plan mentions that its strategy for growth depends crucially on productivity gains as one of the key drivers of growth. It categorically states that the traditional sources of growth are not likely to be enough for India in the coming years and in this context the country, it notes, must focus on productivity improvements using Science and Technology (S&T) to drive innovation along with other constituents such as infrastructure, business regulatory environment etc. (GOI, 2012). The government has declared 2010-2020 as the 'Decade of Innovation', with the aspiration of achieving access, equity and inclusion.

Decade of Innovation
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6.1.2 Institutions involved in setting India's innovation policies

The three science ministries/departments that are key players in driving the S&T agenda are the Department of S&T, the Department of Biotechnology (DBT) and the Department of Scientific and Industrial Research (DSIR).

Department of Science and Technology: The DST is engaged in the formulation of S&T related policies and the promotion of R&D through Extra Mural Research Schemes. Among the various departments and arms of the government, the DST has emerged as the major source of Extra Mural Research funding in the country. Among various scientific programmes there is a programme entitled, Science for Equity Empowerment and Development (SEED) under the 'S&T and Socio-Economic Development' division, with the objective of "Working for technological empowerment and sustainable livelihoods at the grass root levels" (GOI, 2012).

Department of Biotechnology (DBT): The overall strategy for the DBT during the *Twelfth Plan* is to "accelerate the pace of research, innovation and development to advance biotechnology as a strategic area by taking India's strengths in foundational sciences to globally competitive levels and expanding the application of biotechnologies for overall growth of the bio-economy within the framework of inclusive development" (GOI, 2012).

Department of Scientific and Industrial Research: The main thrust of the DSIR is to promote industrial research, technology development and transfer to enable India to emerge as a global industrial research and innovation hub. Emphasis is on attracting industrial research into the country through industry and institution-centric motivational measures and incentives, creating an enabling environment for the development of new innovations to channel benefits to the people. (GOI, 2012).

Other key players are the Department of Atomic Energy, the Department of Space, and the Ministry of Earth Sciences, while ministries dealing with agriculture and health have separate agencies for research in the respective areas. For example, the Indian Council for Medical Research falls under the Department of Health Research, which is in turn under the Ministry for Health and Family Welfare, while the Indian Council for Agricultural Research (ICAR) falls under the Ministry of Agriculture.

The planned outlay of INR 1,204,300 Crore i.e. €14,415,471,000 has been approved for the key, i.e. six, scientific departments/agencies, for the *Twelfth Five Year Plan*.

Table 2: Indicative Outlay for the Twelfth Five Year Plan

S&T Departments/Agencies	**12th Plan (2012-2017) Outlay (in INR million)**
Department of S&T (DST)	215, 960
Department of Biotechnology (DBT)	118, 040
Department of Industrial and Scientific Research (DSIR)	178, 960
Department of Atomic Energy (DAE)	198, 780
Ministry of Earth Sciences (MoES)	95, 060
Department of Space (DOS)	397, 500
Total	**1,204,300**

Source: GOI (2012)

Further Ministries involved in S&T R&D activities are the Ministry of Human Resource Development, which is the major ministry that funds higher education and research, and the University Grants Commission, which is the nodal agency for funding of higher education and

research undertaken through the Ministry of Human Resources Development. The Department of Electronics and Information Technology is the key ministry for funding R&D in Electronics and Information Technology. In the case of Defence related R&D, the agency is the Defence Research and Development Organization (DRDO), which falls under the Ministry for Defence.

6.1.3 Strategy overview

The central strategic focus, according to the *Twelfth Plan*, is to ensure that S&T becomes a major driver in the process of national development. The *Twelfth Plan's* programmes, as relevant to science, aim at three outcomes:

1. Realising the Indian vision to emerge as global leaders in advanced science;
2. Encouraging and facilitating Indian science to address the major developmental needs of the country such as food security, energy and environmental needs, addressing the water challenges and providing technological solutions to affordable health care requirements;
3. Gaining global competitiveness through a well-designed innovation system, i.e. encouraging global research centres of multinational corporations (MNCs) to be set up in India.

I
Fig 9 - Indian Strategy Aims

The Plan holds the view that India's aspiration to emerge as a stronger scientific power at the end of the *Twelfth Plan* period will require additional funding and also an effort to interconnect available resources and competitiveness. The need was felt for much greater flexibility in the way scientific establishments work. It says that "we need to encourage collaboration with universities, with private and public sector corporations and also with global research centres" (GOI, 2012).

As noted earlier, India has declared 2010-20 as the 'Decade of Innovation'. The latest *Science, Technology and Innovation Policy* of 2013 released by the government states that, "science, technology and innovation for the people" is the new paradigm for Indian STI (Science, Technology and Innovation). The STI Policy seeks to send a signal to the Indian scientific community, both in the private and public domains, that science, technology and innovation should focus on faster, sustainable and inclusive development for the people. The policy seeks to focus on both STI for people and people for STI. It aims to bring all the benefits of Science, Technology & Innovation to national development. The policy aims to focus especially on the following aspects:

- Prioritizing critical R&D areas such as agriculture, telecommunications, energy, water, health and drug discovery, materials, environment and climate.
- Promoting interdisciplinary research, including the use of traditional knowledge in research and innovation.

2013 STI Policy
Aims to establish a Fund for Innovations for Social Inclusion and leveraging traditional know-ledge through modern science for finding solutions to national challenges.

- Fostering the delivery and use in society of innovations in the strategic sectors with civilian application potential (cheap and effective disease diagnostic kits, cheap and effective water filters etc.)
- Establishing a Fund for Innovations for Social Inclusion.
- Leveraging traditional knowledge through modern science for finding solutions to national challenges.

To summarize the main point again, according to the STI Policy for 2013, the guiding vision of the aspiring Indian STI enterprise is to accelerate the pace of discovery and delivery of science-led solutions for faster, sustainable and inclusive growth. A strong and visible Science, Research and Innovation System for a high-technology-led path for India (SRISHTI) is the goal of the new STI Policy (DST, 2013).

6.1.4 Challenges and outlook

One of the main challenges for India is how to increase its spending on R&D and ensure that it derives benefits from that. If one of India's strategic goals is to emerge as a top nation in terms of indicators such as patents, it is equally important that the results in terms of innovations, products and services enable India to compete globally.

It has been pointed out that the problems of the supply side and underutilization of R&D capacity have to be addressed (Krishna, 2014a, P180). India will have to invest more in emerging technologies and apply S&T to address global challenges such as climate change. A key question is 'Is it feasible to match Duality of Global Competitiveness and National inclusiveness priorities in one STI system?'. Posing this question, a former S&T policy maker has suggested an Indian model is needed, which has to be significantly different from current models that emphasize high resources and high numbers of full time equivalent R&D scientists/engineers (Ramasami 2014).

A study undertaken for the World Bank acknowledged the innovation potential in India and called for, "Increasing competition and improving innovation infrastructure, strengthening the creation and communication of knowledge and fostering more inclusive innovation," as part of the strategy to realize this potential (Dutz 2007).

6.2 Grand Challenges

The Vision Document, *India as a global leader in Science*, prepared by the Science Advisory Council to the Prime Minister (SAC-PM, 2010), mentions the following as some of the "pressing problems of India":

- Energy independence
- Health-care for all
- Efficient water management
- Food security
- Mitigating effects of possible climate change

It stated that "the pressing problems that we face need complex, interdisciplinary solutions. None of them is easily solved, but there is no way that we will ever solve these problems without the proper use of science" (SAC-PM, 2010).

The *Twelfth Plan* mentions the Grand Challenge Programmes, and launched PAN-India missions to address national priorities in various developmental sectors through bottom-up approaches, particularly in the areas of health, water, energy and food, through consortia of institutions and agencies cutting across public and private sectors.

The Implementation of National Missions will be undertaken as follows:

- Realizing that national challenges cannot be tackled without nationally coordinated mission mode programmes involving interdepartmental and inter-ministerial collaborations, PAN-India S&T missions were selected as priority areas in (*i*) Agriculture, (*ii*) Water, (*iii*) Energy, (*iv*) Environment and (*v*) Health.
- To build programme synergies and facilitate implementation of the above socially relevant missions, a special task force will be created. A separate PAN-India Mission Fund will be built into every department so that this fund can be deployed for building synergies among the programmes proposed by various departments and address gap areas. *The Twelfth Plan* emphasises that PAN-India mission mode projects addressing national needs and priorities may be launched through extensive participation of stakeholders to achieve the goals and targets in a defined time frame.

In addition, the Ministry of Science and Technology, through its Council of Scientific and Industrial Research (CSIR), has launched a CSIR Initiative on Inclusive, Participative and Collaborative R&D. This new initiative for the CSIR will comprise the following four sub-components: Grand Challenge Initiative, Inverted Innovation, Participative Science and Participatory Technology Development, and Centres for Collaborative Research (GOI, 2012):

- *The Grand Challenge Initiative* will focus on solving unsolved problems or providing a comprehensive solution to an enduring national problem. It will help in creating new core competences in the CSIR system; or create leadership in a new domain in trans-disciplinary/interdisciplinary science that would position the CSIR well globally.

- *The CSIR Initiative for Inverted Innovation* is a unique paradigm where children/young engineers invent, and CSIR laboratories provide mentorship and access to industries to commercialise those inventions.

- *The CSIR Initiative on Participative Science and Participatory Technology Development* is an initiative to pursue R&D that can provide mutual benefits to all stakeholders participating in the scheme; so that inclusive innovation can be achieved, translational research be carried out, a fluid team with like-minded people be assembled and the scientific outcome be effectively leveraged.

- *Centres for Collaborative Research — CSIR-Academia, CSIR-R&D Institutes and CSIR-Industry*; the centres will focus on collaborative R&D and will be state-of-the-art setups and work in a

fluid networked organization mode. R&D in such centres will be in domains such as health care, secondary agriculture, civil aviation and green transportation, sustainable energy and infrastructure engineering. It is envisaged that these centres will help develop seamless linkages between the CSIR and academic institutions, the CSIR and R&D institutions, and the CSIR and industry.

6.3 Innovation Policies and Grand Challenges

6.3.1 Extracting societal desirability criteria from innovation policies

Since the 1950s, the Grand Challenges of India were prioritized in innovation policies, and the current emphasis on equity, access and inclusion shows that policy-makers are taking note of the continued need to invest in innovation in order to develop a more inclusive society.

Statements related to the use of science, technology and innovation in India have, since the 1950s, tried to project S&T as an important factor in ensuring *social* and economic growth. For instance, the scientific *Policy Resolution* of 1958 mentioned that the aim of the scientific policy is “to secure for the people of the country all the benefits that can accrue from the acquisition of scientific knowledge” (DST, 1958).

The *Technology Policy Statement* of 1983 also stated that “the use and development of technology must relate to the peoples’ aspirations” (DST, 1983). The basic objectives of this technology policy were to provide the maximum gainful and satisfying employment to all strata of society, with emphasis on the employment of women and weaker sections of society; to reduce demands on energy, particularly from non-renewable resources; and to ensure harmony with the environment, and preserve the ecological balance (DST, 1983). This policy also marked some specific areas for technology development. These were agriculture, food, health, drinking water, low-cost housing, and development and use of renewable non-conventional sources of energy (DST, 1983).

Early Vision
As early as 1983, the Indian Technology Policy Statement *stated that "the use and development of technology must relate to the peoples’ aspirations".*

The *Science and Technology Policy* of 2003 reiterated the key role of technology as an important element of national development. As far as its policy objectives were concerned, it enunciated the following major objectives:

- To ensure food, agricultural, nutritional, environmental, water, health and energy security of the people on a sustainable basis.
- To mount a direct and sustained effort on the alleviation of poverty, enhancing livelihood security, removal of hunger and malnutrition, reduction of drudgery and generation of employment, by using scientific and technological capabilities.
- To promote the empowerment of women in all

2003 Aim
The policy also expressed that special emphasis would be placed on equity in development, so that the benefits of technological growth could reach the majority of the population, particularly the disadvantaged sections, leading to an improved quality of life for every citizen of the country.

science and technology activities and ensure their full and equal participation.

- To encourage research and innovation in areas of relevance for the economy and society. Sectors such as agriculture, water, health, education, industry, energy including renewable energy, communication and transportation were accorded the highest priority.

The policy also expressed that special emphasis would be placed on equity in development, so that the benefits of technological growth could reach the majority of the population, particularly the disadvantaged sections, leading to an improved quality of life for every citizen of the country. It also recognized that scientific and technological developments have deep ethical, legal and social implications and that there are deep concerns in society about these (DST, 2003).

The latest *Science, Technology and Innovation Policy* of 2013 recognized that new and structural mechanisms and models are needed to address the pressing challenges of energy and environment, food and nutrition, water and sanitation, habitat, affordable healthcare and skill building and unemployment. It mentioned that "science, technology and innovation for the people" (DST 2013) is the new paradigm, and innovation for inclusive growth implies ensuring access, availability and affordability of solutions to as large a population base as possible. For promoting gender parity, this policy talks about new and flexible schemes to address the mobility challenges of employed women scientists and technologists.

Case for Societal Desirability in terms of Poverty Reduction: Establishing India's Inclusive Innovation Fund for Innovative Solutions for the Bottom of the Pyramid

Recently, the National Innovation Council (NInC) and the Ministry of Micro, Small and Medium Enterprises (MSME) jointly announced the creation of the India Inclusive Innovation Fund (IIIF) with the initial corpus of US$5 billion. The Ministry of MSME commits 20% (US$1 billion) of the funding, the balance being contributed by banks, insurance companies, as well as overseas financial and development institutions.

The Fund will invest in innovative ventures that are scalable, sustainable and therefore profitable but address the social needs of less privileged citizens in areas such as healthcare, food, nutrition, agriculture, education / skill development, energy, financial inclusion, water, sanitation, employment generation, etc. (PIB, 2014).

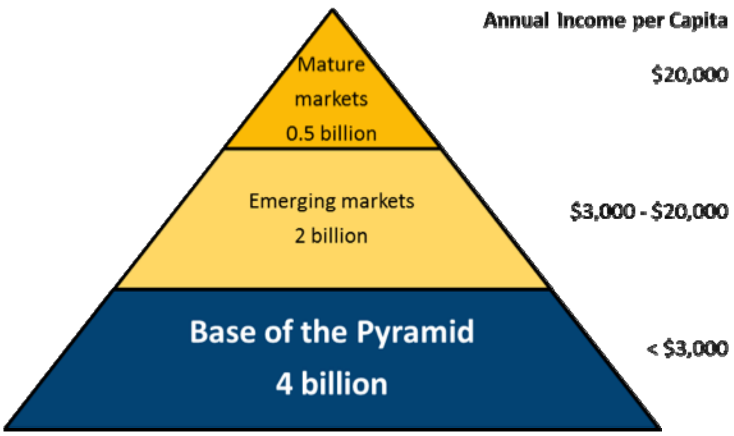

Fig 10 - http://www.inclusivebusiness.se/wordpress/wp-content/uploads/2013/08/BoP-pyramid1.png

6.3.2 Extracting ethical acceptability criteria from innovation policies

The latest *Science, Technology and Innovation Policy* of 2013 also states that people and decision makers must be made aware of the implications of emerging technologies, including their ethical, social and economic dimensions (DST, 2013). However, participatory engagement processes are still rare in India.

In some areas, initiatives are launched that can be linked to the European Commission's RRI action point of open access, for instance India's Open Source Drug Discovery project is an initiative to develop affordable drugs for TB.[37]

6.3.3 Extracting sustainability criteria from innovation policies

Since the *Science and Technology Policy* of 2003, sustainability has been built into Indian innovation policies. Especially the main objective (to ensure food, agricultural, nutritional, environmental, water, health and energy security of the people on a sustainable basis, see above) is clear on this point.

The following provides a case study on how the Indian government tries to address the grand challenges of water, food security, health and energy through the use of nanotechnology.

Case of the Use of Nanotechnology to Address Grand Challenges

Government initiatives on nanotechnology innovation since the early 2000s provide a case study on how the government is trying to leverage the potential of nanotechnology to address Grand Challenges. The nanotechnology research and innovation initiatives were started with the launch of the "*Programme on Nanomaterials: Science and Devices*" in 2000 by the Department of Science and Technology (DST). The DST launched a special initiative to generate and support projects leading to tangible processes, products and technologies after realizing the importance of nanomaterials and their far-reaching impact on technology. "Special emphasis was being laid on projects aimed at solving important national problems such pure drinking water, alternative energy sources, energy conservation, etc. and value addition of materials" (DST 2001).

