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Issues Paper on

Strategic Foresight for the Post-2015 Development Agenda

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Background

In its resolution E/RES/2014/28, the Economic and Social Council encouraged the CSTD to "help to articulate the important role of information and communications technologies and science, technology, innovation and engineering in the post-2015 development agenda by acting as a forum for horizon scanning and strategic planning, providing foresight about critical trends in science, technology and innovation in areas such as food security, the management of water and other natural resources, urbanization, advanced manufacturing and related education and vocational needs, and drawing attention to emerging and disruptive technologies that can potentially affect the achievement of that agenda".

The United Nations (UN) Commission on Science and Technology for Development (CSTD), during its 17th session held in May 2014, selected "Strategic Foresight for the Post-2015 Development Agenda" as one of its two priority themes for the 2014-2015 inter-sessional period, thereby following up on ECOSOC resolution E/RES/2014/28.

This draft Issues Paper has been prepared by the UNCTAD Secretariat[1], as a contribution to the work of the Commission in its Inter-sessional Panel, in order to identify, analyse and present for discussion key issues concerning the role of strategic foresight for policymakers, particularly in developing countries.

The paper is structured in five sections:

Section I provides an introduction to strategic foresight on STI for development and its usage around the world.

Section II explains the methodology used in the meta-analysis and expert survey that was conducted for this Issues Paper.

Section III presents key STI trends that are likely to be relevant for development in the Post-2015 period, based on the findings of the meta-analysis of recent foresight reports and expert survey, together with a critical assessment of their potential socioeconomic and developmental impacts.

Section IV draws lessons for the definition of the future global development framework.

Section V presents recommendations and conclusions.

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I. Introduction to Strategic Foresight

I.1 Definition

Strategic foresight (also referred to in this study as technology foresight or future-oriented technology analysis) is the systematic assessment of the long-term future of STI and their potential impacts on society, with a view to identifying the areas of scientific research and technological development likely to influence change and produce the greatest societal benefits. It is a participatory process that provides a number of tools that help participants (i.e. policy makers, experts and other stakeholders) develop visions of the future and pathways towards these visions.

Strategic foresight is vital for any forward planning or policy activity to be able to meet future challenges proactively. It gathers anticipatory intelligence from a wide range of knowledge sources in a systematic way and links them to today's decision making (cf. ForLearn, 2010). Anticipatory intelligence contributes to policy-making by supporting a continuous and shared approach in order to understand the present in all its complexity, to look at different possible futures and to shape a joint direction to follow that considers different stakeholders' points of view (Carabias & Haegeman, 2013).

As the most upstream element of the technology development process, technology foresight provides inputs for the formulation of technology policies and strategies that guide the development of technological infrastructure. In addition, technology foresight provides support to innovation, and incentives and assistance to enterprises in the domain of technology management and technology transfer, leading to enhanced competitiveness and growth.

I.2 Technology foresight as a means to build consensus on policies

Technology foresight is increasingly been recognized worldwide as a valuable policy instrument for establishing common views on future development strategies among policy-making bodies, bridging the present with the future. In this vein, it has emerged as a key instrument for the development and implementation of research and innovation policy (cf. Andersen & Andersen, 2014; Cagnin et al., 2012; Cagnin et al., 2008). The main focus of activity has been at the national level. Governments have used foresight to set priorities, build networks between science and industry and, in some cases, to change their research system and administrative culture. Foresight has thus been used as a set of technical tools, or as a way to encourage more structured debate among a large number of stakeholders and experts, including government, science, industry and civil society representatives, thereby leading to a shared understanding of long-term issues (Georghiou et al., 2008).

I.3 Common foresight methodologies

Various foresight methodologies are available and used in different countries around the world. Over the years, the sharing of foresight experiences has become part of a research process called '*mapping*'. The mapping of foresight has so far involved the systematic monitoring and analysis of foresight practices, players and outcomes. The actual process of mapping builds on a large international effort aimed at understanding the nature of foresight initiatives around the world (cf. Popper & Teichler, 2011).

The significant number of foresight exercises mapped between 2004 and 2008 (over 2000 initiatives) is clear evidence of the rising interest in strategic foresight. As shown in Mapping Foresight (Popper, 2009), this is mainly because forward-looking activities have become more than just tools to support policy or strategy development in STI. The results of previous mapping activities revealed that the scope of foresight, as practised in the early years of the twenty-first century, involves a wider range of objectives, including: analysis of the future potential of STI, promoting network building, priority setting for STI, supporting methodology and capacity building, and generating shared visions. In addition, these mapping efforts showed that 'multi-scope' or 'multi-purpose' foresight is a global phenomenon, with interesting similarities as well as differences in foresight practices around the world (ibid.).

Information technology (IT) tools are increasingly being applied to most foresight approaches, especially interaction- and evidence-based activities (Popper 2008a). Many applications are available to support several types of modelling, data mining, scanning, participatory processes, and visualisation – there are even tools designed to facilitate creativity, such as online-surveys, big data analysis, web-based horizon scanning, creativity platforms. In particular, the mapping of foresight practices has helped to identify methods that are widely used across the world.

An examination of available data around the world[2] shows that the top ten most widely used foresight methods are the following:

- (56%) Expert Panels
- (47%) Scenarios
- (33%) Trend Extrapolation
- (26%) Futures Workshops
- (22%) Brainstorming
- (19%) Delphi
- (19%) Interviews
- (17%) Key Technologies
- (16%) Questionnaire/Survey
- (15%) SWOT Analysis

Table 1 below presents a breakdown of the top ten foresight methods per region. The results show some similarities, such as the use of *expert panels* as one of the top three methods across all regions, and some interesting regional features, e.g. frequent use of *key technologies* in Southern Europe and North America.

Top 10 Foresight Methods used in 954 cases worldwide	**NW Europe** (511 cases)	**Southern Europe** (71 cases)	**Eastern Europe** (52 cases)	**Latin America** (107 cases)	**North America** (109 cases)	**Asia** (89 cases)	**Africa** (18 cases)
Expert Panels	H	VH	VH	VH	H	M	H
Scenarios	H	M	H	H	L	M	H
Trend Extrapolation	H	M	M	M	L	M	M
Futures Workshops	M	L	M	M	M	L	H
Brainstorming	M	H	H	M	L	M	H
Delphi	L	M	M	H	L	M	L
Interviews	M	L	L	M	L	L	M
Key Technologies	L	H	L	L	M	M	L
Questionnaire/Survey	M	L	M	M	L	L	H
SWOT Analysis	M	M	H	L	L	L	L

Table 1: Top 10 foresight methods and their frequencies per region (Low [L], Moderate [M], High [H], Very High [VH])

I.4 Strategic foresight in different world regions

Europe Experiences in the use of anticipatory intelligence at the European level suggest a considerable importance of the use of creative approaches in not just anticipating, but actually jointly shaping the future. Connected to this is the increasing attention to consider unlikely events, both positive and negative, how we can avoid or mitigate them, or on the contrary make them happen, and how one can align different policies to support this. In more general terms, alignment of strategic foresight with decision-making and the coordination mode of governance seem to prevail in recent foresight exercises, despite the considerable richness of foci on different types of transformations and methodological choices and organisational setups for foresight. The analysis shows increasing evidence of institutionalised forms of foresight and exploitation of foresight networks to provide agile and strategic support for decision-making. Finally, there is a growing interest in sharing experiences on the use of anticipatory intelligence in support of decision-making. Examples are the European Foresight Platform and the International Foresight Academy, which promote the professionalization of the field in support of organisations at the interface of science and decision-making (Carabias & Haegeman, 2013).