In 2001-2002, the DST set up an Expert Group on 'Nanomaterials: Science & Devices'. The Government identified the need to initiate a Nanomaterials Science & Technology Mission (NSTM) in the *10th Five Year Plan* (2002-07) after taking into consideration the developments in nanotechnology:

> In accordance with this and to evolve a framework for the National Initiative on Nanomaterials Science & Technology (Nano Science and Technology Initiative (NSTI)), the DST set up a National Expert Committee. Based on the deliberations of this Committee, a strategy paper was developed for supporting on a long term basis both basic research and application oriented programmes in nanomaterials. An advertisement for "Request of Proposals" was released and an Expert Committee was constituted to review the proposals (DST 2002).

The *10th Five Year Plan* (2002-2007) identified various areas for mission mode programmes such

[37] www.osdd.net

as drugs and pharmaceuticals research programmes, including several new projects relating to nutritional deficiency and related diseases, e.g. iron and protein deficiency, herbal drugs, new drug delivery systems. As part of the plan, new national facilities for screening of anti-viral activity, combinatorial synthesis, high throughput screening, regulatory toxicology, and clinical pharmacology were set up (GOI, 2002). When the *National Nanoscience and Nanotechnology Initiative* (NSTI) was launched in October 2001, nanotechnology was heralded as a revolutionary technology with applications in almost every aspect of life.

In 2006, the then-Minister for Science and Technology, in a written reply to a question in the Upper House of the Indian Parliament, released the news that the government was embarking on plans to launch a Nano Mission to intensify its promotional efforts in this area (PIB, Dec 16, 2006) Accordingly, on 3rd May 2007, a Mission on Nano Science and Technology (Nano Mission) was launched by the DST to foster, promote and develop all aspects of nanoscience and nanotechnology which have the potential to benefit the country.

A Cabinet press release on 3rd May 2007, said:

> Nano Technology is a knowledge-intensive and “enabling technology” which is expected to influence a wide range of products and processes with far-reaching implications for national economy and development.

Capacity-building in this upcoming area of research would be of utmost importance for the Nano Mission so that India could emerge as a global knowledge-hub in this field. Again, the plan was to concentrate on areas of national relevance such as safe drinking water, materials development, sensors development, drug delivery, etc. (PIB, May 3, 2007).

The Nano Mission is still going on with enhanced budgetary allocations and enhanced focus now on applications/product development.

6.4 Conclusion

The government of India is the major funder of S&T research and development and about 55% of its budget allocation is meant for key sectors such as atomic energy, space and defence. Although the concept of Responsible Research and Innovation (RRI) does not figure in India’s S&T policy or programs, attention is being paid to apply S&T to solve Grand Challenges in different sectors. The nanotechnology mission is an example where an emerging technology is used for water purification and health projects, in line with the societal desirability criterion of RRI. Likewise, India’s Open Source Drug Discovery project is an initiative to develop affordable drugs for TB, and the India Inclusive Innovation fund enables investment in innovative ventures that address the social needs of ‘bottom of the pyramid’ citizens.

When compared to the USA, China and Korea, India spends less in funding R&D, but ambitious targets have been set in the current *Five Year Plan* (2012-2017) so that India moves ahead in S&T indicators and increases its share in publications. Although private sector spending in R&D has increased significantly over the last two decades, most of the innovative activity is confined to a few sectors, in particular pharmaceuticals. The thrust on innovation in the STI Policy of 2013 and the emphasis on increasing human resources in S&T may result in India moving ahead in global rankings, but challenges remain in allocation, institutional capacity and linking S&T activity with

innovation. On the other hand India can contribute significantly to Responsible Innovation globally as it has the capacity to produce socially relevant, cost-effective products and offer such services. The Indian pharmaceutical industry is an example of this, and India's capacity in Information Technology has already resulted in successful applications in education and telemedicine in Africa.[38]

[38] http://www.panafricanenetwork.com/index.jsp

7. Japan[39]

Japan is a highly modern society in many respects (e.g. more than 75% of the population live in cities), but also traditional in many others (e.g. Japanese men often still work for only one employer for their entire lives; the distribution of hierarchies and roles between men and women remains relatively inflexible).[40]

The country's Head of State is Emperor Akihito who succeeded his father, Hirohito, in 1989. His role in Japanese governance is purely ceremonial. The country is ruled by the Liberal Democratic Party, which has dominated Japanese politics since the Second World War. Prime Minister Shinzo Abe won the December 2012 election with a landslide.


Golden Temple, Kyoto

An earthquake in March 2011 led to a devastating tsunami, and a nuclear disaster at the Fukushima plant in the Tōhoku region on the island of Honshu. The country is still recovering from the aftermath of the catastrophe.

7.1 Country-specific context

7.1.1 Economic and political situation

Japan is the third largest economy in the world based on gross domestic product (GDP), following the US and China and preceding Germany and France. The unemployment rate in October 2014 was 3.6%,[41] which - by comparison to other modern societies - is low. For instance, French unemployment for the same period is 10.2%,[42] UK unemployment is 6.0%,[43] and German unemployment is 5.0%.[44]

In the past decade the Japanese economy suffered from a long period of deflation. In June 2014, a Cabinet decision reports on the situation at the end of 2012 as follows:

> the socioeconomic situation around our country was becoming more severe ... and the feeling of despair and the sense of uncertainty were growing among the people of Japan. The economic conditions of the country were weakening due to the prolonged deflation and rise of the yen... As to the field of science, technology and innovation, there was a strong sense of crisis that our country is struggling in the face of the recent recession while the global competition becomes increasingly severe.
> (Bureau of Science, Technology and Innovation, 2014: 1)

However, due to the weakening Yen and the recovery of stock prices, the Japanese economy showed signs of recovery in 2013 (Director-General for Policy Planning, 2013: 2). Since then,

[39] This contribution was written by an external advisor to ProGReSS (Shunzo Majima).
[40] http://www.bbc.co.uk/news/world-asia-pacific-14918801
[41] http://www.tradingeconomics.com/japan/unemployment-rate
[42] http://www.tradingeconomics.com/france/unemployment-rate
[43] http://www.tradingeconomics.com/united-kingdom/unemployment-rate
[44] http://www.tradingeconomics.com/germany/unemployment-rate

drastic economic policy through monetary easing including and stimulating consumer consumption has been undertaken by the Second Shinzo Abe Administration. In 2015, reductions in corporate tax are scheduled to stimulate economic recovery further.

7.1.2 Institutions involved in setting Japan's innovation policies

Japanese innovation policy is steered by the Council for Science, Technology and Innovation (CSTI),[45] formerly the Council for Science and Technology Policy (CSTP). The CSTI is one of the four councils covering important policies of the Cabinet Office. The other three are the Council on Economy and Fiscal Policy, the Central Disaster Management Council, and the Council for Gender Equality. The CSTI is comprised of the Prime Minister, relevant Ministers, and external experts.

The roles of the CSTI are to:

1. investigate and debate basic policies concerning S&T,
2. investigate and debate S&T budgets and the allocation of human resources, and
3. assess Japan's key research and development areas.

In order to achieve the above-listed three roles, the CSTI takes the following specific measures:

1. take a lead role in science and technology budget decisions,
2. take responsibility for developing an innovation-friendly environment,
3. investing in cross-cutting innovative research for the future, and
4. realize an innovation cycle through the world's highest-level new research and development corporation system.

To achieve point 4 involves promoting greater integration at all levels, achieving inter-ministry policy guidance on research and innovation, strengthening industry-academia-government collaboration, and speeding up the process from basic research to commercialization (Bureau of Science, Technology and Innovation, 2014: 17).

7.1.3 Strategy overview

The Japanese government identified science, technology and innovation as the key leverage for rebuilding the Japanese economy after the financial crisis of 2008/09 and the tsunami in 2011. On 24 July 2014, the Abe Administration published a Cabinet decision; the "Comprehensive Strategy on Science, Technology and Innovation 2014", in which the Japanese government's policy on innovation is outlined. As the document links very closely with the strategic challenges, more details can be found below in 7.2.

7.1.4 Challenges and outlook

The Japanese government expects to face the following five challenges by 2030:

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[45] On May 19, 2014, The Council for Science and Technology Policy (CSTP) was reorganized into the Council for Science, Technology and Innovation (CSTI), by *Partial Revision of the Act for Establishment of the Cabinet Office* (enforced on May 19, 2014). Also by this legal revision, investigation and deliberation duties on the promotion of innovation were added to its function. The function of the Council as a leader in the field was enhanced, and the function of the Cabinet Office's Secretariat to support the Council was also strengthened.

1) a declining population and rapidly ageing society;
2) an explosive development of the knowledge society, the information society, and globalization;
3) an increase in the number of issues that threaten sustainability (population, natural resources and energy, climate change and environmental change, water and food, terrorism, infectious diseases);
4) structural changes in the international economy due to the rapid economic growth of emerging countries; and,
5) increased urgency for the preparation to counter natural disasters
(Bureau of Science, Technology and Innovation, 2014: 10).

The Japanese Government envisages that its ideal economic society in 2030 will be created through science, technology and innovation. It also envisages the following three ideal states of the economy (Bureau of Science, Technology and Innovation, 2014: 10-12).

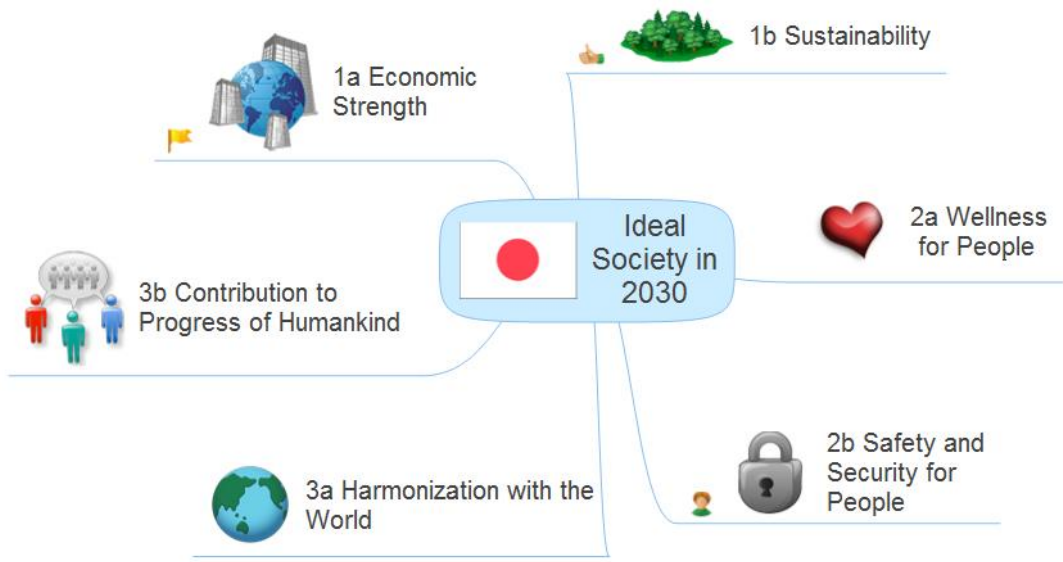

Fig. 11 - Japanese visions of the ideal society in 2030

1. **Economy maintains world-top-class economic strength and develops sustainability**
   Through innovation the vitality of Japanese industry and international competitiveness will be maintained and strengthened, which will help industrial activities expand dynamically and globally. In this way, Japan aims to maintain its international position by winning not only economic demand but also trust abroad. The employment and income to support the lives of people will be adequately secured as a result. The negative factors of economic growth such as a decrease in the labour force will be mitigated by science and technology. The restriction of resources and energy will not be a burden for growth, as energy can be supplied and used safely, constantly, and efficiently. In each region, a unique "strength" is fully displayed with vitality; people can lead a high-quality life at ease and a globally attractive economy will have been established.

2. **A society where the people can enjoy wellness, security and safety**
   People feel that their standard of life is maintained and improving, and a sustainable and dynamic society is realized despite population decrease, low birth-rates, and an ageing population. An environment where women and young people can fully display their

capabilities will have been established. People will enjoy healthy, wealthy, and happy lives. In particular, the elderly are active and have a comfortable life. There will be no health inequalities, and people can smoothly return to society while recovering from an illness or injury, or live at ease while alleviating pathology or disability. The whole country is enveloped with reassurance, and everyone is planning their life looking towards a bright future. Furthermore, the next-generation infrastructure will have been established, and people are assured of the security of their lives and properties from natural disasters.

3. **Economic society harmonizes with the world and contributes to the progress of humankind**
   Japan will have become an exemplar to the world as an advanced country in terms of the issue of low birth-rates and ageing populations well-embedded in the international community. A low-carbon society that is friendly to people and protects the global environment will have been established. Japan will be pioneering the world's frontier of "knowledge" and contribute to the future of humankind. By producing various human resources active on the global stage, Japan will have established its position as "the human resource-based nation" and will have become a dynamic economic society and a platform that attracts people, goods, capital, and knowledge from around the world.

7.2 Grand Challenges

Like South Africa (see below), the Japanese Government uses the term 'Grand Challenges' for major strategic goals that the country wants to achieve through science, technology and innovation. These are:

1. Realization of a clean and economical energy system;
2. Realization of a healthy and active aging society as a top-runner in the world;
3. Development of a next-generation infrastructure as a top-runner in the world;
4. Fostering of new industries by utilizing regional resources, and
5. Recovery and reconstruction from the Great East Japan Earthquake.

In order to deal with these five Grand Challenges, the Japanese government agreed a *Cross-Ministerial Strategic Innovation Promotion Program* (SIP), some measures of which are described below alongside each of the challenges.

Realization of a clean and economical energy system

Due to the shutdown of nuclear power stations at Fukushima, Japan currently relies heavily on traditional energy generation, which increases the amount of carbon dioxide. As new energy technologies take at least decade to develop, implement and become operational, this challenge will be time-consuming. Hence, fossil fuel will still be important for Japan's energy supply in the medium and even long term. To move Japan's energy policies into a new direction and to realise a cleaner and more economical energy system, the *Fourth Basic Energy Plan* was formulated (Bureau of Science, Technology and Innovation, 2014: 16).

In the *Fourth Basic Energy Plan*, as one of the long-term measures regarding energy supply and demand to be implemented in a comprehensive and systematic manner, the acceleration of the introduction of renewable energy is envisaged in order to achieve grid parity over the mid-to long-term. More specifically, it envisages strengthening measures to accelerate the introduction of on-

shore and off-shore wind and geothermal power. For instance, since 2012 data have been gathered on off-shore wind power facilities in the Choshi and Kitakyushu areas. Data includes information required for commercialization, such as the installation method, the weather conditions and the amount of power generated. At the same time, demonstration research projects are under way in the seas off Fukushima and Nagasaki, which aim for the world's first fully-fledged commercialized off-shore stations as early as 2018, after significant environmental assessment (Agency for Natural Resources and Energy 2014, 43-44).

Realization of a healthy and active ageing society as a top-runner in the world

Japan has become a super-aged society ahead of the rest of the world. The change in the composition of the population has already had various impacts on Japanese society and the economy, but it is expected that the impact will further increase.

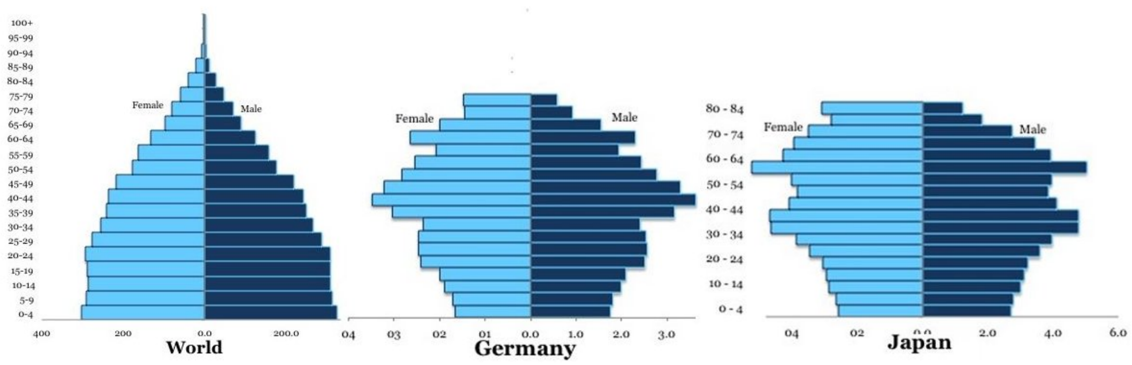

Fig 12 - Age pyramid 2012, World, Germany and Japan, female left, male right, modified from: *http://www.davidmcwilliams.ie/wp-content/uploads/2014/01/Dodgy-Pyramids.jpg*

It is urgent to develop further medical technologies, especially for the aged, by expanding Japan's fundamental scientific research, to realize an extension of *healthy* longevity through cutting-edge medical care. At the same time, the sustainability of health-care systems also needs to be safe-guarded. Given that Japan is already an ageing society, overcoming its limitations can be seen as an advantage in creating a strategic industry with specific medical and health care products that other countries world-wide are soon also going to need. These concerns, as well as strategic interests, have led to measures on research and development for new medical fields, and specific activities have already begun (Bureau of Science, Technology and Innovation, 2014: 31).