[2] The European Foresight Monitoring Network (EFMN, 2005-09), iKnow (2008-11), and the European Foresight Platform (2009-12)

Northwest Europe (511 cases from Austria, Belgium, Denmark, Finland, France, Germany, Iceland, Ireland, Luxembourg, Netherlands, Norway, Sweden, Switzerland, and United Kingdom)

There has been a huge increase in the level of foresight activity over the last decade, owing to the influence of multiple traditions, including technology foresight, sustainability planning, and territorial prospective. Some countries, e.g. France, have a rich history of futures work that stretches back several decades and that still influences practice today. Others, e.g. the UK and Ireland, have a shorter history where recent practice has been more influenced by technology foresight and sustainable futures traditions.

Eastern Europe (71 cases from Armenia, Belarus, Bulgaria, Czech Republic, Estonia, Hungary, Latvia, Lithuania, Poland, Romania, Russia, Slovakia, Slovenia and Ukraine)

Little legacy remains of a tradition of futures thinking in the context of state central planning during the communist era. Instead, foresight activities mapped by EFMN concern more recent work that has been heavily influenced by technology foresight practice in North-West Europe. The EC and UNIDO have played important roles in this policy tool transfer.

Southern Europe (52 cases from Cyprus, Greece, Italy, Malta, Portugal, Spain and Turkey)

Activities in this region started relatively recently and have been heavily influenced by practice in North-West Europe. The level of activity is lower, however, with far fewer exercises carried out than in North-West Europe. The activities mapped by EFMN are mostly technology foresight exercises, and just over half are from one country, Spain.

Latin America (107 cases from Argentina, Bolivia, Brazil, Chile, Colombia, Cuba, Ecuador, Mexico, Panama, Paraguay, Peru, and Venezuela)

Foresight in the region has evolved slowly but progressively. Many countries have launched national programmes and projects incorporating concepts and techniques from a wide range of international foresight exercises, mainly from Europe. However, the region has also managed to achieve its own foresight ‘‘style’’ on account of the creative use of limited resources, which has sometimes resulted in effective innovations in practices and tools – from new management systems and online support tools to new ways of achieving stakeholders’ commitment, for example. International organisations, such as UNIDO, CAB, ECLAC, and, more recently, the EC, have also played a key role in supporting foresight programmes and capacity-building activities in the region.

North America (109 cases from Canada and United States) – Many of the most popular foresight methods were developed in the United States during the 1950s and 1960s and used extensively by both the public and private sectors. While there is still a lot of activity going on at the state and federal levels in both the US and Canada, much of this is not being tracked internationally. Instead, the data is dominated by a lot of industry sector technology roadmapping exercises, an approach that is particularly popular among US firms.

Asia (89 cases from China, India, Japan and South Korea) – Japan pioneered the development of national technology foresight, using the Delphi method since 1970 to forecast and shape future technological trajectories. Besides having an influence in Europe, the Japanese experience has also inspired similar exercises in other parts of Asia, particularly Korea, China, and South-East Asia. Within the context of the Asia Pacific Economic Cooperation (APEC), a Technology Foresight Centre was set up in the late 1990s to conduct region-wide studies and to develop capabilities in member countries. This work has been largely influenced by practices in Australia, North America, Japan, and North-West Europe.

Africa (18 cases from Botswana, Ghana, Kenya, Morocco, Nigeria and Tunisia) – Most cases on Africa have been sponsored or conducted by international organisations, such as the European Union, Food and Agriculture Organization of the United Nations (FAO), African Development Bank, United Nations Development Programme (UNDP), UNAIDS, and the International Food Policy Research Institute (IFPRI). The majority of these cases look at Africa as whole, and only a few cases focus on individual countries.

I.5 Selecting a suitable foresight methodology

The simple identification of the most common foresight methods and their use in different world regions does not suffice to make well-informed decisions when designing a foresight process. A dedicated paper on ‘how to select foresight methods’ (Popper, 2008b) found that decisions on methods selection are not always coherent or systematic. One observation of the study is that the selection of foresight methods is often dominated by insight, impulsiveness and – sometimes – inexperience or irresponsibility of foresight practitioners and organisers. Thus, after a thorough analysis of 800+ cases, Popper shows that two of the most important factors influencing the selection of methods are their *nature* (qualitative, quantitate or semi-quantitative) and the *methods mix* (dependence or influence on other foresight methods). “The former shows that qualitative approaches are definitely favoured while the latter shows that some methods go practically hand-in-hand, such as the apparent use of brainstorming as an input for Delphi” (ibid, p.82).

II. Strategic Foresight methodology used in this Issues Paper

This Issues Paper is based on a global horizon scanning exercise performed in consultation with experts that are members of the International Foresight Academy (IFA) and the European Commission.

A critical meta-analysis of relevant forward-looking reports and technology foresight studies has been carried out to identify key technology trends in the post-2015 context, particularly of direct relevance to the attaining the draft Sustainable Development Goals (see References section for a list of reviewed documents).

To complement the meta-analysis, inputs were obtained on future STI trends from foresight experts in different regions (see Appendix II for a list of contributing experts). In this way, key technology trends were identified, along with an assessment of their socio-economic and developmental impacts. Section III presents these trends.

In addition to analysing future STI trends and their implications for overall development, the paper concludes with policy recommendations for consideration by national governments and other relevant stakeholders.

The trends are based on views expressed by contributing experts in their personal capacity and may not in any circumstances be regarded as stating the official position of any organisation.

III. Key trends in STI for the Post-2015 Development Agenda

The key STI trends that have been identified in the horizon scanning exercise for this Issues Paper are encapsulated under seven areas: natural resources, energy, climate change, converging technologies, health and disaster resilience, urbanization, and mobility.

III.1 Technologies related to natural resources

Economies tend to use more resources as they grow – both renewable biological resources (cf. EEA, 2014d) and non-renewable stocks of minerals, metals and fossil fuels. Industrial and technological developments as well as changing consumption patterns associated with growing prosperity contribute to this increase in demand. While rising living standards and growth of the middle class in developing countries that drive such trends are welcome, they also create risks. The world is a closed material system, implying finite limits on the amounts of resources available. Even if they are not scarce in absolute terms, resources may be unevenly distributed globally, making access uncertain and potentially fostering conflict. Such concerns are particularly apparent with respect to a range of resources designated as 'critical raw materials'.

Innovation plays a complex role in shaping the demand for and supply of resources. Ground-breaking technologies can create new uses for resources and new ways to locate and exploit deposits, potentially increasing the burden on the environment. But innovation can also enable societies to reduce their use of finite and polluting resources and shift towards more sustainable alternatives. The impacts of intensifying global competition for resources will therefore depend greatly on whether technological development can be steered towards establishing more resource-efficient ways of meeting society's needs (EEA, 2014c).

The following will look at potential technologies identified in the horizon scanning exercise that can be particularly useful in assisting developing countries manage food and water resources more efficiently.

III.1.1 Food resources

Changing demands and uses for agricultural products are driving a subsequent change in food production (OECD/FAO, 2014). As diets shift away from cereals towards more protein, fats and sugars, and plant-based energy production increases, a nexus point forms between differing interests of: quality and quantity increases of food, environmental capacity for agriculture, climate change adaptation, economic accessibility of food, and increased vulnerability. Within this very broad context, a few key technology trends – often derived from scenario development – are highlighted in the following.

III.1.1.1 Nanofood applications

Nanofood applications will cover the entire food chain process and can result in increased productivity of agricultural processes, decreased inputs and waste, improved quality and safety of food and water supplies, all culminating in higher efficiencies of food processing. While nanotechnology applications are currently focused on developed countries, researchers are optimistic that the potential improvements will also soon be felt amongst developing countries (Alexandratos, N. & Bruinsma, J., 2012).