One example of realizing world cutting-edge medical care is in the field of regenerative medicine by utilizing iPS cells (induced pluripotent stem cells). By 2015, 10 cases of transitioning from basic research into clinical trials are envisaged in areas such as age-related macular degeneration, corneal disease, knee meniscus injury, and bone/cartilage regeneration. By 2020, new agents are planned to be transferred to clinical sites, increasing the number of pharmaceutical approvals on regenerative medicine (Bureau of Science, Technology and Innovation, 2014: 36).

Development of a next-generation infrastructure as a top-runner in the world

Japan and other highly industrialised nations currently experience similar challenges, namely population decline through declining birth-rates, ageing populations, the changing industrial structure with heavy manufacturing being outsourced to cheaper labour countries, global environmental problems, resource and energy problems, and the need to prepare for large-scale

natural disasters. At the same time, the infrastructure developed during the high-economic-growth era such as roads will require major renovation, requiring a large investment which might overreach current public sector financing power (Bureau of Science, Technology and Innovation, 2014: 40f).

An example of how the Japanese government aims to use innovation to develop a resilient society that responds well to natural disasters are disaster response robots that can be operated remotely by 2018, and become highly sophisticated support by 2030 (Bureau of Science, Technology and Innovation, 2014: 48). Likewise, the increased use of earth observation data and geospatial information from satellites to enhance earthquake resistance has already begun.

Fostering of new industries by utilizing regional resources
Japanese culture is highly varied in different regions, which could be a point for strategic developments and the opening of new employment and market opportunities. For example, in 2013, UNESCO recognized “Washoku” (traditional Japanese cuisine) as Intangible Cultural Heritage, which has prompted a growing global interest in the food culture of various Japanese regions. Building on this, the Japanese government wants to promote new business opportunities that take advantage of the unique characteristics of regional communities (Bureau of Science, Technology and Innovation, 2014: 50).

The policy aspect of this move can be summarized in the following sequence of events:
1. Regional communities are becoming homogenized across the nation, due to factors such as depopulation, ageing, reduction in employment opportunities resulting from weakened regional economies, and a decline of local industries, which fail to take advantage of their unique characteristics
2. The new aim is to foster agriculture, forestry, and fisheries using local community support and characteristics as a growth engine.
3. This in turn will strengthen industrial competitiveness globally and lead to a revitalization of local communities.

Recovery and Reconstruction from the Great East Japan Earthquake
The Great East Japan Earthquake of 11 March 2011, was an unprecedented disaster caused by multiple factors; in addition to a massive earthquake and tsunami, radioactive materials were released due to a nuclear plant accident. As a result society and the environment were very badly affected. The events' social and economic impacts spread not only in the disaster-affected areas but throughout the country. Achieving early recovery from the Great East Japan Earthquake and revitalizing people’s lives and industries are pressing and important issues for the country. Accelerating such recovery and revitalization is highly important in the government's plan (Bureau of Science, Technology and Innovation, 2014: 60).

One of the focused measures taken by the Japanese government is mitigating and addressing the existence of radioactive materials that were spread over a vast area around Tokyo Electric Power Company’s Fukushima No. 1 nuclear power plant. Research is ongoing on efficient decontamination and disposal measures as well as the decontamination of agricultural and fishery products. Part of this work includes developing innovative techniques for monitoring radioactive materials in foods (Bureau of Science, Technology and Innovation, 2014: 65-66).

7.3 Innovation Policies and Grand Challenges

Through the *Comprehensive Strategy on Science, Technology and Innovation* 2014, the Japanese Government strongly promotes science policy to ensure that science, technology and innovation play the following three roles:

1. Be a driving force for ensuring economic revitalization
2. Provide a breakthrough for sustainable development in the future
3. Enhance Japan's presence in the global economy

Japan’s high levels of human resources and technological capability are sources of national strength. However, in addition Japan wants to attract talent from around the world to create the world’s leading innovation hub and secure income and employment. Six principles have been developed to managing science technology and innovation policies:

Principle 1 - Build strategies with clear time frame and goals;
Principle 2 - Conduct comprehensive policy management, which can grasp the whole picture ofscience, technology and innovation and not just specific aspects;
Principle 3 - Produce policies seamlessly covering “upstream” and “downstream” research and development stages from the “upstream” through to the “downstream”[46].
Principle 4 - Clarify the role of each player in the innovation system and establish bettercollaboration between industry, academia, and government;
Principle 5 - Coordinate and combine various policy measures and
-Principle 6 - Evaluate and revise the policy measures through annual PDCA process, which aredirectly connected to budget (Bureau of Science, Technology and Innovation, 2014: 8).

7.3.1 Extracting societal desirability criteria from innovation policies

What counts as societally desirable innovation in Japanese society faces the same problem as in other countries: who decides? For the purposes of this report, we therefore take societally desirable innovations and policies to be those that are linked to Grand Challenges. However, in agreeing this focus, it was assumed that Grand Challenges of humankind, as they play out locally, were identified around the world by the relevant governments, similar to the ***Lund Declaration*** (2009). If a country then puts economic goals such as improving international competitiveness as their Grand Challenges, it is no longer so clear that benefits for the whole society are aimed for. For instance, GDP growth does not trickle down well in some countries.[47] However, looking at the five Grand Challenges the Japanese government identified in the *Comprehensive Strategy on Science, Technology and Innovation* 2014, one can make the following points. To recall, the five Grand Challenges are.

[46] For example, in energy policy, in order to realize a clean and economic energy system, the Japanese government envisages that energy policy integrates research at the stages of energy production (constant and low-cost supply of clean energy), energy consumption (improvement of energy utilization efficiency and reduction of consumption through new technologies), and energy distribution (integration of sophisticated energy network) (Bureau of Science, Technology and Innovation, 2014: 17-18).

[47] http://www.economist.com/news/leaders/21586578-americas-income-inequality-growing-again-time-cut-subsidies-rich-and-invest

1. Realization of a clean and economical energy system;
2. Realization of a healthy and active aging society as a top-runner in the world;
3. Development of a next-generation infrastructure as a top-runner in the world;
4. Fostering of new Industries by utilizing regional resources, and
5. Recovery and reconstruction from the Great East Japan Earthquake.

Number 5, achieving recovery and reconstruction from the Great East Japan Earthquake is very clearly societally desirable as it will benefit all of society and it represents a major issue in the country. Number 1, realization of a clean and economical energy system, links with Number 5, but also with the global challenge of climate change which is recognized around the world. Likewise, number 2, healthy ageing societies has been identified as a Grand Challenge in countries around the world; mostly in highly industrialised countries, but also, for instance, in China. As such three of the five strategic challenges map well onto the Grand Challenges as presented in other sections. Improving the country's infrastructure and fostering new industries that use regional resources are standard economic goals that are not tailored to specific Grand Challenges for humankind, or Japanese society in particular.

7.3.2 Extracting ethical acceptability criteria from innovation policies

The Japanese government takes various measures to ensure innovation policies take note of ethical issues. An example is the above mentioned innovation policy on research and development of regenerative medicine by utilizing iPS cells. Before the first paper on the human iPS cells technology was published in November, 2007, by Dr Shinya Yamanaka, Professor at Kyoto University, the Ministry of Health, Labor and Welfare (MHLW) issued the *Guideline on Clinical Research by Using Human Stem Cell*s on July 3, 2006. Whilst research and development on iPS cells progresses, the MHLW has substantively revised the guideline twice (first revision on November 1, 2010; second revision December 1, 2013). As newly emerging technologies progress through various innovation stages, the Japanese government takes measures to deal with new situations.

7.3.3 Extracting sustainability criteria from innovation policies

Understandably, after the 2011 earthquake, sustainable energy supply is an important goal for the government, which is reflected in the fact that it is goal number 1 under the strategic Grand Challenges. The Basic Energy Plan aims to achieve a situation where Japan can rely on a constant, low-cost energy supply that improves on economic efficiency and safeguards the environment and Japanese citizens. In the process, energy self-sufficiency needs to be improved and a higher reliance on clean, renewable energies achieved (Bureau of Science, Technology and Innovation, 2014: 16).

7.4 Conclusion

Japan is one of the scientific leaders in the world. The impact from the catastrophic accident at Fukushima is likely to occupy the country, including scientists, for considerable time to come. In the light of the accident, it is also understandable that two out of five of Japan's Grand Challenges focus either on clean energy supply or recovery from the atomic disaster.

8. South Africa

The post-apartheid government in South Africa has institutionalised a national system of innovation (NSI) with the explicit intention to improve the lives of its citizens through increased economic growth as well as through the personal and social development of the nation's people (DST 2012). The government has recognised the crucial role that science and technology innovation play in creating an economy that is globally competitive, but as yet, South Africa has been unable to mobilise innovation effectively in support of economic growth. This 'innovation chasm' has been identified as a major weakness in the economy and various strategies have been set up to address the challenge of linking local research to market needs (DST 2008).

South Africa faces many socio-economic challenges, including unacceptable levels of poverty within one of the most unequal societies in the world. Whilst strategic innovation policy in the country has attempted to address these pressing issues, there is still much to be done on the implementation of the well-intentioned policies governing this sector. This section of the report reviews the effectiveness of the innovation frameworks in South Africa for addressing broader societal challenges.

8.1 Country-specific context

8.1.1. Economic and political situation

In May 2014, South Africa re-elected the African National Congress (ANC) to lead the country's fifth democratic administration. In his State of the Nation address, President Jacob Zuma highlighted the key economic challenges that the country faces, most notably that of creating decent work in the campaign to fight poverty. Although he set a target of 5% growth in GDP by 2019, on 13 June 2014 Standard and Poor's[48] downgraded the country's long-term foreign currency sovereign credit rating to BBB- status, citing poor growth prospects. This means that while the country currently has adequate capacity to meet its financial commitments, adverse economic conditions or changing circumstances are more likely to lead to a weakened capacity do to so. Standard and Poor's expect full-year GDP growth of 1.9% in 2014, rising to 2.9% in 2015 and 3.2% in 2016 following slow growth of 1.9% in 2013 and 2.5% in 2012.[49] These lacklustre economic growth prospects are combined with pressure from public-sector wage negotiations and increased public spending needs. At the same time as experiencing poor economic growth prospects, South Africa also faces an unemployment rate of 25% with a high rate of youth unemployment (STATSSA 2014).

President Zuma delivers his State of the Nation address, 17 June 14

[48] Standards and Poor's is an American financial services company that does research and analysis to provide information on credit ratings. It is a leading firm in this regard, having been in existence for over 150 years, and as such its ratings carry considerable weight in the global financial community.
[49] www.standardandpoors.com Accessed June 17, 2014.

This poor economic scenario has been exacerbated by a variety of factors in the resource-based economy including prolonged strikes in the mining sector as well as energy shortages. The continued tension in the mining sector has led to political debates that came to the fore in the run-up to the recent elections, including calls for nationalization of the mines, which has dis-incentivised foreign investment. Furthermore, South Africa's fifth democratic elections were marked by concerns of corruption and a lack of service delivery. In this context, the country has entered into its fifth democratic administration with a set of pressing and serious concerns that need to be addressed.

8.1.2 Institutions involved in setting South Africa's innovation policy

The main government department involved in South Africa's National System of Innovation (NSI) is the Department of Science and Technology (DST), which functions as the designated policy coordinator of the NSI. Other relevant government departments include the Departments of Trade and Industry (DTI), Health (DOH) and Agriculture, Forestry and Fisheries (DAFF) which function as line managers for relevant research councils.

Key research and innovation agencies involved include the following:

- The National Advisory Council on Innovation (NACI), established to prioritise and set agendas for the NSI.
- The Council on Higher Education (CHE), an independent statutory body established in 1998 with functions to report on, assess and develop the higher education sector in South Africa.
- The National Science and Technology Forum (NSTF), established in 1995 to play a consultative and lobbying role in Science, Engineering and Technology Institutions (SETI) policy matters. It also organises an annual competition to reward high achievers in science and technology.
- The National Research Foundation (NRF) - the country's main public research funding agency.
- The Science, Engineering and Technology Institutions, which include the Council for Scientific and Industrial Research (CSIR), the Human Sciences Research Council (HSRC), the Medical Research Council (MRC) and the Agricultural Research Council (ARC).
- The Technology Innovation Agency (TIA), established under the *10 year Innovation plan* and incorporating previously separate innovation bodies such as the Innovation Fund, the Biotechnology Regional Innovation Centres and the Tshumisano incubators,[50] into one organisation.
- The National Intellectual Property Management Office (NIPMO), which aims to enhance protection of intellectual property rights, ensure synergy with other policies and develop national capacity to manage technology licensing and commercialisation.
- The Academy of Science in South Africa (ASSAf), which represents South Africa in the international community of science academies.

[50] Tshumisano (meaning partnership in Venda and Northern Sotho) incubators are situated at 'universities of technology' with the aims of providing technology services to Small and Medium Enterprises (SMEs) in order to enhance their competitiveness whilst at the same time exposing students to practical training in industry (DST 2004).

8.1.3 Strategy overview

Under apartheid, the South African policy and institutional environment was driven by national objectives such as military dominance in the region, food security and energy self-sufficiency (DST 2002; DST 2012). State support for science and technology was not a transparent process and was heavily skewed in favour of programmes and para-statal institutions designed to build up competencies in politically strategic areas such as agriculture, energy and the military. The dawning of South Africa's democracy in 1994 led to a radical change in state priorities and the process by which priorities were identified, with a strong emphasis on public participation and transparency.

In the science and technology arena, a Green Paper process, providing for broad public consultation on developing policy objectives and strategies, was initiated in 1995. This culminated in the 1996 White Paper on Science and Technology entitled *Preparing for the 21 Century* (DACST 1996). This document established a National System of Innovation (NSI) approach as the framework within which Science and Technology (S&T) policy would be developed and directed towards achieving national socio-economic targets. The foundation of the 1996 White Paper was based on the principles espoused in the *Reconstruction and Development Plan* (RDP 1994), which was South Africa's first strategy document for the newly elected government under Nelson Mandela, to build a united, non-racial and non-sexist South Africa. It was given effect through the establishment of the NRF (transformed from the apartheid-associated Foundation for Research and Development) and the National Advisory Council on Innovation (NACI) in 1998, and the DST in 2002.

> ***Reconstruction and Development Plan, 1994***
> *South Africa's first strategy document for the newly elected government under Nelson Mandela to build a united, non-racial and non-sexist South Africa*

In 1999, the *National Research and Technology Foresight* was published, followed in 2002 by the DST's *National Research and Development Strategy* (DST 2002), which forms the main strategic document outlining the specifics of the country's NSI. This document emphasised the need to strengthen the place of Research and Development (R&D) in the nation's economy and promised an investment target of 1% of GDP towards R&D. The setting of this target yielded measurable success because by the 2005/2006 reporting period, Gross Expenditure on R&D (GERD) as a proportion of GDP had reached 0.92%, which was heralded as a success (DST 2008). These figures improved to 0.93% in the 2007/2008 period, but declined again to 0.92% in 2008/2009 with the 1% target remaining elusive (DST 2012). The key emphasis of these two strategy documents was to move South Africa towards becoming a knowledge-based economy for the benefit of her citizens. The strategic pillars were identified as:

- Innovation,
- the economic and institutional regime,
- education, and
- information infrastructure

In 2008, following from an OECD review of South Africa's Innovation Policy (OECD 2007), the DST published *The Ten-Year Plan for Science and Technology* (DST 2008), the objective of which was to strengthen the effectiveness of the NSI to yield tangible socio-economic benefits. The emphasis

once again was to use the NSI to transition from a resource-based economy to a knowledge-based economy. The following four elements were identified as central to this transition:

- Human capital development,
- Knowledge generation and exploitation (R&D),
- Knowledge infrastructure, and
- Enablers to address the 'innovation chasm' between research results and socio-economic outcomes.

The strategic vision for South Africa outlined in the plan included a focus on being one of the top three emerging economies in the global pharmaceutical industry, based on an expansive innovation system using the nation's indigenous knowledge and rich biodiversity. It also focused on the deployment of satellites to provide a range of services for the government, the public and the private sector. Diversifying the energy sector was emphasised, together with an ambition of achieving a 25% share of the global hydrogen and fuel cell catalysts market with novel platinum group metal catalysts. Socio-ecological goals included becoming a world leader in climate science and responding to climate change and meeting the 2014 Millennium Development Goals to halve poverty.