Socio-economic/developmental impacts
Applications of nanotechnologies in all areas will be significant tools in contributing to global issues, including food security and poverty. Developing countries can increase the competitiveness of their food producers and improve their market access (Gruére et al., 2011).

III.1.1.2 Shifting meat consumption: cultured meat and efficient animal production

As meat production is increasing due to the demand in developing countries, production intensification is one solution. This includes growth-enhancing technologies that have led to improved efficiency and lower environmental impacts (Lusk, 2013, Capper & Hayes, 2010). Furthermore, vaccines are available for livestock to protect animals and humans against harmful viruses, but cost-effective production and distribution systems are lacking (USAID, 2013a). Meanwhile, meat alternatives are also possible, such as in-vitro meat (manufacturing of meat products through "tissue-engineering" technology) (Tuomisto, Teixeira de Mattos, 2011).

Socio-economic/developmental impacts
Process improvements could be efficient enough to supply the global demand for meat. Although the acceptance of alternative meats is challenging (Smil, 2014), they could have financial, health, animal welfare and environmental advantages over traditional meat (Tuomisto, Teixeira de Mattos, 2011).

III.1.1.3 ICTs in agricultural production
Sensors are increasingly being used for real-time tracking of crops, animal and machines. Automation of specific tasks by robots or microrobots improves harvesting, picking, weeding, irrigation, etc. Use of mobile phones provides access to markets, fertilizer and weather reports for farmers, as well as suppliers, retailers and policy makers. The use of mobile technologies and other ICT applications can make a big difference for farmers' income. Currently available services include market (price) information, local weather forecasts, disease diagnostics, etc. The further penetration of mobile use (2G, but also increasingly 3G and 4G) will open new opportunities to support rural areas. In the Asia-Pacific region also tablet computers with low-cost architecture that can be connected to cell phone networks have become very popular.

Socio-economic/developmental impacts
Developing countries have high agricultural potential that can only be realized through efficiency improvements. Step change improvements in productivity help to relieve the pressure on developing countries in terms of ensuring food security. Continuous technological inputs help to maintain increases in yields.

Box 1. Mobile Information Project (DatAgro)

The Mobile Information Project (MIP) in Chile delivers targeted agricultural information from the web directly to farmers via SMS messages, using software to create news channels on mobile phones. The system works on simple mobile phones and even with slow networks with intermittent connectivity. The DatAgro service proves to be popular. One farmer reported that his entire crop for 2009 was saved by an SMS message that urged him to delay planting because of impending bad weather (FAO, 2013).

III.1.1.4 Functional foods
Functional foods have optimised nutritional aims to supply dietary requirements for improving the body, decreasing risk, or even curing diseases. They were first developed in Japan in 1991 as foods for specified health use and introduced to combat increasing health care costs (Saarela, M., 2011).

Socio-economic/developmental impacts
Food security remains a problem in developing countries, with one aspect being nutritional quality. Aging populations are looking to have an improved quality of life in their later years and functional food addresses this need (Bigliardi, Galati, 2013).

III.1.2 Water
Water will take an even more prominent place in the SDG agenda than ever before. The convergence of issues related to economic opportunity, environmental quality, human health, energy production, social well-being and equality require technological innovations that are holistically implemented to consider all three pillars of sustainability. Some of the most challenging problems that can be addressed by technology are: water scarcity particularly groundwater extraction, water quality in developing countries, access to water and sanitation in rural and urban settings, and materials recycling (Global Water Intelligence, 2009; OECD, 2012a). Therefore, the deployment of water supply and sanitation infrastructure in developing countries has to be accelerated. Innovative options that consume less water, energy or capital are being explored. Key technological trends to address these problems are presented in the following.

III.1.2.1 Decentralized and sustainable sanitation

New sanitation systems in developing countries address the cost and institutional problems associated with the traditional expansion and connection to a centralized piped wastewater treatment plant. Sustainable systems consider the entire service chain, as well as the final end products, and additionally contain pathogens where contamination could occur, and often incorporate hand washing or flushing. This has been done using new treatment materials such as sand, soil, urine separation, and incorporating energy recovery, nutrient reuse, and ecological sanitation (Katukiza et al., 2012).

Socio-economic/developmental impacts

Long-term durability is expected to be achieved in sanitation by minimizing health risks and environmental impacts with low upfront costs.

III.1.2.2 Energy and nutrient recovery from wastewater

The energy and nutrient content of wastewater has been realized and the trend is of capturing this 'waste' stream and recovering it for reuse. For energy production, anaerobic digestion processes of wastewater and solids produce a methanol-based biogas (Katukiza et al., 2012). Recently, microbial fuel cells have started to produce electricity from the metabolism of microorganisms treating the wastewater (Oh et al., 2010). Phosphorus and nitrogen are also in appreciable concentrations in biosolids and urine, thus composting the end product or directly recovering the phosphorus by chemical precipitation, pyrolysis etc., can be done at various scales (Etter et al., 2011; Global Water Intelligence, 2009).

Socio-economic/developmental impacts

Decentralized energy and fertilizer sources can bring synergies within the larger economic development context. However, infrastructure constraints for implementation may arise when new technologies involve the renovation of current sanitation systems.

III.1.2.3 Membranes and advanced water filtration for drinking and wastewater treatment

Separation processes that remove pollution, salts, or solids from fresh or wastewater open up safer water re-use, as well as the potential to be economically productive with previously unusable sources.
Nanotechnology for filtering, membrane filtration, and seawater desalination have been advancing in technical and economic feasibility (EC, 2010). New designs include: forward osmosis and high efficiency energy recovery or integration of renewable energies such as solar (Penate, Garcia-Rodriguez, 2012).

Socio-economic/developmental impacts

Cheaper, smaller and energy-efficient treatment devices allow a wider population access to clean drinking water, which improves economic productivity, overall health, and environmental quality. Nanofilters are likely to be employed in developing regions of the world to provide potable water by 2020 (RAND, 2006).

III.2 STI for sustainable energy systems

Access to reliable and affordable energy services is essential for social, technological and economic development and therefore crucial for reaching many of the SDG. At the same time, energy generation, processing, transportation, and use entail a large number of negative consequences for society and the environment. In particular, the burning of fossil fuels, which in 2012 covered about 80% of global primary energy demand (REN21, 2014), is a key driver of CO_2 emission (Stocker et al., 2013), thus contributing to climate change. The following analysis highlights the challenge for policy makers to provide modern energy services to an ever-larger share of the global population in different economic situations, while also transforming the energy system to a more sustainable state.

The energy system can be seen as a coupled system: On the **demand side** there is a need for energy services and specific energy carriers, such as fuels or electricity. On the **supply side** there exist a variety of potential energy resources, ranging from fossil-based (such as oil, coal or gas) to renewable sources (such as wind, solar radiation or geothermal energy). Depending on a variety of factors, such as economic considerations, technological development, environmental concerns, as well as geopolitical constraints, these resources are converted into different energy carriers. The **interface of supply and demand** is a complex system of local and global markets, transport infrastructures (e.g. the electricity grid) and institutions (such as transmission system operators) whose interplay ensures that energy production matches demand.

What makes the energy system even more complex is that the required infrastructure entails large upfront costs and long life cycles – usually decades. Additionally, a variety of non-technical factors play a role: ranging from regulatory constraints to consumers' lifestyles. Finally, the energy system also comprises a variety of different actors: planning and future strategizing is done at the political, financial, scientific, as well as agriculture and specific industrial levels (Lin, Chan, & Ien, 2013).

New technologies promise to contribute to cheaper, more sustainable, resilient, and integrated energy systems. Their relevance varies depending on the regional context. This includes the available energy resources and existing infrastructure, the structure of national economies, the development of the consumer base, financial resources to implement novel technologies, national legal frameworks, and political (in)stability. Bearing in mind that technology is only one part of the picture, the following section provides an overview of technology trends and is structured according to the three facets "demand for energy", "supply of energy" and "interface of energy supply and demand".