The Ten-Year Plan for Science and Technology also presented a framework of indicators to guide investment and action for the period 2008-2018 (Table 3).

Table 3: Innovation towards a knowledge-based economy: the transformation (DST 2008: 8)

Innovation towards a knowledge-based economy: the transformation

Indicator	*Measure*	*2018*
SA positioned as knowledge-based economy	Economic growth attributable to technical progress (10% in 2002)	30%
	National income derived from knowledge-based industries	>50%
	Proportion of workforce employed in knowledge-based jobs	>50%
	Proportion of firms using technology to innovate	>50%
	GERD/GDP (0.92 in 2005; short-term 2008 target was 1%)	2%
	Global share of research outputs (0.5% in 2002)	1%
	High- and medium-tech exports/services as a percentage of all exports/services (30% in 2002)	55%
	Number of South African-originated US patents (100 in 2002)	250
Research and technology enablers	Matriculants with university exemption in maths and science (5.2% maths and 5.9% science in 2005)	10%
	SET graduates as percentage of all students in public higher education institutions (28% in 2005)	35%
	Number of SET PhD graduates per year (561 in 2005)	3 000
	Number of full-time equivalent researchers (was 11 439 in 2005)	20 000
	FTE researchers per 1 000 workforce employed (1.5 in 2005)	2.6

8.1.4 Challenges and outlook

The DST's *Ten-Year plan for Science and Technology in South* Africa (DST 2008) recognised that despite the inroads that South Africa has made in the science and technology system, there is still a gap between South Africa and other 'knowledge-driven' economies. Building on the NSI, the overarching goal of the plan was therefore to close this gap by focussing on long-term objectives, emphasising the commercialisation of scientific research and producing 'knowledge workers' capable of building an economy that is globally competitive.

Five so-called Grand Challenges were described in the plan, although it should be noted that South Africa's Grand Challenges have been conceptualised somewhat differently to those usually incorporated internationally under the banner of 'Grand Challenges', equating more to areas of research focus, rather than to challenges *per se*.

Thus the Grand Challenges address a range of social, economic, political, scientific, and technological issues of relevance to the National System of Innovation, and are designed 'to stimulate multidisciplinary thinking and to challenge the country's researchers to answer existing questions, create new disciplines and develop new technologies' (DST 2008: viii). The idea is not to encourage innovation for innovation's sake, but to encourage innovation that meets the country's deep and pressing socioeconomic challenges.

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The five challenges for innovation in South Africa between 2008-2018 include: the bio-economy; astronomy; energy security; global change science; and human and social dynamics - focused on improving understanding of shifting social dynamics, and the role of science in stimulating growth and development. Figure 11 outlines these grand challenges as well as the enabling foundations required in order to meet these challenges.

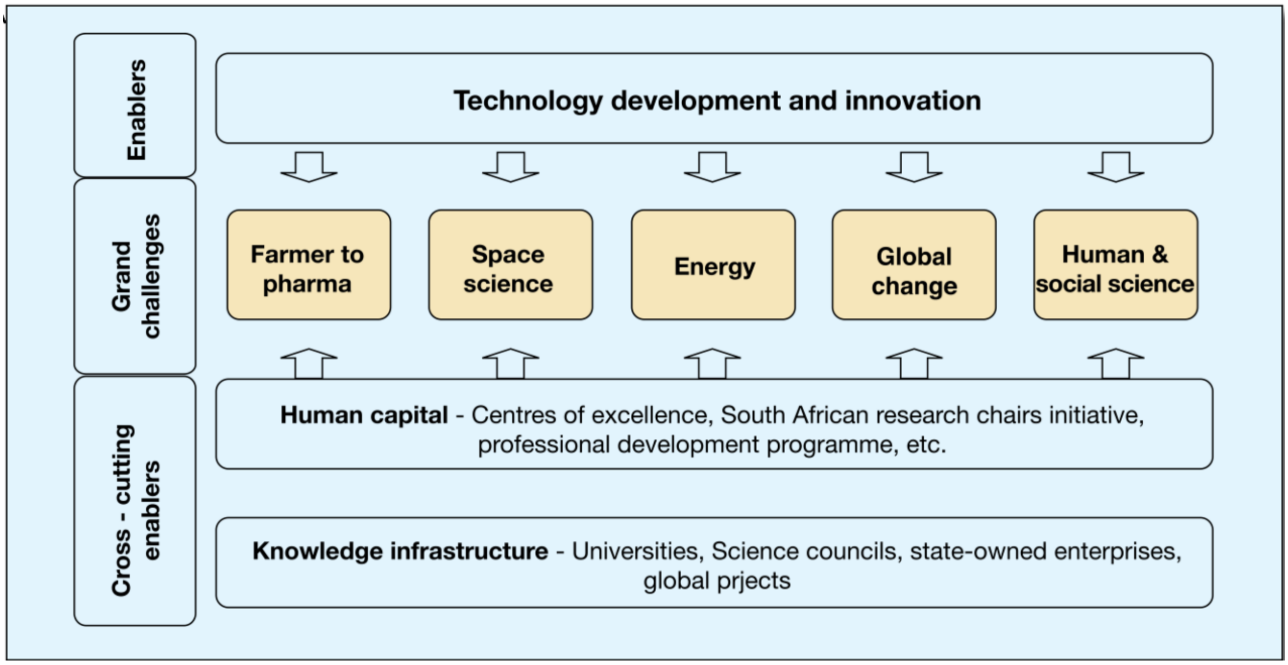


Figure 12: Grand challenges and enablers of the 10 year plan (DST 2008: 9).

Strengthening the Bio-Economy

The first challenge is focused on strengthening the bio-economy, which, while initially conceptualized as the "farmer to pharma" value chain, has since been replaced to a large extent by the adoption of the 2013 Bio-economy Strategy (DST, 2013) – see below). The goal is that over the next decade South Africa becomes a world leader in biotechnology and pharmaceuticals, based on the nation's indigenous resources and expanding knowledge base. The results of

investment in this sector would aim to focus on the heavy burden of poverty-related disease in the country as well as on improving biotechnology in the agricultural sector to meet not only food security, but also to boost participation in the agricultural economy. The plan identifies a number of critical factors necessary to grow South Africa's biotechnology industry:

- Greater networking and collaboration (domestic and international) across all sectors (academia, science councils, industry and government).
- The development of business skills to help identify viable projects.
- A clearer strategic focus on selected platforms and markets.
- Improved funding mechanisms to close the gap between basic research and commercialisation; and shorter turnaround times between application and receipt of funding.
- Investment in platforms (including infrastructure) to bridge the gap between research and commercial implementation.

South Africa is ranked as one of the most biologically diverse countries in the world.

Space science and technology

Given the range of projected problems facing the Earth's system, including climate change, this challenge is linked to making South Africa a key contributor to global space science and technology, having been thus far a consumer of space technologies. This challenge involves the development of a National Space Agency, growing a satellite industry, and encouraging a range of innovations in space sciences, earth observation, communications, navigation and engineering.

Energy security

Energy security is identified as a key challenge for the country, not only to meet medium-term energy supply requirements, but also to enable innovation for the long-term development of a safe, clean, affordable and reliable energy supply. In 2008 less than 1% of South Africa's energy came from renewable sources despite a conducive environment for power generation from solar and wind energy (DST 2008). Major R&D thrusts in this challenge include developing clean coal technologies, revisiting nuclear and renewable energy, which had been invested in previously, and investigating the promise of the "hydrogen economy".

Global change science with a focus on climate change

South Africa has recognized its unique geographical position, given its proximity to the Antarctic, the Southern Ocean, and the Agulhas and Benguela currents, to serve as a laboratory for understanding climate change. This is, above all, a strategic consideration because of the country's dependence on ocean resources, the impact that drought and flood patterns could have on food security and agricultural production in the country and a recognition that South Africa's unique biodiversity could be destroyed by temperature changes and invasive species. Furthermore, the plan identifies the economic opportunity for South Africa to take advantage of mitigating climate

change by becoming a "Green Economy". The *Global Change Grand Challenge National Research Plan* outlines a research plan for developing competencies in this area (DST 2009). In particular, the following societal benefits of earth observation have been identified (DST 2008: 14):

- Disasters - Reducing loss of life and property from natural and human-induced disasters
- Health - Understanding environmental factors affecting human health
- Energy - Managing energy resources
- Climate variability and change - Adapting to climate variability and change
- Water - Improving resource management
- Weather - Improving forecasting and warning
- Protection of ecosystems - Improved management of terrestrial, coastal, and marine resources
- Agriculture - Supporting sustainable agriculture and combating desertification
- Conserving biodiversity - Understanding, monitoring, and conserving biodiversity

Human and social dynamics

Human and social dynamics lie at the core of nearly every major challenge facing South Africa. The fifth Grand Challenge focuses on improving our ability to anticipate the complex consequences of change; to understand the dynamics of human and social behaviour better at all levels; to better understand the cognitive and social structures that create and define change; and to help people and organisations better manage profound or rapid change. It is envisaged that as a leading voice among developing countries, South Africa should contribute to a better understanding of shifting social dynamics and what role the intertwining elements of behaviour, science and technology play in development.

The plan recognises that focusing on technological innovation to solve socioeconomic problems is insufficient without appreciating how it will be received by human beings. The plan therefore requires work by teams of cross-disciplinary experts. Specific research areas include evidence-based support for interventions in learning processes and education, indigenous knowledge systems and heritage literacy.

Interdisciplinarity

The plan recognises that focusing on technological innovation to solve socioeconomic problems is insufficient without appreciating how it will be received by human beings. The plan therefore requires work by teams of cross-disciplinary experts.

Two challenges related to this final Grand Challenge include tackling the persistence of chronic poverty and service delivery. This challenge aims to leverage the NSI to identify the role that science and technology innovation can play in addressing socio-economic problems such as the delivery of affordable energy, health, water and sanitation systems. It includes a recognition of the potential scope for ICT platforms in improving the lives of the poor.

The 2012 ministerial review recognized that the NSI was making an inadequate contribution to poverty reduction and wider inclusion in the mainstream economy (DST 2012). Whilst the implementation of South Africa's innovation policy has been problematic in creating an inclusive, knowledge-based economy, there are elements of societal desirability embedded within the *Ten-*

Year Plan (DST 2008). However, one of the contradicting aspects of the *Ten-Year Plan* is that there is still a big emphasis on 'big science,' for example through the space sciences and cutting-edge new technologies such as hydrogen for energy. This historical focus has been at the expense of supporting the technological requirements for the business economy and social development priorities (DST 2012: 12). The ministerial review committee thus recommends that demand-pull approaches to the development of the NSI should be given as much attention as science supply-push approaches (DST 2012). This would go a long way towards addressing some of the concerns about developing an NSI that meets society's needs as identified in the *National Development Plan* (DST 2012). This is discussed further in section 4 with reference to the 2013 *Bio-economy strategy* (DST 2013).

8.2 Grand Challenges

In 2011 South Africa's National Planning Commission released a new framework document entitled the *National Development Plan* (NDP). The NDP replaces the *Reconstruction and Development Plan* (1996) in setting a 2030 vision for the country of which innovation in an inclusive economy forms an important aspect. The *New Growth Path* (NGP) was also adopted in 2011 (EDD 2010), setting out the framework for the country's economic policy and jobs' creation strategy. Following from the OECD's (2007) review report on South Africa, a Ministerial Review Committee on the Science, Technology and Innovation Landscape in South Africa was established. The purpose of the Committee was to identify what was being achieved by the NSI in creating a knowledge-based economy in South Africa and to propose recommendations for strengthening it in order to align better with the goals and priorities set out in the NDP and NGP (DST 2012). Many of the findings and recommendations of this committee reflect the need for re-aligning the NSI framework and institutions in order to meet the country's challenges and priorities areas.

The failure to meet key goals in the *Reconstruction and Development Plan*, especially poverty reduction, has been explained in the *National Development Plan* as a result of a combination of external financial factors, such as the Asian crisis in 1998, the 2001 collapse of the South African Rand, combined with "an overly optimistic view of the capacity of the state," both in terms of internal co-ordination as well as working with the private sector and civil society (NPC 2011: 4). The NDP instead shifts the focus onto government fulfilling a supportive role that enables communities "to become their own engines of development" (NPC 2011: 4). The plan aims to invigorate the economy as the driving force behind poverty alleviation by investing in infrastructure and encouraging private investment, more innovation and entrepreneurialism. The NDP identifies nine central challenges in South Africa (NPC 2011: 3):

1. Too few people work
2. The standard of education for most black learners is of poor quality
3. Infrastructure is poorly located, under-maintained and insufficient to foster higher growth
4. Historical patterns of land allocation and use exclude the poor from the fruits of development
5. The economy is overly and unsustainably resource intensive
6. A widespread disease burden is compounded by a failing public health system
7. Public services are uneven and often of poor quality
8. Corruption is widespread

9. South Africa remains a divided society.

The NDP then goes on to suggest some key areas in which improvement in addressing these challenges could be made. These are summarised and briefly discussed below. Each challenge has a designated set of targets and a total of 87 specific actions for achieving these targets.

- **An economy that will create more jobs**

A key focus of the NDP (NPC 2011) is to create an "inclusive economy" for creating jobs and improving livelihoods through eliminating poverty. The document proposes to increase employment and growth by increasing the size and effectiveness of the innovation system and ensuring closer alignment with companies that operate in sectors consistent with the growth strategy, namely: mining, construction, mid-skill manufacturing, agriculture, agro-processing, tourism, and business services. This challenge recognises that long-term growth requires trust and co-operation between government, business and labour. Ongoing, sometimes violent tensions, especially with labour organisations, need to be dealt with in an open and honest manner, but this is easier said than done and is a looming challenge in the country.

- **Improving infrastructure**

This goal aims to increase both public and private sector investment in developing and maintaining infrastructure, such as for delivering energy and water services as well as information and communications technology.

- **Transition to a low carbon economy**

The need to move away from the unsustainable use of natural resources is recognised in this goal, which includes not only emitting less carbon, but also using water resources more sustainably. This transition has been recognised as challenging and potentially disruptive and so managing it in a way that keeps costs down - especially for the poor - is essential and requires competent institutions, innovative economic instruments, clear and consistent policies and an educated and understanding electorate.

- **An inclusive and integrated rural economy**

The focus of this challenge is on providing greater opportunities for rural communities to participate fully in the economic, social and political life of the county. Achieving these opportunities requires good quality education, healthcare, transport and other basic services, successful land reform, job creation and rising agricultural production. As such, this challenge includes a focus on creating jobs in agriculture, developing the agro-processing industry and emphasises food security as critical.

Overcoming embedded inequality

- **Reversing the spatial effects of apartheid**

This challenge reflects the legacy of apartheid on the country as it skewed the availability of resources and infrastructure to meeting the needs of only the white minority. Overcoming this embedded inequality is a unique challenge in South Africa. This goal is linked to the focus area of transforming urban and rural space. With 63% of the population now living in urban areas, there is a need to

focus attention on transforming urban areas, especially with regards to making transport safer, more reliable, affordable and energy efficient. At the same time the rural areas, which supply most of the resources, such as food, to the urban areas, also require improved services that balance the social, cultural and agricultural needs of these communities.

- **Improving the quality of education, training and innovation**

Poor education, especially for black learners, compromises not only their access to employment, but also reduces the dynamism of South African business. The NDP recommends a multi-pronged strategy that starts from improved nutrition for children to foster their physical and mental development and encompasses reduced bureaucracy in schools and improved management skills of principals. As well as improving the education system, this goal includes a shift to a knowledge-economy and a wider system of innovation that links key public institutions (universities and science councils) with areas of the economy consistent with South Africa's economic priorities. It also focuses on R&D by creating centres of excellence in universities in order to improve the link between innovation and the needs of business.

- **Quality healthcare for all**

Good health is seen as essential for a productive and fulfilling life. The aim is that by 2030, South Africans will have access to good quality healthcare that is either free at point of service or paid for through public or privately funded insurance. The HIV/Aids epidemic showcases how South Africa could make "monumental social and political mistakes - as well as... correct them and implement a complex programme effectively" (NPC 2011: 20). This challenge also highlights the broader systemic influences on health, such as lifestyle, education, diet, sexual behaviour, exercise, road accidents, and the level of violence to which one is exposed. The key message is that the focus areas of sex education, nutrition, exercise and combating smoking and alcohol abuse are social responsibilities that need to be taken seriously by all citizens, not just the government.

Health care for all
The aim is that by 2030, South Africans will have access to good quality healthcare that is either free at point of service or paid for through public or privately funded insurance.