III.2.1 Demand for energy

On the back of economic and demographic growth, global energy demand is expected to grow significantly in the coming decades. The majority of the growth will be due to developing countries (mainly in China and India), while for developed ones it is widely expected to stabilize in the mid-term (IEA, 2013b). However, one key determinant of energy demand is not of technical but of a non-technical nature, such as energy prices, sufficiency strategies or regulatory factors for carbon emissions. In the following, key technological trends concerning the demand for energy are described.

III.2.1.1 Gradual increase in energy efficiency

Driven by technological development and cost considerations, energy efficiency, mainly of industry and transport, is widely expected to increase (Geller, Harrington, Rosenfeld, Tanishima, & Unander, 2006). Overall, energy efficiency must be expected to improve gradually, but continuously, and no technological breakthroughs are in sight. This is particularly relevant for developing countries, where environmental concerns by consumers and pressure by policy-makers create incentives to implement efficiency measures that would not be implemented from a purely economic point of view.

Socio-economic/developmental impacts

Long term economic viability through budget relief from fuel cost (fossils) and reduced need for generation capacities. For developing countries, not only will population and economic growth overshadow efficiency improvements, there may also be fewer resources available to invest in energy efficiency.

III.2.1.2 Electrification

In the future, demand for more energy services will be provided by electricity. In developed countries, where a reliable electricity supply is widely guaranteed, this will be due to the widespread implementation of electric cars (e-mobility) or heat pumps. In developing countries, it will mainly be the more widespread use of ICTs that enable economic and social development (IEA, 2013a and 2014; WBCSD, 2011).

Socio-economic/developmental impacts
Access to new economic potential through service provision, access to broader markets, communication and information exchange.
Electrification is the basic foundation to unlock access to ICT applications that bring about an increased quality of life.

III.2.1.3 Development of the building stock

Residential consumers account for a large share of global energy demand. In developing countries it may be as high as up to 40% of overall consumption (Pérez-Lombard, Ortiz, & Pout, 2008). In developed countries a widespread implementation of zero-energy buildings is in sight. For example, the EU has set the target that until 2020 all new houses should be near-zero energy buildings (European Union, 2010). In developing countries urban migration will demand a lot of new housing infrastructure for the next 30 years and with this the associated energy infrastructure. For example, one estimate is that between 2000 and 2030, 65M people will be moving to cities annually (Annez et al., 2009).

Socio-economic/developmental impacts
How the numerous buildings in growing urban areas are built will considerably impact energy demand (e.g. with respect to heating and cooling) and the development of energy infrastructure, such as the electricity grid (IRENA, 2014). If implemented with a holistic, long term perspective: improves quality of life, access to job markets, health services, and behind it all, energy security.

III.2.2 Supply of energy

One key aspect of a sustainable transition of the energy system is to expand the use of renewable energy resources. Large subsidizing efforts have been made to bring renewable energies up to scale, such as direct government subsidies for technology, feed-in-tariffs, and external financing such as for climate change mitigation. In the following, three technological trends concerning energy supply are discussed.

III.2.2.1 Tapping unconventional fossil resources

Extraction of unconventional fossil fuels, such as shale gas, oil sands, coal-based natural gas, has dramatically expanded in the past decade. This extends the static lifetime, i.e. reserve volume divided by current annual consumption, of fossil fuels considerably (IEA, 2010). The condition for unconventional sources to be economically interesting was a result of both technological development (such as, horizontal drilling, fracking, multilateral wells and microseismic monitoring) and higher energy prices (Chew, 2014).

Socio-economic/developmental impacts
Develop energy security as new sources are discovered and recoverable. Unconventional reserves will also function as a buffer for price increases of fossil fuels, however, only in the mid- to long term due to the time lag between exploration and production.

III.2.2.2 Expanding established renewables

Relatively established renewable energy technologies, such as biogas, wind and solar energy, are expected to further mature, which will bring down their cost and reduce their implementation risks. The production from these sources is therefore thought to increase considerably in the next decades from the status quo of almost 20% (REN21, 2014). Estimates for 2050 range up to 65% (IEA, 2014)[3].

Socio-economic/developmental impacts

Developing energy security is one of the main impacts of renewables. Advantages are that renewables are widely carbon neutral, can be modularly implemented, are rapidly online, and can be used to connect between regions. However, their impact in different world regions depends on the local availability of renewable resources (e.g., wind and sun), which are key determinants of the generation cost.

Box 2. Wind Adoption in Colombia (from Haselip et al., 2011, 71-86)

Wind power generation in Colombia was, as is in many countries, economically unattractive due to high upfront costs of the installation. While Colombia is already oriented towards renewable energy technologies (RET) with a large share (up to 63%) of the electricity mix coming from hydropower, the lack of diversity in the energy portfolio is risky for supply security. Federal monetary incentives were in place since 1994 for any new technologies that would provide stable energy supply, but until 2011, there was only one wind farm (19.5 MW) in the country, although the potential is estimated to be up to 18 GW. Additionally, wind power appears to be a viable option during the dry season when water flows do not generate as much power. In 2002, a general framework was established to promote RETs, which encompassed monetary incentives for research in the form of funding and institution building, and a 15-year tax exemption and carbon certificates for supply companies. However, it did not lower the largest entry barrier of initial capital costs. Additionally, the hydropower companies have a strong monopoly over technology and market structure. Thus, the following is proposed for the regulatory structure to overcome these challenges: feed-in-tariffs and policies to promote a diverse energy portfolio, learning by doing and new technology adoption. First steps in this direction are to set measurable goals for wind power penetration and establishing the economic conditions to support transmission and distribution in the grid.

III.2.2.3 New opportunities through technological innovation

Many renewable energy technologies have not yet reached widespread industrial commercialization, such as wave, tidal and geothermal energy, as well as biomass and nuclear fusion (Beringer et al., 2011; Khan et al., 2009; Rybach, 2014). However, this may be just a matter of a specific technological innovation or simply time, and the change will occur. As subsidies, advantageous economic conditions, consumer acceptance or technology scaling develop, these technologies may expand in kind.

Socio-economic/developmental impacts

Diversification, and thus security of the energy mix through additional and complementary renewable energy production (Haselip et al., 2011).

III.2.3. Interface of energy supply and demand

At the meeting of both the supply and demand side of energy, i.e. transport, delivery, storage and consumer services, new challenges from renewable energy will come, such as large-scale intermitting power generation, which will either require additional reserve capacities or demand side management measures to ensure supply adequacy. Adding to the complexity of the supply/demand interface is that new technologies, such as cheap solar power panels or (bio-)gas-fired micro turbines may also empower consumers to become so-called ‘prosumers’ making traditional supply chains rather resemble networks (Grijalva & Tariq, 2011). Thus in electricity supply, one of the biggest challenges is to manage the grid to accommodate intermittent and decentralized production along with the centralized one, as well as flexible pro- and consumers, and storage capacities. In the following, three technological trends that address the interface for managing a sustainable energy transition are highlighted.

[3] For an overview of different renewable energy technologies for developing countries see UNCTAD (2010).

III.2.3.1 Smart energy systems

The advancement of IT services and the mining of big data have led to the personalization of energy use for end customers. Intelligent devices that measure energy use, provide instant feedback, adapt to individual lifestyles, and respond to changes in the energy grid all result in a demand side that is more adaptable to the current energy situation and more aware of energy use. Integration of decentralized renewable energy into the grid is possible with relevant grid codes, i.e. operational practices that account for interruptions from renewably sourced generators. Most transmission grids in developed countries are already capable of taking in 25% variable energy. Forecasting, balancing areas, and flexible resources are all foreseeable improvements to grid technology and management in order to transition to a mix of reserve and renewable energy (Madrigal & Porter, 2013). Combining smart grids and energy supply technologies with smart mobility and smart buildings as well as with good governance enable the development of smart cities in a participative way (cf. Carabias et al., 2014; sub-section III.8).