- **Social protection**

An effective social protection and welfare service is highlighted as an essential element of the country's transition to an inclusive economy as well as towards the elimination of poverty and reduction of inequality. The NDP highlights three key roles of social protection:

1- to set a floor or safety net below which a person should not have to live,
2- to mitigate risks that households can be subjected to, and
3- to ease labour market transitions contributing to a more flexible labour market and economic dynamism.


Citizens should have confidence in the criminal justice system.

- **Building safer communities**

With South Africa's well-known high crime rate, making people feel safe everywhere is a crucial aspect of the country's vision for 2030. When people feel safe, they are more likely to develop their capabilities, to pursue personal goals and to take part in social and economic activities. A key emphasis of this challenge is to ensure that all citizens, especially vulnerable groups like women and children have confidence in the speed and effectiveness of the criminal justice system.

- **Reforming the public services**

This overarching goal refers to the challenge of building a capable state that can deliver on the 2030 vision of enhancing economic opportunities, supporting the development of capabilities and intervening to ensure a rising floor of social rights for the poor. As the NDP (NPC 2011: 22) states, "a plan is only as credible as its delivery mechanism is viable" .

- **Fighting corruption**

In Transparency International's global corruption survey, South Africa had fallen from 38th place in 2001 to (a worse position of) 54th in 2010 out of 178 countries (NPC 2011: 24). The perception of high levels of corruption at senior levels of government makes it all the more important to have political will to fight this 'scourge'. Enhanced accountability in both public and private sectors in the country is a key challenge and requires tackling the social dimensions of corruption, such as focussing on values through education. The targets are to create a corruption-free society, a high adherence to ethics throughout society and a government that is accountable to its people (NPC 2011: 39).

> ***Fighting Corruption***
> *The targets are to create a corruption-free society, a high adherence to ethics throughout society and a government that is accountable to its people.*

- **Transforming society and uniting the nation**

This is an all-encompassing challenge that sits at the heart of sustainable and equitable development in South Africa - the basis of which is that a more cohesive society is not only a national objective, but the means of eradicating poverty and inequality. The vision driving this challenge is a society where opportunity is not determined by race or birthright; where citizens accept that they have both rights and responsibilities; in essence the establishment of a united, prosperous, non-racial and democratic South Africa. This challenge centres on three main themes (NPC 2011: 25):

- Reducing poverty and inequality by broadening opportunity through economic inclusion, education and skills, and specific redress measures.
- Promoting mutual respect, inclusiveness and cohesion by acting on the constitutional imperative that South Africa belongs to all who live in it, and that all are equal before the law.
- Deepening the national appreciation of the responsibilities and obligations that citizens have towards one another.

8.3 Innovation Policies and Grand Challenges

The DST's 2013 *Bio-Economy strategy* is an important policy through which to discuss the relationship between South Africa's 'Grand Challenges' that were identified in the NDP (NPC 2011)

and the policies resulting from the DST's *Ten-Year Plan for Science and Technology* (DST 2008). The *Bio-economy strategy* is the most recent of the policy documents to come out of the DST's plan and as such offers some key insights regarding responsible innovation in the country.

Of particular relevance to the criteria outlined below, the *Bio-economy strategy* identifies that "at a macro-economic and developmental level, South Africa's thriving bio-economy has the potential to make the country more competitive internationally (especially in the industrial, health and agricultural sectors); create more sustainable jobs; enhance food security; and create a greener economy as the country shifts towards a low-carbon economy" (DST 2013: 3). These goals speak specifically to some of the challenges outlined in the NDP, including the need to build an inclusive and integrated rural economy, to improve the quality of innovation, to transition to a low carbon economy, and to provide improved healthcare for all. Three key economic sectors – agriculture, health and industry – are identified as being most in need of, and likely to benefit from the strategy.

8.3.1 Extracting societal desirability criteria from innovation policies

"Bio-economy" is defined differently by different countries and groups, although all have in common a strong focus on the biosciences. The European Commission (2012) for example, links it to renewable biological resources and their conversion to value-added products such as food, feed and bioenergy. The *OECD Bio-economy strategy* (OECD, 2009) includes a strong emphasis on biotechnology – which is shared by the South African strategy. Of interest is that the South African definition, reproduced below, includes a normative component that is absent elsewhere, focused on generating ***sustainable*** economic, social and environmental development:

> Bio-economy" refers to activities that make use of bio-innovations, based on biological sources, materials and processes to generate **sustainable** economic, social and environmental development. In the bio-economy the entire innovation system/network, ranging from ideas, research, development, productisation and manufacturing to commercialisation, should be used to its full potential in a coordinated manner.
> (DST 2013: 6 - our emphasis)

In addition to this normative aspect, it is also noteworthy that the bio-economy strategy explicitly refers to the fact that it has been "formulated to be more productive, more responsive and **more relevant to the needs of South Africans**; and to make a marked positive impact on the lives of all South Africa" (DST 2013: 3 - our emphasis).

This was affirmed by the then DST Minister Derek Hanekom, who, speaking at the launch of the strategy remarked: "We are confident that the strategy we are launching today will address the full value chain, going beyond the mere generation of new technologies to ensuring that **technology development is informed by the needs of the country and the people**, and that social and economic value is generated (our emphasis)". [51]

[51] http://mg.co.za/article/2014-01-14-science-department-launches-sas-bio-economy-strategy

8.3.2 Extracting ethical acceptability criteria from innovation policies

The three focus areas – health, agriculture and industry – have been contested by some civil society groups who have remarked on their similarity to OECD sectors and "the role of the rich man's club in promoting the neo-liberal, corporate driven green economy" (CSO statement, 2014).

A strong focus, for example, is placed on requiring high levels of research and technical skills in genomics, proteomics, synthetic biology and bioinformatics, but without giving due attention to the skill set required in the social sciences to deal with the social and environmental implications of technology roll-out.

Important questions are also raised with regard to distributive justice. It is not clear, for example, whether research will be led by commercial interests or those of the poor, with the strategy clearly displaying a balancing act between economic realities (and the behaviour of profit-seeking companies), and the needs of society. On paper, it seems as if the "needs of industry" are given prominent attention to guide science innovation – but less so the needs of communities, who may not have the necessary resources to pay for important new drugs, vaccines or agricultural innovations. At the same time, and reflecting this divide to some extent, the strategy emphasises the importance of commercial research on indigenous crops and livestock to develop traits appropriate to emerging and subsistence farmers.

One of the most controversial aspects of the strategy, and indeed its underpinning element, sees biotechnology as the central driver of innovations in the identified focus areas, yet largely brushes aside the deep resistance to genetic modification from various sectors in society stemming from concerns about safety, environmental risk, religious beliefs and corporate control of the food and health sectors (CSO statement, 2014). Although biosafety and "responsible genetic engineering" are flagged as important considerations in the strategy, this managerial approach has in the past proved to be insufficient to deal with the complex and much-contested issues raised by modern biotechnology.

> ***GM***
> *One of the most controversial aspects of the strategy, sees biotechnology as the central driver of innovations, yet largely brushes aside the deep resistance to genetic modification from various sectors in society.*

Distributive justice issues are also raised through the strategy's emphasis on using biodiversity and indigenous knowledge in commercial applications through bioprospecting. Again, little attention is given to the highly contested nature of these issues, with the language focused on "beneficiating" communities and indigenous knowledge holders, rather than on respecting the rights of communities and ensuring that research is carried out in an ethical way. In practice, a plethora of other policies and laws have been developed in South Africa to deal with these questions, but are seemingly not well represented in their translation in the *Bio-economy strategy* or its coordination which could be cause for concern.

8.3.3 Extracting sustainability criteria from innovation policies

Sustainability is put forward as a central driver and challenge of the strategy, and is articulated in different ways in each of the focus areas. In particular, strong statements with respect to resource guardianship are included. The chemical industry, for example, has historically been driven by the

exploitation of non-renewable fossil fuels, but the strategy signals a clear intent to reduce the environmental footprint of this sector by improving energy intensity, water usage, waste management and greenhouse gas emissions. Significant attention is also placed on creating a "greener economy" through use of renewable materials and improving water efficiency in the agricultural sector.

Risks to biodiversity are also acknowledged to some extent. The strong focus on biofuels, for example, in consort with South Africa's approach to promote biofuels, takes cognisance of potential risks to indigenous biodiversity and food security while some, albeit token, recognition is given to the environmental risks of GM crops. The use of biocontrol products is also promoted to reduce the use of chemical fertilisers and pesticides, with potentially important benefits for biodiversity and human health.

8.4 Conclusion

South Africa's challenges are closely linked to the history and policies of apartheid, which resulted in a racially segregated and highly unequal society. The policies that have been instituted by the government since the country's first democratic election in 1994 have been aimed at addressing these past injustices in order to create a more equal, cohesive, non-racist, and non-sexist society. The innovation system in the country has likewise mirrored these broader concerns, and recent policy developments have made a more express link between meeting the broader challenges of the country and the country's national system of innovation.

South Africa's *Ten-Year Plan for Science and Technology* (DST 2008) refers to five main areas where the country is focussing its innovation system to move from a resource-based economy to a knowledge-based economy. These are the bio-economy, global change, energy, human and social science and space science.

Of the specific strategy documents arising from the identification of these challenge areas, the *Bio-economy strategy* (DST 2013) provides the most recent and most relevant document for discussing how well South Africa's innovation policy maps onto meeting the Grand Challenges of the country. Given South Africa's mix of developed and developing economies, it is not surprising that the strategy represents a sometimes schizophrenic combination of intent between pursuing goals of industrialisation, profit and competitiveness, versus those of societal desirability, reducing inequality and addressing the needs of the poor. Thus the strategy aims to achieve competitive industrial, agricultural and health sectors, whilst simultaneously creating more sustainable jobs; enhancing food security; providing improved healthcare for all; building an inclusive and integrated rural economy; and transitioning to a low carbon, more environmentally sustainable future. Whether or not these ambitious goals can be successfully implemented remains to be seen.

United Kingdom

The United Kingdom (UK) is currently governed by a coalition between the Conservative Party and the Liberal Democrats. Prime Minister David Cameron, the leader of the Conservative Party, was appointed in May 2010. The next UK general election will be in 2015. The main political development in recent years was the September 2014 referendum for citizens residing in Scotland. The vote on devolution was narrowly lost by those in favour of independence and Scotland will thus remain a part of the UK.

Scotland will remain part of the UK after the September 2014 Referendum.

8.1 Country Specific Context

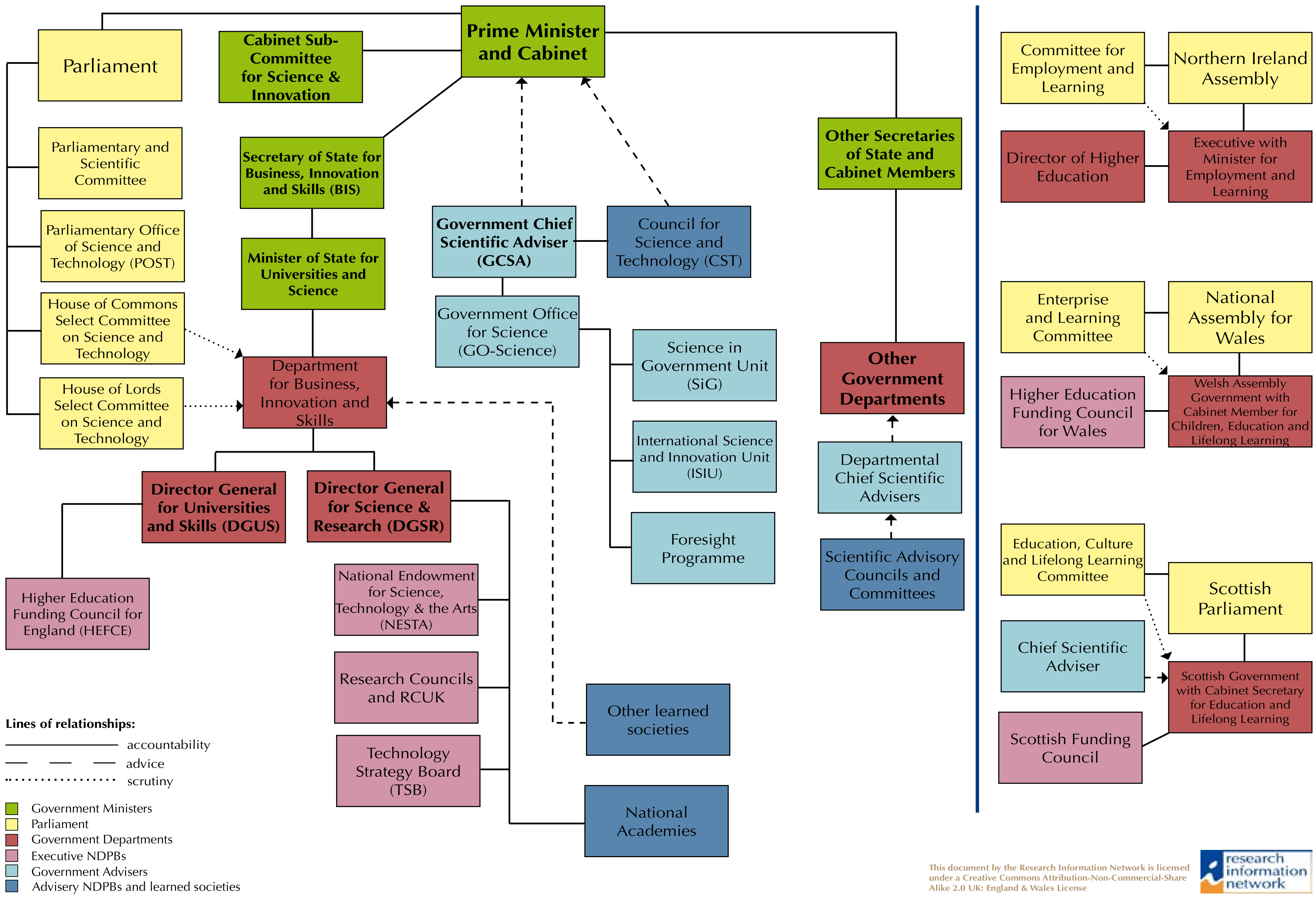
8.1.1 Economic and Political Situation

In the list of world economies, judged on gross domestic product (GDP), the UK is currently in place 6. Due to the importance of the financial sector in the UK, the country was hit especially hard by the financial crisis in 2008, which led to the country's worst recession since the end of the Second World War in 1945. As a result, the Government is introducing hefty cutbacks for almost all departments (emergency budget), however keeping the overall funding for science and research stable. GDP growth recovered to 1.7% in 2013.

8.1.2 Institutions Involved in Setting UK Innovation Policy

Science and innovation are at the heart of the UK government strategy for promoting prosperity and growth as well as addressing societal and environmental challenges. As a result the UK has a complex network of government, **non**-government and 'arm's-length' bodies responsible for the development, setting and implementation of innovation policy (see Figure 13 on next page).[52] While overall responsibility for research and innovation rests with the Department for Business, Innovation and Skills (BIS) there are a number of other Government departments that have a direct interest in research and innovation policy, and some of these also have their own significant research budgets including the Departments of Health (DoH); Environment, Transport, Food and Rural Affairs (Defra);; International Development (DFID); The Home Office, and the Ministry of Defence (MoD). Most Government departments also have a Chief Scientific Advisor who provides the Ministers with independent scientific advice. Many departments also have scientific advisory bodies. In addition, there is cross-cutting strategic policy input from the Government Office for Science (GOScience) which is headed by the Government Chief Scientific Adviser, who is the personal scientific adviser to the Prime Minister and provides advice to all government Departments. He or she also chairs the Committee of Scientific Advisers of all other Departments across Government. GOScience has an important role in ensuring 'joined-up' cross-Departmental policy and practice.

[52] *Government and research policy in the UK: an introduction, A guide for researchers* (2010) Pub: Research Information Network is licensed under a Creative Commons. Attribution-Non-Commercial-Share Alike 2.0 UK: England & Wales License http://www.rin.ac.uk/our-work/research-funding-policy-and-guidance/government-and-research-policy-uk-introduction


Parliament
Cabinet Sub-Committee for Science & Innovation
Prime Minister and Cabinet
Parliamentary and Scientific Committee
Secretary of State for Business, Innovation and Skills (BIS)
Other Secretaries of State and Cabinet Members
Parliamentary Office of Science and Technology (POST)
Minister of State for Universities and Science
Government Chief Scientific Adviser (GCSA)
Council for Science and Technology (CST)
House of Commons Select Committee on Science and Technology
Government Office for Science (GO-Science)
Department for Business, Innovation and Skills
Science in Government Unit (SiG)
Other Government Departments
House of Lords Select Committee on Science and Technology
International Science and Innovation Unit (ISIU)
Departmental Chief Scientific Advisers
Director General for Universities and Skills (DGUS)
Director General for Science & Research (DGSR)
Foresight Programme
Scientific Advisory Councils and Committees
National Endowment for Science, Technology & the Arts (NESTA)
Higher Education Funding Council for England (HEFCE)
Research Councils and RCUK
Other learned societies
Technology Strategy Board (TSB)
National Academies
Committee for Employment and Learning
Northern Ireland Assembly
Director of Higher Education
Executive with Minister for Employment and Learning
Enterprise and Learning Committee
National Assembly for Wales
Higher Education Funding Council for Wales
Welsh Assembly Government with Cabinet Member for Children, Education and Lifelong Learning
Education, Culture and Lifelong Learning Committee
Scottish Parliament
Chief Scientific Adviser
Scottish Government with Cabinet Secretary for Education and Lifelong Learning
Scottish Funding Council
Lines of relationships:
accountability
advice
scrutiny
Government Ministers
Parliament
Government Departments
Executive NDPBs
Government Advisers
Advisery NDPBs and learned societies

However, while governmental commitment to developing and setting innovation policy is apparent, there may also be potential for disconnection between policies originating in different departments and ministries, given the number of different institutions involved, and across different areas of application of innovation policy. In relation to this, there is some indication that attempts at policy harmonisation are being implemented. The Science and Innovation network "works across the UK science and innovation ecosystem", in relation to collaborations with other countries, while the International Science & Innovation Unit (ISIU) supports the Government Chief Scientific Adviser and GOScience in relation to international innovation policy. The Council for Science and Technology is a high level independent advisory body, also chaired by the Government Chief Scientific Adviser, which advises the Prime Minister, as well as Devolved First Ministers, on cross-Departmental strategies on science and innovation.

A large number of other bodies also have input into the development of UK Science and Innovation policy including the seven[53] UK Research Councils; the Higher Education Funding Council for England (HEFCE); the Technology Strategy Board (TSB); the National Endowment for Science, Technology and the Arts (NESTA); various academies and learned societies; the Parliamentary Office of Science and Technology (POST), and various Parliamentary bodies and science policy-related Parliamentary committees. There are also specific Science and Society initiatives to engage with society at large on issues of science and technology, often through initiatives of the UK Research Councils.

For example, the Biotechnology and Biological Sciences Research Council (BBSRC) hosts a dedicated Science in Society programme.[54]The Engineering and Physical Sciences Research Council (EPSRC) specifically promotes Responsible Innovation,[55] stating "Responsible Innovation is a process that seeks to promote creativity and opportunities for science and innovation that are socially desirable and undertaken in the public interest". However, whilst the commitment to responsible innovation is stated as a policy objective by the UK Research Councils, there is less evidence of this being achieved, for example through evidenced impact of public or stakeholder engagement on research strategies or research agenda setting (Emery et al, in press). In addition, the Knowledge Transfer Partnerships (KTPs) are specifically tasked with supporting "…UK businesses wanting to improve their competitiveness, productivity and performance by accessing the knowledge and expertise available within UK Universities and Colleges".[56]

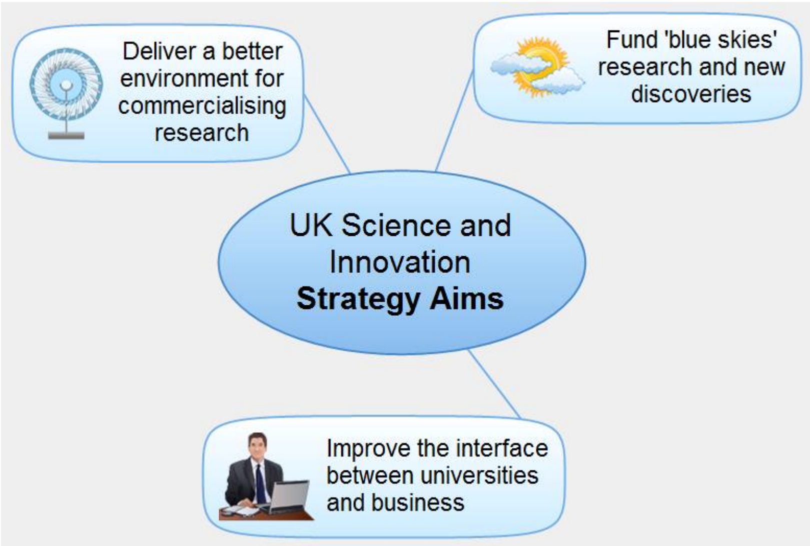
> ***Responsible Innovation***
> *Responsible Innovation is a process that seeks to promote creativity and opportunities for science and innovation that are socially desirable and undertaken in the public interest.*
> Engineering and Physical Sciences Research Council

[53] Arts and Humanities Research Council (AHRC); Biotechnology and Biological Sciences Research Council (BBSRC); Engineering and Physical Sciences Research Council (EPSRC); Economic and Social Research Council (ESRC); Medical Research Council (MRC); Natural Environment Research Council (NERC); Science and Technology Facilities Council (STFC).
[54] http://www.bbsrc.ac.uk/society/pe-strategy-and-funding.aspx, accessed 20th August 2014. See also http://www.rcuk.ac.uk/pe/ (accessed 20th August 2014) for an overview of UK research council initiatives.
[55] http://www.epsrc.ac.uk/research/framework/ accessed 27th August 2014.
[56] http://www.ktponline.org.uk/ accessed 27th August 2014

8.1.3 Strategy Overview

As described above, the UK has a complex network in which research policy and also strategy are developed. The driving force of innovation policy is the desire to achieve significant economic growth (which aligns with the European Horizon 2020 strategy) as this is seen as being the way for delivering on many of the Grand Challenges identified in the *Lund Declaration* (2009). There is also recognition that the government has a role in helping innovators, entrepreneurs and financiers to accelerate the commercialisation of emerging technologies. Therefore the UK science and innovation strategy has three key aims: funding 'blue skies' research as well as new discoveries and inventions; improving the interface between Higher Education Institutions and business; and delivering a better environment for commercialising research (NAO 2013 Report).

Fig. 14 UK Science and Innovation Strategy Aims:



Measures taken include both direct and indirect funding as well as other specific strategic actions. This has included an additional £1.5bn of funding for research infrastructure to strengthen innovation as well as ring fencing revenue funding for research. Much of the indirect funding of R&D by Government is in the form of tax incentives. For example, both SMEs and larger companies that are subject to UK corporation tax can reduce their tax bills by a proportion of their revenue spending on R&D. Some companies that have no tax bill can also claim tax credits up to 10% of their R&D spend (NAO 2013 Report).

Increased attention is also being paid to the impact of government funded research activities, for example in relation to research outputs of HEFCE funded universities.[57] In the 2014 Research Excellence Framework evaluation, impact will account for 20% of the evaluation and this may increase for the 2019 exercise.

8.1.4 Challenges and Outlook

In terms of challenges other than those noted in 8.2 below, it is worth mentioning the Government's review of university funding, given the importance of higher education to research and innovation. In November 2009, Lord Browne of Madingley, the former chief executive of BP,

[57] http://www.ref.ac.uk/ accessed 29 August 2014.

was charged to review the future direction of higher education funding in England. His team's recommendations were published in October 2010 and included removing the cap on university tuition fees (until then, the fees were capped at £3,290). Instead of removing the cap entirely, the government suggested to raise it to £9,000 pounds per year. The House of Commons voted on the proposal in December 2010 and the government gained very narrow support for the measure. The main criticism of the National Campaign Against Fees and Cuts (NCAFC)[58] was its impact on the already considerable rich and poor divide in the UK and working class students.

Protests over the tuition fee rise, UK 2010.

8.2 Grand Challenges

According to the *Lund Declaration* (2009), the "Grand Challenges" or "major societal challenges" of our time are:[59]

- **Tightening supplies of energy, water and food**: How to improve efficiency in consumption, as well as the recycling rate and waste reduction?
- **Pandemics:** How to improve the prevention and management of wide spread, contagious diseases to avoid considerable impact on the economy and social stability?
- **Ageing societies**: How to address the challenges of ageing societies, which include issues of economics, but also questions of social inclusion?
- **Global warming**: How to improve the prevention and management of natural disasters such as flooding, forest fires, hurricanes, and dry area extensions?
- **Public health**: How to provide medical care to everyone without discrimination?
- **Security**: How to improve the security of citizens within but also outside of Europe?

Addressing these challenges is at the heart of UK innovation policy and within the context of these Grand Challenges, the UK Government has identified a series of priority areas for innovation. These include: Agriculture and Food; Built environment (reducing carbon emissions); Digital Economy; Emerging and Enabling technologies; Energy; Health and Care; High Value Manufacturing Resource Efficiency; Space Applications; Transport; and Urban Living. [60]

8.3 Innovation Policies and Grand Challenges

Macnaghten and Stilgoe (2012) note that there are various drivers of responsible research and innovation policies. While responsible research and innovation (RRI) may be contextualised by societal rejection of novel technologies and their applications (e.g. see, *inter alia*, Coles and Frewer, 2014; Frewer et al, 2013 , Gaskell et al, 2003; Pidgeon et al, 2008), (UK and European) mitigation strategies associated with responsible innovation are frequently described as being characterised to increase 'democratic governance', institutional 'responsiveness' to societal

[59] Significant challenges identified by the Lund Declaration as pointed out by Chuberre N., Liolis K. (2010).
[60] Priority Areas, Innovate UK, Technology Strategy Board. https://www.innovateuk.org/our-priorities;jsessionid=D602FA6753C262A4708C21E1055A21E4.2 Accessed 28 August 2014.

requirements, and institutional acceptance of the unintended effects of increased democratisation of technological implementation strategies.

Democratisation emphasises an increased orientation towards delivering societally approved and desired impacts. Responsiveness emphasises the institutionalisation of, and policy responsiveness to, deliberation associated with research and innovation. In practice, institutional responsiveness to, and acceptance of, societal rejections of specific innovations have not been framed in policy. It is the latter which is least well documented in existing policy documentation. Exceptionally, in research funded by the UK research councils, Stilgoe, Owen, and Macnaghten (2013) provide a framework for understanding and supporting efforts aimed at "responsible innovation" associated with research, which was validated in the area of geo-engineering. The authors argue that such a framework has broader applicability to responsible research and innovation policy beyond that dealing with science funding.

> ***Democratisation***
> *Democratisation emphasises an increased orientation towards delivering* ***societally approved and desired impacts.***

At this point, it is worth considering UK policy responses to one of the Grand Challenges identified in the *Lund Declaration* (2009); Food Security. Policy is primarily focused around research and research funding rather than regulation and non-research based policies.[61] In fact, the food security issue is not treated primarily as one requiring a UK policy response, but one that is contextualised as a European or even a global issue. The UK Biotechnology and Biological Sciences Research Council (BBSRC) coordinates the UK food security research agenda (which incorporates various government departments as well as all of the UK research councils) in an effort to embed research programmes across academic disciplines, as well as government departments which fund research in this area directly. The involvement of the Department for International Development (DFID)[62] emphasises the global policy perspective taken by the UK government. BBSRC also represents UK interests in the Joint Programming Initiative[63] Agriculture, Food Security and Climate Change (FACCE). Public engagement and consultation appears to represent a key part of the policy strategy,[64] but formal evaluation of policy and research agenda setting impacts is not available.

8.3.1 Extracting societal desirability criteria from innovation policies.

Societal desirability criteria which are cited in UK policy documents tend to be at an abstract level, with few policy recommendations providing concrete and actionable guidelines regarding how to implement and measure activities against social desirability criteria. For example, while many policy websites commit to the *concept* of inclusive and responsible innovation practices, how this may be conducted in practice is less well described. However, the primary issue relating to the extraction of societal desirability criteria may be methodological.

The need for public and stakeholder engagement with innovation policy has been discussed widely (e.g. see Rowe and Frewer, 2005), although in practice implementation of outputs derived from

[61] see http://www.foodsecurity.ac.uk/resources/reports.html Accessed 26 August 2014.
[62] https://www.gov.uk/government/policies/reducing-hunger-and-malnutrition-in-developing-countries Accessed 22 August 2014.
[63] http://www.faccejpi.com/ Accessed 26 August 2014.
[64] http://www.foodsecurity.ac.uk/assets/pdfs/gfs-exploring-public-views.pdf Accessed 26 August 2014.

stakeholder engagement has been either problematic or ill defined (Emery et al, in press; Rowe et al, 2005). An alternative approach involves more explicit inclusion of societally desirable features in science and technology applications as part of the technology implementation and commercialisation process, which speaks directly to the responsible research and innovation agenda. For example, Frewer et al. (2014; accepted) have noted that the current levels of societal acceptability of a broad range of nanotechnology applications may reflect the identification by innovators and manufacturers of those factors which may result in societal acceptance and desirability of products and processes, and their consequent utilisation of these in technology processes and the development of specific products. For example the personal benefits of nanotechnology in advanced cosmetic products.

In part, this may reflect the process of co-development of nanotechnology research and development lines, the governance landscape surrounding nanotechnology and the application areas it will affect (Robinson, 2009). However, in the case of the commercialisation of synthetic biology, there may be additional technological features or characteristics of relevance to society which need to be addressed as part of the responsible innovation process. For example, even assuming that research indicates that the technology and/or its different applications are, in themselves, acceptable to society, further research is needed to determine what needs to be done to 'fine tune' the development and implementation of applications of synthetic biology to align with societal priorities for commercialisation of specific applications (e.g. see Douglas and Stemerding, 2014; Raley *et al.,* submitted). Further to this, there may be specific features of the regulatory framework which are required to ensure societal acceptance of specific applications, for example, formal and institutionalised ethical analysis and socioeconomic impact analysis (see, *inter alia*, Bubela et al., 2012). This will be discussed further in the next section.

8.3.2 Extracting ethical acceptability from innovation policies

The extent to which ethical analysis of innovation processes is formally included in UK policy is somewhat mixed. For example, tools are available to address the ethical concerns of stakeholders associated with innovation in the agrifood sector (Kaiser et al, 2007), but there is no place in policy for such instruments to be applied. Against this, ethical analysis is addressed, albeit through expert consultation, as part of the activities of for example, the Human Fertilisation and Embryology Authority (HFEA),[65] the Gene Therapy Advisory Committee,[66] and the Medicines and Healthcare Products Regulatory Agency (MHRA)[67] which is responsible for regulating all medicines and medical devices. It can be posited that there is a 'sliding scale' of responsible innovation in policy, such that medical innovation is associated with the greatest level of responsible innovation, policies which affect safety more generally reside at the next level, and those which focus on other innovations related to industrial competitiveness have the least formalised policy measures being implemented to promote responsible innovation. Taebi et al. (2014) have noted that an essential part of responsible innovation involves assessing the ethics of technology, in order to investigate the role of values in design. Fostering Corporate Social Responsibility (CSR) also involves adopting an "ethical" stance towards innovation policy (Asongu 2007), although in the UK ethical analysis this is not routinely enforced through policy measures. Exceptions to this have been noted above

[65] http://www.hfea.gov.uk/ accessed 27th August 2014.
[66] http://www.hra.nhs.uk/resources/applying-to-recs/gene-therapy-advisory-committee-gtac/ accessed 28 August 2014.
[67] http://www.mhra.gov.uk/Aboutus/index.htm accessed 28 August 2014.

as being primarily related to medical innovation (see for example, The University of Leeds, 2014[68]) e.g. in relation to clinical trials (Gaskell et al, 2012) or animal testing (UK Government,[69]). Gaskell et al (2013) note that, even in the medical area, there are public concerns about responsible innovation processes.

For example, UK (and European) public support for biobanks is variable and dependent on peoples' concerns about privacy and data security, and their trust in the socio-political system, as well as key actors and institutions involved in biobanks. Another area where Government commitment to ethical acceptability would be important, and one which may be unique to the UK, involves the proposed incorporation by the National Health Service (NHS) of all patient medical records into a single database in order to improve NHS service delivery, facilitate medical research and provide a massive data resource to qualifying commercial organisations.[70] In this particular instance the important ethical issue of a patient's autonomy in determining who should have access to their personal medical data and having the opportunity to provide appropriate informed consent appears to be being set aside, without the opportunity for effective public consultation and engagement, in favour of a presumed consent in order to maximise the amount of data collected.

8.3.3 Extracting sustainability criteria from innovation policies

Various bodies (e.g. The Food Ethics Council, 2014[71]), have noted that greater public engagement is necessary, but not sufficient, for making science and technology socially and ethically robust. For example, the current UK government's focus on 'wealth creation' as the primary objective of research and innovation policy may not support improved sustainability, and instead UK government policy should prioritise sustainable development. One route to improved sustainability associated with innovation has been linked to 'soft governance' policies. For example, the role of UK and indeed European government policies designed to foster Corporate Social Responsibility (CSR) with regard to sustainability has been noted by Garriga and Mele (2004), where the focus is on incentivising industry to promote sustainability, rather than policy designed to enforce sustainability activities. As for other areas of responsible innovation, the distinction between compulsion through regulation and incentivisation through 'soft' policy implementation, tends to distinguish safety from sustainability policies.