Socio-economic/developmental impacts

Consumer can become more energy efficient through better information transfer. In developing countries where blackouts are ubiquitous, additional renewable supply may bring even larger challenges and opportunities in ensuring energy security. Integration of energy and transport systems may be beneficial on the way towards smarter cities. This includes “smart energy,” the intelligent networks that improve efficiency and security by receiving and distributing energy – such as electricity – based on users’ behaviour.

III.2.3.2 Development of energy transport infrastructure

One crucial factor for the integration of renewables in the future is whether the energy transport infrastructure can be developed in the necessary places. For Europe, for example, this requires building a high voltage electricity grid that is capable of connecting the large scale renewable electricity production sites in the north sea (offshore wind) and North Africa (solar thermal power production) with the demand hotspots (mainly the continent’s large cities) in a robust way (Trieb & Müller-Steinhagen, 2009). Off-grid developments (i.e. mini-grids) are foreseen as a solution for rural, decentralized or community-scale energy production.

Socio-economic/developmental impacts

Large upfront costs require long-term financial viability, but small-scale and off-grid are possible for energy security in the face of institutional challenges. In developing countries, decentralized (so-called off-grid) electricity systems are promising, although they require a form of storage or high flexibility in demand in order to avoid costly transmission systems and minimize grid power losses over long distances.

III.2.3.3 Storage

Especially for electricity, which – in contrast to oil products and natural gas – is hard to stockpile and for which there is no buffer in the grid (production and consumption need to be balanced at all times), storage systems will become ever more important. These include traditional approaches, such as pumped hydropower but also technological options that are – mostly due to cost constraints – not yet available on a large scale, such as batteries, supercapacitors or fuel cells, which are, e.g., powered by hydrogen (Ferreira, Garde, Fulli, Kling, & Lopes, 2013).

Socio-economic/developmental impacts

Greatly facilitates renewable energy integration, which may be a necessary flexibility for rural energy provision.

III.3 STI for climate change mitigation, adaptation and carbon offset

Communities in developing countries that are particularly dependant on primary raw resources are most vulnerable to climate change impacts and should thus be the target groups for implementing climate change adaptation technologies. A complementary increase in economic opportunity for these communities will help bring enhanced engagement, as environmental considerations are only taken after ensuring socio-economic existence. Hence empowering these communities through policies like the ones listed below can amplify the positive impact of emerging technologies:

- Privatization of a good or service that allows the community to take ownership of particularly vulnerable and unaddressed social problems (e.g. sanitation and water access that is exacerbated by extreme weather).
- Granting land rights where otherwise continued insecurity is prevalent (e.g. agricultural land that does not receive climate adaptation measures due to lack of ownership).
- Fostering economic development in less climate-sensitive industries (e.g. secondary or tertiary resource production, such as drying, flavouring, packing, exporting food).

The following will consider five technology trends that play an important role in addressing climate change: decarbonization, reducing energy use, increasing efficiency, adaptation, and mitigation pathways.

III.3.1 Technology trends combating climate change through decarbonization

Decarbonizing (i.e. reducing the carbon intensity of) electricity generation is a key component of cost effective mitigation strategies in achieving low-stabilization levels (430-530 ppm CO2eq); in most integrated modelling scenarios, decarbonization happens more rapidly in electricity generation than in industry, buildings, and transport sectors (IPCC, 2013a, p.21).

GHG emissions from energy supply can be reduced significantly by replacing current world average coal-fired power plants with modern, highly efficient natural gas combined-cycle power plants or combined heat and power plants, provided that natural gas is available and the fugitive emissions associated with extraction and supply are low or mitigated. In mitigation scenarios reaching about 450 ppm CO2eq concentrations by 2100, natural gas power generation without Carbon dioxide Capture and Storage (CCS) acts as a bridge technology, with deployment increasing before peaking and falling to below current levels by 2050 and declining further in the second half of the century (IPCC, 2013a, p.22)

Socio-economic/developmental impacts

Substantial reductions in emissions would require large changes in investment patterns. Mitigation scenarios in which policies stabilize atmospheric concentrations (without overshoot) in the range from 430 to 530 ppm CO2eq by 2100 lead to substantial shifts in annual investment flows during the period 2010 - 2029 compared to baseline scenarios (IPCC, 2013a). Over the next two decades (2010 to 2029), annual investment in conventional fossil fuel technologies associated with the electricity supply sector is projected to decline by about USD 30 (2 – 166) billion (median: − 20 % compared to 2010) while annual investment in low-carbon electricity supply (i.e., renewables, nuclear and electricity generation with CCS) is projected to rise by about USD 147 (31 – 360) billion (median: + 100 % compared to 2010).

Climate change is projected to affect energy sources and technologies differently, depending on resources (e.g., water flow, wind, insolation), technological processes (e.g., cooling), or locations (e.g., coastal regions, floodplains) involved (IPCC, 2013a).

III.3.2 Climate change mitigation through the reduction of energy use

Recent advances in technologies, know-how and policies provide opportunities to stabilize or reduce global buildings sector energy use by mid-century. For new buildings, the adoption of very low energy building codes is important and has progressed substantially. Most mitigation options for buildings have considerable and diverse co-benefits in addition to energy cost savings. Building codes and appliance standards, if well designed and implemented, have been among the most environmentally and cost-effective instruments for emission reductions (IPCC, 2013a, p.24).

The energy intensity of the industry sector could be directly reduced by about 25% compared to the current level through the wide-scale upgrading, replacement and deployment of best available technologies, particularly in countries where these are not in use and in non-energy intensive industries. Furthermore, significant improvements are achievable in the transport sector, which is covered in detail under Section III.7. Additional energy intensity reductions of about 20% may potentially be realized through innovation (IPCC, 2013a, p.24).

Socio-economic/developmental impacts
In some developed countries applied standards have contributed to a stabilization of, or reduction in, total energy demand for buildings.

Annual incremental energy efficiency investments in transport, buildings and industry is projected to increase by about USD 336 (1 – 641) billion up to 2029, frequently involving modernization of existing equipment (IPCC, 2013a, p.27).

III.3.3 Reduction of GHG emissions through increased efficiency

Improvements in GHG emission efficiency and in the efficiency of material use, recycling and re-use of materials and products, and overall reductions in product demand (e.g., through a more intensive use of products) and service demand could, in addition to energy efficiency (cf. section III.2.1.1), help reduce GHG emissions below the baseline level in the industry sector.

Systemic approaches and collaborative activities across companies and sectors can reduce energy and material consumption and thus GHG emissions. The application of crosscutting technologies (e.g., efficient motors) and measures (e.g., reducing air or steam leaks) in both large energy intensive industries and small and medium enterprises can improve process performance and plant efficiency cost-effectively. Cooperation across companies (e.g., in industrial parks) and sectors could include the sharing of infrastructure, information, and waste heat utilization. Important options for mitigation in waste management are waste reduction, followed by re-use, recycling and energy recovery (IPCC, 2013a, p.25).

Socio-economic/developmental impacts
The implementation of energy efficiency measures might bring a return of investment once the respective amount of energy has been saved. Bioenergy can play a critical role for mitigation, but there are issues to consider, such as the sustainability of practices and the efficiency of bioenergy systems (IPCC, 2013a, p.25).