> ***Public engagement***
> *Greater public engagement is necessary, but not sufficient, for making science and technology socially and ethically robust.*

For example, consider the REACH[72] legislation on the safety of chemicals, where industry is required to demonstrate safe use, and which has been implemented in the UK by the Health and Safety Executive.[73] An exception however, is the application of the Sustainable Use of Pesticides Directive,[74] which emphasises the need for safe application of agricultural use of pesticides to

[68] http://www.medical-technologies.co.uk/support-for-innovation/responsible-innovation/ Accessed 27th August 2014.
[69] https://www.gov.uk/government/policies/ensuring-research-and-testing-using-animals-is-safe-and-reasonable, accessed 20th August 2014).
[70] http://www.england.nhs.uk/ourwork/tsd/care-data/ accessed 27 August 2014.
[71] http://www.foodethicscouncil.org/ accessed 27th August 2014.
[72] http://ec.europa.eu/enterprise/sectors/chemicals/reach/index_en.htm, accessed 20th August 2014.
[73] http://www.hse.gov.uk/reach/compauth.htm accessed 20th August 2014.
[74] http://ec.europa.eu/food/plant/pesticides/sustainable_use_pesticides/index_en.htm, accessed 20th August 2014.

ensure sustainability. This has been translated into UK national policy through adoption of a national action plan, which applies a number of provisions aimed at achieving the sustainable use of pesticides by reducing risks and impacts on human health and the environment, including, for example, compulsory testing of application equipment; provision of training for, and arrangements for the certification of, operators, advisors and distributors; a ban (subject to limited exceptions) on aerial spraying; provisions to protect water, public spaces and conservation areas; the minimisation of risks from handling, storage and disposal; and the promotion of low input practices[75] through the implementation of Integrated Pest Management Plans (IPMP) in which the holistic use of available plant protection methods and keeping the use of pesticide and other interventions to levels that are economically and ecologically justified minimizes risks to human health and the environment.[76] There are also requirements for safety training for end-users, in particular operators, workers, residents and bystanders, although there is less clarity in the UK policy as to how this might be implemented (Remoundou et al, submitted).

8.4 Conclusion

The UK demonstrates a complex policy development network for science innovation in which many of the bodies and actors have clear policy statements on responsible innovation. Responsible innovation is described by RCUK (2014) as "the process that helps researchers understand the benefits and risks of emerging technologies early on in the innovation process. It includes public engagement, risk management, life cycle analysis, ethical approval and regulation". The RCUK engagement agenda refers in particular to the inclusion of societal and ethical desirability criteria in innovation policies, although other policy issues, (including , for example, those relating to sustainable consumption) are not excluded, and it is assumed, will also benefit from public and stakeholder engagement (see, *inter alia*, Reed 2008; Renn 2006). Whilst such purported inclusivity appears to speak directly to the implementation of a responsible innovation agenda, some caution is warranted regarding the analysis of societal engagement (whether that engagement involves participation of experts or the public) and science policy impact.

There is widespread recognition in the literature of a lack of credible evidence to measure and demonstrate the policy impacts of engagement in science and technology (innovation and other) policies (Abels 2007; Emery, Mulder and Frewer, in press; Fischer, Wentholt Rowe and Frewer, 2013; Kurath and Gisler 2009; Pidgeon and Rogers-Hayden 2007; Powell and Colin 2009; PytlikZillig and Tomkins 2011; Rowe and Frewer 2000; Wathen et al. 2011; Wilsdon et al. 2005). At the same time, there is increased societal demand for transparency and inclusivity in decision–making processes regarding policy development. Emery et al (in press) note that "without substantiated evidence of policy impact, it is unclear whether the deficiency represents the failings of Engagement to actualize policy impacts, or whether it simply indicates that the means for discerning policy impact are poorly developed". In particular, there is limited understanding both of the extent to which engagement is taken into the policy process, and the potential contradictions between them in their alternative quests for legitimacy. Both engagement practitioners and policy-makers must demonstrate policy impacts in order to evaluate engagement processes, and allow monitoring and continuous improvement of engagement practices and their policy connections.

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[75] http://www.pesticides.gov.uk/guidance/industries/pesticides/News/Collected-Updates/Regulatory-Updates-2012/July/Sustainable-Use-PPP-Regulations-2012, accessed 20th August 2014.

[76] http://www.nfuonline.com/ipm-plan/ accessed 20th August 2014.

9. United States

The United States (US) federal government is currently presided over by Barack Obama who is serving his second term as President. He was inaugurated in this role in January 2009 and re-elected in November 2012. The first Black President of the US and a lawyer by training, he is known abroad mostly for his efforts to reform the health care system, his attempts to end military US involvement in Iraq and Afghanistan and his receipt of the Nobel Peace Prize only nine months after taking office.

9.1 Country Specific Context

9.1.1 Economic and Political Situation

Like many economies around the world, the US struggled after the economic downturn of 2008. The federal government responded with the 2009 *Recovery Act,* including large expansions in funding for fundamental research. Innovation policy passed in the years following has sought to build on this expansion by focusing efforts on the private sector and seeking to facilitate private sector investment and innovation.

As of June 2014, unemployment stands at approximately 6.1% and has been slowly decreasing since its high of 9.9% in 2009. Gross government debt has reached around 103.4% of GDP (first quarter, 2014) (FRED, 2014). The President's Financial Year 2015 budget request released in March 2014, proposes US$135.4 billion for federal research and development funding activities, an increase of US$1.7 billion over Financial Year 2014 actual levels (U.S Office of Science Policy, 2014). One major push in this budget is the Opportunity, Growth, and Security Initiative that puts over US$5 billion into programs that promote applied research in clean energy, advanced manufacturing, health, and agriculture. This initiative includes a national competition to establish 45 federally-funded manufacturing institutes that will help firms work with experts in academia to bring innovative technology to market, as well as increased funding of federal research grants for the National Institutes of Health (NIH) and the National Science Foundation (NSF).

9.1.2 Institutions Involved in setting US innovation policy

The following are the main US institutions involved in setting innovation policy:

- **The Office of Science and Technology Policy** advises the President about the effects of science and technology on domestic affairs.
- **The Office of Budget and Management** assists the President to meet his policy, budget, management and regulatory objectives and to fulfil its statutory responsibilities.
- **The National Science and Technology Council** is the principal body of the executive branch, which coordinates science and technology policy across the many entities that make up the federal research and development enterprise.
- **The National Academies** produce independent recommendations and policy reports by enlisting top scientists and engineers to address the scientific and technical aspects of society's challenges.
- **The Council of Economic Advisors** offers the President expert economic advice on the formation of domestic and international economic policy.

- **Congressional Committees** such as the House Committee on Science, Space and Technology, the House Committee on Natural Resources, and the Senate Committee on Commerce, Science, and Transportation. These committees monitor government operations around their area of specialization, identify issues where legislative review is needed, gather and evaluate relevant information, and recommend courses of action to their parent body.

9.1.3 Strategy Overview

Unlike many industrial nations, the United States does not have a comprehensive national innovation strategy. Instead, the US tends to address specific needs and goals through targeted, short-term legislation or programs that shift from one Administration to the next. Due to the recession of 2008, recent Administrations have paid more attention to innovation and competitiveness issues than previous ones as one way to help economic recovery. The US spends more money on research and development than any other country in the world, US$415 billion in 2010, as compared to US$149 in China, US$148 billion in Japan, and US$89 billion in Germany in that same year.[77]

Unlike many industrial nations, the US does not have a comprehensive national innovation strategy. Instead, the US tends to address specific needs and goals through targeted, short-term legislation or programs that shift from one Administration to the next.

The US federal government also subsidizes research and development through a tax credit called the Research and Experimentation Tax Credit, which allows private sector companies to subtract a portion of their eligible R&D spending from their federal taxes (Kennedy, 2012). In 2007 and 2008, businesses claimed about US$8.3 billion in tax credits, with the majority of claims coming from five industries: computer and electronic products; chemicals, including pharmaceuticals and medicines; transportation equipment, including motor vehicles and aerospace; information, including software; and professional, scientific, and technical services, including computer and R&D services (NSF, 2012).

Contemporary innovation policy in the United States emphasizes both economic and social development as explicit goals for public research providers. As Hellström states when looking at this trend world-wide,

> The aforementioned shift in focus from social to economic development may be read as a response to geopolitical developments such as the oil crises, the emergence of newly industrialized countries, and industrial competition from Japan. These considerations triggered a science policy emphasis on economic (commercial) competition through industrial innovation, typically deriving from a national capacity to innovate around core (platform) technologies and integrate technological forecasting into science policy. (Hellström , 2012)

In February 2011, the Obama Administration, in conjunction with the National Economic Council, the Council of Economic Advisors, and the Office of Science and Technology Policy released *A*

[77] Total global R&D spending reached US$1,252 billion in 2010 (Battelle, 2010).

Strategy for American Innovation: Securing Our Economic Growth and Prosperity.[78] The strategy updates the version released in September 2009, and includes the following key elements:

- **Startup America Initiative**: help to accelerate high-growth entrepreneurship by investing US$3 billion in initiatives for innovation, impact investing, and early-state seed financing.
- **Invest in the Building Blocks of American Innovation**: Invest in STEM education from kindergarten to secondary education levels, double funding for the National Science Foundation, the Department of Energy's Office of Science, and the National Institute of Standards and Technology laboratories, and invest in infrastructure including an advanced information technology infrastructure.
- **Promote Market-Based Innovation**: through tax credits, innovation hubs, patent reform, investing in nationwide high-speed wireless infrastructure.
- **Catalyze breakthroughs for National Priorities**: Provide support for areas where market failures impede progress, such as enhancing alternative energies, reducing health care cost and improving its quality, catalyzing advances in educational technologies, and helping to continue the United States' lead in the areas of bio- and nanotechnology (National Economic Council, 2011).

Along with the 2011 strategy, one other law exemplifies current US innovation policy; The *America Creating Opportunities to Meaningfully Promote Excellence in Technology, Education, and Science* (*America COMPETES*[79],[80], P.L. 110-69). *America COMPETES* was first passed in 2007 and then reauthorized in 2010. It aims to "invest in innovation through research and development and to improve competitiveness of the United States." Both versions of the law provided increased funding for basic research in the sciences, technology, engineering, and mathematics, as well as in education.

Both the 2007 and the 2010 Acts also supported teacher training and professional development for existing STEM teachers, STEM undergraduate programs focused on encouraging or improving STEM education, and graduate programs focused on supporting and training new STEM educators. Despite funding shortages, a study of these programs found that they generally produced positive outcomes and met their stated goals, though teacher retention in public elementary and high schools continues to be a problem (GAO, 2013).

Prizes to spur innovation
Prizes allow federal agencies to pay only for success, and freed them from having to predict which team will succeed.

One other notable feature of *America COMPETES* was its authorization of federal agencies involved in research to conduct prize competitions to spur innovation. The reasoning behind this was that prizes allow federal agencies to pay only for success, and freed them from having to predict which team will succeed. The competitions also allowed agencies to recruit individuals beyond the normal pool of grant applicants and to maximize the return on tax-payer dollars (OSTP, 2013). The National Aeronautics and Space Administration (NASA), Department of

[78] A Strategy for American Innovation: Security Our Economic Growth and Prosperity, 2011 http://www.whitehouse.gov/innovation/strategy.

[79] *America COMPETES Act*, *2007* (H.R. 2272) 110th Congress https://www.govtrack.us/congress/bills/110/hr2272.

[80] *America COMPETES Reauthorization Act*, *2010*, (H.R. 5116) 111th Congress https://www.govtrack.us/congress/bills/111/hr5116.

Defense (DoD), and Department of Energy (DoE) were early adopters of this initiative. In Financial Year 2012 seven agencies sponsored 27 prize competitions. An example of this is DoE's Sunshot: a "Race to the Rooftops" challenge competition, which offered a total of US$10 million in prizes to the first three teams to deploy at least 6,000 rooftop solar power systems with non-hardware costs averaging US$1 per watt.

There is also a growing emphasis on coordination among federal agencies to work with state and local governments to support specific regional innovation clusters aimed at meeting national needs. The Regional Innovation Program at the Department of Commerce provides grants for regional business, government, and university leaders to collaborate on using a region's existing assets to enhance long-term economic growth in the area. In a similar way, the Department of Energy (DoE), in collaboration with a number of other federal agencies, is working to establish "energy-innovation hubs" which are regional innovation clusters in solar power, energy-efficient buildings, nuclear energy and advanced batteries. These Innovation Clusters provide planning and technical assistance to researchers in the areas of demonstration, deployment, technology transfer, and marketing activities, as well as developing relationships between different sectors and clusters in other regions of the United States.

America COMPETES, which is up for renewal, is currently the subject of hot debate as Democrats and Republicans (the two main US parties) seek to shape the future of US innovation policy. There is a major push to double the amount of funding for basic and applied research by 2023 as well as reauthorizing the Regional Innovation Program and the Energy Innovation Hubs and continuing support for the *US National Nanotechnology Initiative* (see case study box). The Democrats' bill also includes the implementation of a *Federal Strategic Plan for STEM Education* and increased funding for educational programs for undergraduates and graduates in these fields. The Republican version of the bill provides increases of educational funding at a much slower rate, only doubling it by 2075 (Hourihan, 2014).

Case Study - *US National Nanotechnology Initiative*

Begun in 2001, the *United States' National Nanotechnology Initiative* (NNI) has been a key program in the country's innovation policy. This multi-agency, multi-disciplinary initiative is a collection of research programs and other activities which are all linked by the vision of "a future in which the ability to understand and control matter at the nanoscale leads to a revolution in technology and industry that benefits society" (NNI, 2013). From the beginning, one of the major goals of the National Nanotechnology Initiative has been to support the responsible development of nanotechnology. The NNI strategic plan states that "the NNI aims to responsibly develop nanotechnology by maximizing the benefits of nanotechnology, while, at the same time, developing an understanding of potential risks and the means to assess and manage them," (NNI, 2014b). Total funding for the program has exceeded $21 billion, and investments in nanotechnology-related environmental, health, and safety research since 2005 now totals nearly $900 million (NNI, 2014a).

Birck Nanotechnology Center

One example of such an investment is the Birck Nanotechnology Center at Purdue University's Discovery Park. Supported by private, industrial, and federal funds, the Center focuses on nanoscale science and engineering with application in areas such as health care, energy, communication, computer technology, and food safety. The Center is also highly multidisciplinary in its reach, involving more than 300 faculty, staff, and students from 36 of Purdue's schools and departments annually.

Researchers at the Birck Nanotechnology Center work closely with other, multidisciplinary groups located at the Discovery Park, such as with scientists from the Bindley Bioscience Center, to pioneer cancer treatments using micro-sensors implanted in tumours, allowing doctors to monitor radiation and to develop low-cost diagnostic tools to detect the AIDS virus (Wessner, 2012). Other research at the Center focuses on developing a new kind of biosensor that can detect glucose in saliva and tears for diabetes testing, while also being manufactured at a low cost. In 2012, Dr Jean Paul Allain, an associate professor of nuclear engineering addressed the US Congress about a collaboration between the US Army, researchers at the Birck Center, and a team of neurosurgeons worldwide working on creating a new type of "bioactive" coating for stents used to treat brain aneurisms, including aneurisms caused by head trauma from bomb blasts. The nano-coating on these stents attract cells to the inside lining of blood vessels, thereby helping to repair damage.

One final policy that, while passed in 1980, still has a huge impact on innovation in the United States is the *Bayh Dole Act* (Pub. L. 96-517). It allows universities, businesses, and non-profit institutions the ability to pursue ownership of an invention coming from federally funded research and to license these inventions exclusively. Prior to this Act, the US government retained ownership of the intellectual property resulting from federally funded research, and would only grant non-exclusive licenses to companies wishing to commercialize it. Without the title to the inventions, businesses were usually reluctant to invest the substantial time and money necessary to commercialize a product or process. By 1978, the US government had acquired 28,000 patents from the research it funded, but had only licensed fewer than 4% of them (Loise, 2010). After passage of the Act, there was a large increase in university-industry partnerships, with universities doing the fundamental research and being able to license its intellectual property to industry, which could undertake the applied research needed to bring any products to market. In 2012 alone, there were 5,130 patent licenses executed and 705 startup companies begun to capitalize on patented inventions (AUTM, 2012).

9.1.4 Challenges and Outlook

The *American Recovery and Reinvestment Act* of 2009, which provided US$787 billion for economic stimulation, also included US$59 billion in new spending and tax credits for the development and expansion of new technologies. This bill was, however, a one-time, non-recurring event that has now ended. This lack of continuity in funding separates the US from many of its global competitors. For some technologies, like wind energy, unstable funding of the production tax credit has resulted in huge drops in investment, which have damaged the development of a robust US wind industry (IER, 2012).

This lack of continuity has also hampered the impact of the Research and Experimentation Tax Credit mentioned earlier. This program was begun in 1981 as a temporary tax break under President Ronald Reagan as an incentive for businesses to pursue discoveries and innovations that could benefit society at large and help the US regain a competitive edge in the world economy. However, Congress has let this program expire six times over its long history, most recently in December of 2013. There is little doubt that Congress will renew this bill eventually, but the continuous lapses of this bill make businesses hesitant to make large investments which they may not be able to recover. Many supporters of the bill want to make the program permanent, streamline the paperwork needed to claim the credit, and broaden the definition of covered research to allow more businesses to take advantage of this tax break. Critics, however, state that the tax credit often rewards companies for doing research they would have undertaken regardless, and call for a narrower definition of covered research to include only research that has possible social benefits (Malakoff, 2014).

Underfunded public universities, high public deficits, and public debts are exerting pressure on federal and state lawmakers to cut spending on innovation. Federal and local governments are having to choose between funding universities, funding applied-research programs, helping small businesses, and providing for other public needs (Wessner, 2012). In the past, US science and technology policy was based on the assumption that funding in basic research will be translated by the private sector into commercial products and new industries. In reality, government financial support has been necessary throughout this translational period. That was certainly the case with nuclear power, computers, and aerospace.

> ***Translational research***
> *In the past, US science and technology policy was based on the assumption that funding in basic research will be translated by the private sector into commercial products and new industries. In reality, government financial support has been necessary throughout.*

The reauthorization of *American COMPETES* in 2010 also called for funds allocated for the physical sciences and engineering to be doubled in seven years. At the funding rate, this will happen in 58 years. It is also becoming necessary to look at reforming tax, trade, intellectual property, immigration, education, and training policies and programs, all of which play a role in innovation. This is happening in some areas already. For instance, improving the US educational system in the areas of math, science and engineering has been an ongoing theme in innovation policy since 2007, though actual funding for STEM education has fallen far short of expressed goals (Sargent, 2014).

The US is also losing competitiveness as a location for new investment in advanced manufacturing, even in industries where the US is a technological leader (Wessner, 2012). Current immigration

policies make it difficult for skilled scientists and engineers to come to the US to work. In addition, many US companies with important technologies cannot make the high-risk, long-term investments required to support job-creating advanced manufacturing at home, due to a lack of government support. Whilst other countries devote substantial policy attention to developing the infrastructure and supply chains needed to support manufacturing, and make it easier for skilled immigrants to join their workforce, US companies continue to send their manufacturing jobs overseas.

The *Bayh-Dole Act* has also had some negative impacts on innovation in the United States. Though it has led to closer cooperation between industry, government and academia in research leading to marketable products, these collaborative partnerships have also provided increased opportunity for conflict of interest, redirection of research, and less openness in sharing scientific discovery as researchers are driven to pursue a patent from their work (Schacht, 2012). Some also argue that the legislation should be altered to allow for the noncommercial use of technologies developed with public funds, as in some cases patents have limited the access of researchers to broad enabling technologies, like gene transfer methods, that are essential for producing a wide range of new products and inventions (Boettiger, 2006).

9.2 Grand Challenges

One could venture that US policy seems to equate a stronger economy with societal desirability and the common good. While many of its policies pursue socially desirable goals such as improving health care and promoting clean energy use, it is job growth, international competitiveness, and national prosperity that are the explicitly stated goals. In the US, the political reality is that words such as ‘social’ can be politically polarizing, so it is more expedient for politicians to frame innovation policy as a way to improve the economy. President Obama’s *Strategy for American Innovation* states, “Innovation-based economic growth will bring greater income, higher quality jobs, and improve health and quality of life to all US citizens.” In these policies, a stronger economy is expected to lead to socially desirable outcomes naturally, but the actual social benefits of these policies or how these benefits will be equitably distributed, is rarely directly addressed.

Currently, US policy is focused on investing heavily in infrastructure, education, and offering economic and tax break incentives to private organizations, rather than spending government funds directly to meet specific goals as is done in Horizon 2020. Instead of overarching societal goals, the present policy charges each federal agency to “…identify and pursue clearly defined ’Grand Challenges’ – ambitious goals that require advances in science, technology and innovation to achieve, and to support high-risk, high-return research,” (Office of Management, 2013). This call to identify area-specific Grand Challenges also involves companies, research universities, foundations, and philanthropists to help identify and pursue these goals. While many of the Grand Challenges identified by US agencies seek to benefit the whole of society, many others will benefit only a small portion of the population. For example, the Department of Energy (DoE) has a series of five Grand Challenges, including:

1. controlling materials and processes at the level of electrons,
2. mastering energy and information on the nanoscale to create new technologies with capabilities rivalling those of living things, and
3. characterizing and controlling matter away from equilibrium.

While many of these advances would have immediate practical applications for clean energy and sustainability, others would take years if not decades to have any societally desirable effect at all. Drawing from the Grand Challenges posted by the agencies and identified in President Obama's 2011 *Innovation Policy* and the 2007 and 2011 *America COMPETES* Acts, the following goals seem to line up with the *Lund Declaration* Grand Challenges (2009).

Lund Declaration Grand Challenges	**US Grand Challenges**
Tightening supplies of energy, water and food: How to improve efficiency in consumption, as well as the recycling rate and waste reduction?	Unleash a clean energy revolution, develop new sources for energy that are clean, reliable, and affordable, and improve management of water resources
Pandemics: How to improve the prevention and management of widespread, contagious diseases to avoid considerable impact on the economy and social stability?	No matching goal
Ageing societies: How to address the challenges of ageing societies, which include issues of economics, but also questions of social inclusion?	Focus via the Defense Advanced Research Agency of the DoD, NIH, and NSF BRAIN Initiative which works to revolutionize understanding of the human brain to find cures for disorders like Alzheimer's
Global warming: How to improve the prevention and management of natural disasters such as flooding, forest fires, hurricanes, and dry area extensions?	Develop better space capabilities to warn of national disasters
Public health: How to provide medical care to everyone without discrimination?	Drive breakthroughs in health care technology, utilize biotechnology, nanotechnology and advanced manufacturing to improve health care quality and delivery.
Security: How to improve the security of citizens within but also outside of Europe?	Develop space technologies that help contribute to national security, improve cybersecurity to protect information of US citizens and businesses from cyberattacks.
No matching goal	Improve public education in STEM fields, increase public literacy on science and technology, create a quantum leap in educational technologies as a way to help implement new education strategies and systems

9.3 Innovation Policies and Grand Challenges

9.3.1 Extracting society desirability criteria from innovation policies

As shown above, US innovation policy roughly mirrors many of the Grand Challenges set forth by the *Lund Declaration* (2009), especially in the areas of improving energy efficiency and use of national resources, lowering the cost of health care while improving care, and improving public security through the development of new and improved technologies. However, these goals tend

to focus on smaller pieces of overall problems identified by the *Lund Declaration*. Below is a summary of parts of the US innovation policy that, in effect, focus on societal desirability.

The President's 2011 *Innovation Strategy* highlights the need to fund new and improved energy technologies that will help unleash a clean energy revolution. The strategy includes increased investments by the Department of Energy's Office of Science, and the development of three new Energy Innovation Hubs. An Energy Innovation Hub is a large, multi-disciplinary team of scientists and engineers who work to achieve a specific priority goal. Currently, three hubs exist focusing on developing more energy efficient buildings, developing liquid fuels from sunlight, and modelling nuclear reactors.[81]

Food security is also an issue that the *Innovation Strategy* addresses. The *Feed the Future Initiative*, which President Obama began in 2010, seeks to advance global agricultural development, increase food production and food security, and help improve nutrition for vulnerable populations such as women and children living in poverty. The program promotes the exploration of biotechnology, training food producers worldwide in new agricultural practices and food safety, and open data initiatives to improve nutrition and agriculture practice by making research data in these areas open for use by all stakeholders (Feed the Future, 2014). Led by the US Agency for International Development, the research section of the program builds partnerships with universities in the US and other countries, international agricultural research centers, non-governmental organizations, and private industry.

For public health, the innovation strategy focuses on biotechnology and nanotechnology as a way to find new breakthroughs in health care and improve health care for all. The strategy calls for major investments in projects to complete DNA sequencing for major diseases. An example of this is the Cancer Genome Atlas, a project begun in 2005, which is the most comprehensive analysis of the molecular basis of cancer ever undertaken. This project may unleash new possibilities for cancer treatment, diagnosis, and personalized care. The *National Nanotechnology Initiative* is also working on many potential health applications including smart-anti-cancer therapeutics that target tumours without the devastating side effects of chemotherapy. The strategy also calls for the development and adoption of Health Information Technology as a way to accelerate the adoption of Electronic Health Records for exchange of health information over the Internet and to break down information barriers between health service providers.

The US has also adopted a relatively novel, market-driven scheme to encourage the development of new drugs and vaccines for neglected diseases such as malaria, which is called Priority Review Vouchers. Under this scheme, the Food and Drug Administration (FDA) awards a transferable priority

Innovation Incentives
The US has also adopted a relatively novel, market-driven scheme to encourage the development of new drugs and vaccines for neglected diseases such as malaria, which is called Priority Review Vouchers.

[81] As it is extremely difficult to observe what happens in an operating nuclear reactor safely, this modeling technology called the Virtual Reactor, runs on a supercomputer and allows scientists and engineers to stand in the center of a virtual reactor, observing coolant flow, nuclear fuel performance, and even the reactor's response to changes in operating conditions. This model therefore allows researchers to help make reactors safer, more efficient, and overcome small scale problems (U.S. Energy Department, 2010). Full footnote: United States Department of Energy, 2010. Modeling and Simulation for Nuclear Reactors Hub. [Online] Available at: http://energy.gov/articles/modeling-and-simulation-nuclear-reactors-hub.[Accessed 13 October 2014].

review voucher to any drug developer who obtains marketing approval for a new drug that targets a neglected tropical or rare paediatric disease. The developer can either use this voucher to get expedited approval for a product of its choice, or sell the voucher to another developer. This voucher entitles the holder to a FDA priority review of a drug of its portfolio that would otherwise receive a standard review-and therefore a later commercialization date. (Sanchez, 168). A study from 2009 of the voucher system found that using these vouchers sped up the process by around seven months. These vouchers can therefore be worth hundreds of millions of dollars for companies, especially when used to speed up approvals for pharmaceutical products which are expected to be big sellers (Grabowski, 3), as an additional seven months in the patent protected period is likely to ensure considerable additional income.

9.3.2 Extracting ethical acceptability from innovation policies

In terms of ethical acceptability, US policies focus on 'diversity' (involvement of women and underrepresented minorities), open access to data emanating from government-funded research, and ensuring that student researchers receive training in the responsible conduct of research.

Section 1009 of the *America COMPETES* Act of 2007 required that the Office of Science and Technology enact policies to ensure the open exchange of data and research results with other agencies, policy-makers, and the public. The policies cover any research done by a scientist employed by or receiving funding from a federal civilian agency. Section 527 of the 2010 Act also outlines a National Science Foundation program for Twenty-First Century Graduate Education that includes a stipulation that grant money awarded to institutions developing new graduate programs must include seminars, workshops and other professional development activities focused on increasing the ability of graduate students to communicate their research findings effectively to both technical and nontechnical audiences. These provisions together show a growing concern that information from government-funded research be shared both within and outside of the research community, and that the next generation of scientists have a greater understanding of how to discuss their research with a wider audience.

Both of these innovation policies emphasize the need for individuals from a variety of backgrounds to become involved in research and innovation. For example, the 2007 *America COMPETES* Act requires that agencies setting up educational programs have a program to recruit and provide mentors for women and underrepresented minorities who are interested in careers in science, engineering, and mathematics (Sec. 3195). It also requires the National Academy of Sciences to publish a report no later than one year after enactment of the Act to report on barriers to increasing the number of underrepresented minorities in science, technology, engineering, and mathematics and to identify strategies for bringing more underrepresented groups into these areas of the workforce (Sec. 7032).

The *American COMPETES Reauthorization Act* of 2010 stipulates that in all of the educational programs it supports, one of the main goals is to promote the participation of underrepresented minorities in research areas supported by these programs. For the National Science Foundation's Research Experience for Undergraduate's Program, the Act further stipulates that "at least half of the students participating in a program funded by a grant under this subsection at each site shall be recruited from institutions of higher learning where research opportunities in STEM are limited, including 2-year institutions (Sec. 514(1)).

The 2011 *Innovation Policy* also seeks diversity, stating in its section on strengthening America's workforce that "it is imperative to extend STEM educational and career opportunities to women and minority groups that are underrepresented in these areas, so that all Americans can find quality jobs and lead our innovative economy in the decades ahead."

The responsible training of new researchers is also a concern. In the *America COMPETES* Act of 2007, the National Science Foundation was required to ensure that all grants it awards include training of funded students or postdoctorates in the responsible conduct of research (Section 7009). This requirement augmented an earlier requirement that institutions receiving a National Science Foundation (NSF) award develop robust programs for teaching students about research ethics. The Act also supported NSF's development of a number of workshops and web resources designed to help principal investigators integrate research ethics education into their grant-funded projects.[82]

9.3.3 Extracting sustainability criteria from innovation policies

In President Obama's 2011 *Innovation Strategy*, there is little focus on issues of sustainability. Yet, developing "affordable, appropriate and sustainable technologies" and "sustainable food production" are part of the *Feed the Future* program (which focuses on improving food production both in the US and abroad). The 2010 *National Nanotechnology Initiative* also focuses on developing sustainable nanomanufacturing, which includes attention to the environmental impact of the manufacturing process and the final product throughout its life-cycle, as well as on potential health and safety impacts on workers and users of these products (NSTC, 2011). Finally, the 2011 strategy includes, "unleash[ing] a clean energy revolution" as one of its national priorities, which involves both fostering research in clean energy and confronting environmental challenges of producing and using energy.

The 2007 *America COMPETES* Act covers issues of sustainability in more detail, especially in the area of sustainable energy. Chapter 7 of the Act deals with the National Energy Education Development Program that focuses on improving energy education at all levels. It includes the goal of educating students about the science, economics, and environmental impacts of energy production and consumption. Grants given under this program must serve this goal in any educational curricula designed under it. The Act also supports the development of Discovery Science and Engineering Innovation Institutes that support education and research activities relating to sustainable energy technologies (Sec. 2007).

In the *America COMPETES Act Reauthorization* of 2010, the National Institute of Standards and Technology is charged with beginning a green manufacturing and construction program to help develop accurate sustainability metrics and practices for use in manufacturing, and to advance the development of high performance green building standards. These standards would focus on improving energy performance, service, life, and indoor air quality of both new and retrofitted buildings. The program also aims to create an information infrastructure to communicate sustainability information about suppliers to the manufacturing and construction sectors (Sec. 408).

[82] For example, see http://ethics.iit.edu/eelibrary/

In this same Act, the National Science Foundation is required to establish a "Green Chemistry Basic Research" program to award grants supporting research in green and sustainable chemistry that should lead to clean, safe, and economical alternatives to traditional chemical products and practices. The grants will also support conferences and symposia to increase outreach, dissemination, and collaboration on green chemistry advances and practices as well as improving the education and training for students and professional chemists on these newly developed practices (Sec. 510).

9.4 Conclusion

The US is strong on diversity, collaboration, and using the funding of basic research to fuel innovation in the private sector. It is weak on identifying Grand Challenges with Europe's clarity, of organizing its policies to overcome those challenges, and in following through with funding. To sum up, "the absence of a non-partisan consensus on the role of the federal government in promoting innovation and fostering the creation, accessibility, and use of new technology deprives public technology policy of continuity, increases the temptation for political manipulation of public investments, and fails to deliver the value Americans should expect from a $75 billion annual investment in government-funded research and development" (Brascomb, 1998).

Photo: BSK

The US is strong on diversity, collaboration, and using the funding of basic research to fuel innovation in the private sector.

Hence, the US is not currently suitable as a model for a Responsible Research and Innovation strategy but many of the individual programs may be worth looking at, especially the following:

1. innovation clusters that foster collaboration and provide facilities and tools to stimulate research,
2. education programs that help train the next generation of researchers to be mindful of how science and engineering can help find solutions to local and global challenges,
3. diversity programs that help attract women and minorities into science and innovation, and
4. the power of prize challenges, as a way to spur innovation.

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