III.3.4 Adaptation to climate change

Climate change is projected to reduce energy demand for heating and increase energy demand for cooling in the residential and commercial sectors (IPCC, 2013a, p.19).

Significant co-benefits, synergies, and trade-offs exist between mitigation and adaptation and among different adaptation responses; interactions occur both within and across regions. Increasing efforts to mitigate and adapt to climate change imply an increasing complexity of interactions, particularly at the intersections among water, energy, land use, and biodiversity, but tools to understand and manage these interactions remain limited (IPCC, 2013a, p.28).

Socio-economic/developmental impacts
Examples of actions with co-benefits include (i) improved energy efficiency and cleaner energy sources, leading to reduced emissions of health-damaging climate-altering air pollutants; (ii) reduced energy and water consumption in urban areas through greening cities and recycling water; (iii) sustainable agriculture and forestry; and (iv) protection of ecosystems for carbon storage and other ecosystem services (IPCC, 2013a, p.28).

III.3.5 Technology routes for climate change mitigation

Many different pathways are possible for achieving a given mitigation target. The policy scenarios investigated by the OECD model different technology pathways to reduce emissions (OECD, 2012a). These scenarios all aim at achieving the same 450 ppm emission pathway, with the same timing of emission reductions but assuming different patterns of technological developments to achieve it:

- Low efficiency and renewables: assumes lower efficiency improvements in energy use compared to the default assumptions in the 450 Accelerated Action scenario, through less improvement of energy inputs in production, and slower increases in production of renewables.
- Progressive nuclear phase-out: assumes that nuclear capacity currently under construction and planned until 2020 will be built and connected to the grid. However, after 2020, no new nuclear unit will be built so that the world total capacity by 2050 will be reduced because of the natural retirement of existing plants.
- No CCS: assumes no greater use of CCS technologies beyond the levels projected in the Baseline.

In the short run – to 2020 – altering the set of mitigation technologies results in only limited changes in the electricity generation mix and level because the carbon penalty is too low to overcome the inertia in the energy system. In all simulations the bulk of emission reduction over this timeframe is therefore achieved by decreasing emissions of methane, nitrous oxide and F gases, although there is also some reduction in energy consumption induced by the carbon price.

However, the role of renewable energy technologies in the longer run – to 2050 – is more pronounced as low carbon technologies are projected to have taken over in all regions of the world.

Socio-economic/developmental impacts
By 2050, when all technologies are assumed to be available, renewable electricity is assumed to supply about half of the needs in OECD and BRIICS, which will also rely on capital-intensive nuclear and fossil fuel plants with CCS. The results reveal strong complementarities between nuclear and fossil fuels (with or without CCS) in most regions. Phasing out nuclear facilities in the BRIICS countries, where most new capacity is expected to be built in the coming decades, causes a substantial reduction in electricity generation. Power plants with CCS become competitive around 2030 and increasingly so by the end of the time horizon in both OECD and BRIICS. In the absence of CCS power plants by 2050, switching to more expensive technologies increases electricity prices and alters consumption patterns. Fossil fuel power plants without CCS are projected to decline to about 10% of total power supply worldwide, due to the high carbon price, unless nuclear is phased out, in which case such a steep decline is not feasible. The rest of the world is projected to follow a different mitigation strategy, predominantly relying on increasing renewable energy sources, and is therefore very sensitive to the assumptions about energy efficiency and productivity of renewable energy technologies, but less affected by the exclusion of nuclear and CCS. Given this projected strategy, substituting away from renewable energy sources is more difficult and costly (OECD, 2012a).

The 2011 incident at the Fukushima nuclear plant in Japan and the following reconsideration of nuclear energy use in other countries was a harsh reminder that possible large-scale disruptions to the energy system cannot be ignored.

III.4 Converging technologies

The history of technological progress provides compelling evidence that change is not linear but exponential (Kurzweil, 2001). The dynamics will increasingly come from the convergence of sciences and technologies: This acceleration in technological change will also lead to breaktroughs that could affect economic sectors that have been slower to change in the past, notably energy and transport (EEA, 2011). The following will particularly emphasize three key convergence areas that have been identified as potential game-changers in the horizon scanning exercise: biotechnology, nanotechnology, and advanced manufacturing/materials.

III.4.1 Biotechnology Trends and Applications

Recent advances in the manipulation and modification of living systems have enabled dramatic improvements in health monitoring, disease control, and therapeutic and prosthetic options, and they have even given rise to the possibilities of designed organisms. The reaction to these developments has varied widely throughout the world, with some countries and regions opting for slower development because of ethical issues and concerns about environmental risks, while other countries and regions have embarked on a faster development path. It is suggested that by 2020, the following applications of biotechnology will be technically feasible[4]:

- Performance of many different bioassays on a sample at once, which will enable rapid analyte identification from very small amounts of material, for both medical diagnoses and forensic evaluations
- Personalized medicine, based on large databases of patient information and disease states, as well as the ability for rapid and parallel gene sequencing
- Development of GM insects, such as pests that produce sterile offspring or that do not carry or transmit disease vectors
- Widely available capability for GM staple food crops, with especially strong impact in the developing world
- Ability to design and test new drugs using computer simulations (“in silico”), as well as new capabilities to test for harmful side effects on model systems assembled on computer chips (“lab-on-a-chip”)
- Targeted drug delivery to organs or tumors using molecular recognition
- Implants and prostheses that mimic biological functions, restore critical functions to existing organs or tissues, or even augment those functions.

III.4.2 Nanotechnology Trends and Applications

Nanotechnology, which for the purposes of this report (cf. section III.1.1.1) is taken to mean R&D in nanometer scale science and related technologies, is a burgeoning field worldwide. This worldwide interest is based on the belief that the ability to understand and affect atomic and molecular interactions at the nanoscale is both a prerequisite and an enabler for a host of technological capabilities, from smart, multifunctional materials to designer drugs and new generations of information and communications systems. It is suggested that the following applications of nanotechnologies will be feasible by 2020[5]:

- New families of miniaturized, highly sensitive and selective chemical and biological sensors
- Improvements in battery power management and capacity
- Individually worn sensors, especially for military and emergency personnel
- Computational devices embedded in commercial goods (already being done today and likely to become more widespread)
- Wearable personal medical monitoring devices with data recording and communications capability
- Functional nanostructures for controlled drug delivery and for improved performance of implants and prosthetic devices
- Capability for widespread human and environmental surveillance and monitoring.

[4] RAND (2006)

[5] Ibid.

Nanotechnologies are especially relevant because with decreasing size, the properties of materials change. Being able to design and manufacture materials and increasingly complex structures and devices at the scale of atoms and molecules offers many approaches and tools that can vastly enhance the ability to detect and remedy environmental deterioration (EEA, 2011). Examples include nanotechnologies for energy conversion and storage, such as dye-based solar power cells. Nanomaterials are also likely to enable development of functional building materials such as self-healing and self-cleaning concretes.

III.4.3 Advanced Manufacturing and Materials Trends and Applications

The multidisciplinary field of advanced materials has grown over the past few decades through integration of physics, chemistry, metallurgy, ceramics, polymer science, and most recently biology, to become a rich source of technological advancement. Indeed, advanced materials are enablers of many of the applications listed above under biotechnology and nanotechnology trends. Based on the continued developments in materials science and engineering and manufacturing, RAND (2006) suggests that the following may be feasible by 2020[6]:

- Fabrics that incorporate power sources, electronics, and optical fibers
- Clothes that respond to external stimuli, such as temperature changes or the presence of specific substances
- On-demand manufacturing of components and small products to individual personal or corporate specifications (initially limited to low-complexity items)
- Widespread adoption of “green” manufacturing methods that substantially reduce the introduction of hazardous materials into commerce and the volume of hazardous waste streams
- Nanostructured coatings and composite materials with greatly enhanced strength, toughness, wear resistance, and corrosion resistance
- Organic electronics for increased brightness of lighting systems and displays
- Mass-producible solar cells using composite materials based in part on nanostructured, organic, or biomimetic materials
- Water purification and decontamination systems based on nanostructured, activated membranes and filters
- Designed catalysts for chemical processes based on combined rapid computation and materials screening
- Engineered multifunctional tissues grown in vivo from biodegradable scaffolds (likely limited initially to selected tissue and organ types)

Revolution in materials is always the corner stone of product innovations. In coming years, disruptive advances are expected in the area of nanomaterials (graphene, carbon nanotubes, nanoparticle), 3D circuit, universal memory, multicore and photonics which are basic devices and components to run ICT products and processes.

Socio-economic/developmental impacts

The following drivers and barriers to implementing technology applications have been identified: cost and financing; laws and policies; social values, public opinion, and politics; infrastructure; privacy concerns; resource use and environmental health; R&D investment; education and literacy; population and demographics; governance and stability. By 2020, green manufacturing techniques are likely to provide a variety of more environmentally friendly alternatives to manufacturing processes that currently use or produce hazardous materials. Using these methods, manufacturers will be able to sustain levels of production in what will likely be a stricter regulatory environment, while consuming fewer non-renewable resources, creating less hazardous waste streams, and having reduced impact on the environment.

Additive manufacturing (3D printing) will reduce time-consuming long distance transports of product or components that are being produced today in processes of mass production. Additive manufacturing may thus bring back a shift of industrial production from peri-urban areas to city centers.

[6] RAND (2006)

Constant adaptability will pervade all aspects of manufacturing, from research and development to innovation, production processes, supplier and customer interdependencies, and lifetime product maintenance and repair. Products and processes will be sustainable, with built-in reuse, remanufacturing and recycling for products reaching the end of their useful lives. Closed loop systems will be used to eliminate energy and water waste and to recycle physical waste (Foresight, 2013). Advances in science and technology, especially in materials science, microelectronics and information technology, biotechnology and nanotechnology will profoundly affect manufacturing and help manufacturers master the challenges ahead (Geyer et al., 2003).

Meanwhile, it is important to note that advanced manufacturing and materials technologies are within their infancy period. Their long-term impact, particularly in terms of value chains, represents a new research area yet to be explored.

III.5 STI for health and disaster resilience

The areas of health and security are strongly related and are therefore grouped under the same section. In the following, a set of technological trends are described, together with an indication of possible impacts of each trend for developing countries. Each trend is also illustrated with a brief case description.

III.5.1 New technologies expected to make healthcare personalised, predictable, cost-effective and easy to access (including in remote places)

Human life will be greatly extended, giving growing importance to lifelong health and health innovation around the globe, and focusing on personalised, predictable and preventive medicine and self-care. Healthcare technologies will gain in importance worldwide, however with different applications for each country. As some new technologies may make treatments more complex and expensive, some argue that innovations should focus on technologies that make present treatments cheaper, more efficient and available for all (See "The Pratt Pouch" box below). Examples of such applications include targeted drug therapies and increasingly accurate diagnostic and surgical methods using biological materials and processes (EC, 2010).

Emerging technologies such as mobile systems, the Internet of things, semantic web, big data approaches, and next generation genomics may lead to a new personalised paradigm for disease risk assessment (Beyan, 2014).

Increased electrification in developing countries and spread of the use of clean fuels for cooking and heating will yield large health benefits. The transition away from the use of traditional biomass and the more efficient combustion of solid fuels will reduce air pollutant emissions, such as sulphur dioxide (SO2), nitrogen oxides (NOx), carbon monoxide (CO), and black carbon (BC) (IPCC, 2013a, p.30).

Socio-economic/developmental impacts

Reducing infectious, child, and maternal mortality rates to low levels universally by 2035, is both technically possible and economically a good investment.

Average age of populations around the world is expected to increase thanks to health technologies. The greatest gains in healthy longevity are expected in countries with developing economies as the size of their middle class population swells (NIC, 2012).

According to Global Health 2035, reductions in mortality account for about 11% of recent economic growth in low-income and middle-income countries as measured in their national income accounts, leading to a very high return on investment for health investments. The estimated benefits of further investing in mortality reduction are expected to exceed the investments by a factor of about 9-20 (Jamison et al., 2013).

Novel funding frameworks are being designed based on citizen science, crowd funding and angel philanthropy for a new health informatics and biotechnology disruptive innovation ecosystem (Hizel et al. 2014). Such funding frameworks aim to provide for personalized, predictive, preventive and participatory medicine in the developing world. In line with this, development aid may focus on supporting such funding frameworks to take full advantage of technological opportunities.

Box 3. The Pratt Pouch

The Pratt Pouch, developed by Duke University, is a ketchup packet-like container with a premeasured dose of antiretroviral medication. It allows to substantially decrease a new-born's chances of contracting HIV. It goes with a set of training materials for the pharmacists and other workers who need to fill and heat-seal the pouches (Source: World Health Organisation and Intrahealth, www.intrahealth.org, 29/10/2014).

III.5.2 Technologies for disaster resilience

Big data, social networks, increased mobile communication facilitating disaster management: Major pandemics are widely seen as the biggest threat to health globally, and prevention is difficult, due to the various ways in which a pandemic may develop makes prevention even more difficult. Also natural disasters (e.g. due to climate change) and conflicts over natural resources form an increasing threat.

Socio-economic/developmental impacts

The availability and analysis of big data from social media can support field workers in analysing the needs of people in danger in different geographical parts of an area where a disaster has taken place. Also the use of online social networks for crisis communication in developing countries may save lives (Ishengoma, 2014). In general, the use of ICT for Disaster Management (ICT4DM) has received quite some attention in the past, and now seems to get renewed attention.

Caring Cloud is one example of an assistive technology project that will deliver better care for those in need by enabling them to stay in their own homes for longer and lead more independent lives.

III.6 Urbanization and habitat

Urban areas host a continuously growing share of the global population. Creating urban living spaces that allow for an adequate quality of life, including opportunities for economic and social development, is a key challenge, particularly due to the following urban planning issues (UN Habitat 2013: 9):

- Environmental challenges of climate change and the excessive dependence of cities on cars using fossil fuels.
- The demographic challenges of rapid urbanisation, shrinking cities, and large youth populations in some parts of the world and ageing in others.
- Economic challenges of uncertain future growth and increasing informality in urban activities.
- Increasing socio-spatial challenges, especially social and spatial inequalities, urban sprawl, unplanned peri-urbanization and the increasing spatial scale of cities.
- The institutional challenges related to governance and the changing roles of local government.

Demographic, socio-economic, and political developments in urban areas are based on emerging technological developments, which may at the same time produce new strategies to address urban challenges. Economic growth in cities and improvements in infrastructure (energy or water supply, transport systems, sewage, and others) has shown to intensify urban migration (strengthening of the so-called ‘pull-factor’ (Lee, 1966). In addition, cities are a prime example for socio-technical systems, where technical and socio-economic developments co-evolve. In particular, trends concerning urbanization are strongly interlinked with other trend areas discussed in this report, such as mobility, use of natural resources or energy.

Thus, for the achievement of the post 2015 Sustainable Development Goals not just technology trends are important, but mainly the impacts of demographics, and socio-economic processes. The goal of this section is to provide insights into how ongoing and emerging technologies interact with these developments. Therefore four key trends will be discussed, including their main technological enablers, i.e. technologies that will play a central role for these trends. The four trends comprise (i) the growth of the global urban population, (ii) cities as engines of economic development, (iii) an increasing segregation and privatization of public spaces, and (iv) growing detachment of urban areas from rural areas.

The CSTD covered the priority theme of "Science, technology, and innovation for sustainable cities and peri-urban communities" during its sixteenth session. A report of the UN Secretary General prepared for that session provides an overview of how STI can address key challenges of rapid urbanization, particularly in developing countries, and proposes technology and policy options with a view to promoting sustainable urban development (CSTD, 2013)[7].

III.6.1 Strong growth of urban and suburban population

The rise in the global urban population remains a continuing trend, led by Asia, Latin America and particularly Africa. By the year 2050, the global share of people living in urban areas will be approximately 66% respectively 6.2 billion (UN-Department of Economic and Social Affairs World Urbanization Prospects, 2014: 7). However, growth rates vary greatly across cities around the globe. In many regions, medium-sized cities are expected to grow faster than megacities with over 10 million inhabitants (Cohen, 2006: 73-75; EEA, 2014: 11). One particularly strong trend is that of an extension of city areas: efforts to promote a reurbanization of the city core, also known as ‘densification’ or ‘compact cities’, are unlikely to compensate for the trend towards sub-and peri-urbanization.

Main enabling technologies

There exist a range of technologies that enable and support the trend of continued urban population growth. All of them have a common characteristic in that they allow for a more efficient organization of society. This includes, e.g., an improvement of transport infrastructure, in engineering, construction- and building-technologies, as well as better means to govern and administer ever-larger cities. City authorities and administration, in particular, will have access to ever more sophisticated ICT tools to manage and visualize (e.g. in geographical information Systems, or GIS) the big amounts of data

[7] http://unctad.org/meetings/en/SessionalDocuments/ecn162013d2_en.pdf

relevant to the city development. Also, cities are becoming ever smarter, meaning that the administration has access to and may combine a growing variety of data sources in real or near-real time. These includes not only the various sensors installed in the public spaces (cameras, air quality measures, traffic monitoring, etc.), but also external sources, such as satellite imaging, data on energy consumption, weather forecast, street-level imagery or mobile crowd sourcing (CSTD, 2013).

Socio-economic/developmental impacts
The trend towards larger urban areas creates a number of significant socio-economic opportunities and threats.

- Overall, if people are more concentrated in compact urban areas, huge scale effects can be achieved in building the infrastructure for providing them with services, such as housing, sanitation, healthcare or access to electricity. From a resource-requirement point of view this certainly is beneficial. However, in contrast to this global perspective cities also have a high demand on local resources, such as water, air quality, or land (e.g. in the surroundings), which may lead to a series of environmental problems.
- Ever more people will not be able to sustain themselves through agriculture, meaning that the dependence on highly productive industrial agriculture increases.
- Many people living together very closely also bring about the higher risk of diseases (Zhao, 2011, p.42). A recent example is the recent spread of Ebola.

III.6.2 Cities as economic engines

Cities are places of markets and innovation. They are at the forefront of economic wealth creation, as most innovation and paid employment tends to be located in urban areas. Therefore the urbanization process normally acts as an engine of economic development. The economic welfare generated in cities can create the starting position for the development of the whole surrounding region or country. The factors of this economic dynamism are, e.g., the existence of a skilled workforce, access to information, a creative environment, leisure time facilities and the availability of a variety of infrastructures, such as energy, water, and waste management.

Main enabling technologies
ICTs (followed by improved communication networks, increased productivity, improvements in energy, health and education sectors and by tertiarization) and enhanced transportation systems (improvement of merchandise trade and inflow of work force) accelerate both the attractivity of the city and the efficiency of all social and economic processes within the city. Combined with the benefits of the co-location of multiple companies, economic growth is the consequence of these enabling technologies.

Socio-economic/developmental impacts
Compared to their rural surroundings, cities are strong enough to generate a surplus of economic welfare. They have the potential to generate enough economic pull that most citizens may benefit from, and may therefore help to eliminate extreme poverty. This will increase access to information and adequate education upgraded by ICT-infrastructure. However, there are also downsides:

- Growing inequality, as the rich will profit more from economic growth relative to the poor (cf. below section on increase of segregation). Through higher incomes, the majority of habitants allow themselves more luxury in terms of housing (example: raising energy demand), combined with distinctive augmentation of demand for floor space. In addition, new lifestyles lead in all urban areas to smaller number of people by apartment (smaller families, single-households).
- The majority of present building plans are not designed with sufficient flexibility to meet the needs of future inhabitants with different urban lifestyles: For instance dwelling forms with shared infrastructure or with high shares of home-office-spaces.
- Even a denser (or higher) construction or a conversion of former industrial areas will probably not be able to satisfy the growing demand for space. Therefore, it is expected, at least on a medium-term, that an increasing sub-urbanization (urban sprawl) will be observable.

III.6.3 Increase of segregation and privatisation of public spaces

Emerging, improved security technologies, such as comprehensive video surveillance make it much easier to protect rich classes of population. This phenomenon is well explored especially in cities of developing and emerging countries, and is described as 'gating' (Wehrheim, 2012).

Main enabling technologies

ICT and security technologies that draw from the many sources of information on individuals, such as real-time image recognition, the use of biometric characteristics to grant individuals access to certain areas or geolocalization based on cellphone data, are among the main enablers of segregation and privatisation in cities.

Socio-economic/developmental impacts

In addition to various positive aspects of emerging ICT-technologies, this gating and gentrification process must be seen as a backlash in terms of sustainable development. The increasing social segregation is particularly evident in urban centres. These may give rise to local riots or civil war like conditions. What is more, increasing social tensions are to be expected if public spaces – for persons, classes and opinions – inside cities are gradually disappearing.

Against the broad narrative of rising living standards associated with urbanisation, the rapid growth of slums described above also represents a serious concern. Slum inhabitants endure poor living conditions and high crime rates. The lack of access to basic services is also associated with increased risks of infectious disease.

III.6.4 Lower dependence of urban areas on rural areas

Emerging technologies like solar or wind energy are promising to reduce the dependence of cities on surrounding rural areas in terms of energy supply, by enabling energy production inside urban areas. In addition, improved thermal insulation of buildings reduces the influx of fossil fuels.

The supply of urban areas with goods and resources is becoming ever more complex. While in earlier times most food and other consumer goods for cities were produced in its urban hinterland, large cities are nowadays embedded in international trade networks. Thus, while the dependence of urban areas on surrounding rural ones is decreasing, their dependence on global markets is increasing (Elmqvist, Redman, Barthel, & Costanza, 2013).

Main enabling technologies

These include decentralized energy supply, smart cities, decarbonised cities, additive manufacturing (3D-Printing), urban agriculture, water technologies, construction- and building technologies. Urban agriculture, partly based on biotechnologies, or organized in multi-storeyed platforms (e.g. construction and building technologies), can reduce the inflow of food from rural areas and increase the self-sufficiency of the urban population. An example from Hong Kong is provided below on the use of sky gardens for urban agriculture (Box 4).

Box 4. Utilizing ecosystem services in urban areas: Sky gardens in Hong Kong

Green spaces in cities are desirable for a number of reasons, including fulfilment of a number of important ecological and social functions. These include lowering air and surface temperature, intercepting and retaining rainfall water, absorbing pollutants, providing natural habitats or abating noise. In Hong Kong – one of the most densely populated cities in the world – the government has recognized a lack of such green spaces due to a clear deficit in ground-level plantable spaces. One strategy the city pursues to address this deficit is to promote so-called sky gardens. These are green areas planted on rooftops, which may have a variety of different vegetation types, ranging from mere grass-covered surfaces to ones consisting of more complex ecosystems, including trees, shrubs and grasses. After having commissioned a study on the potential for such sky gardens, the government has realized sky gardens on their new buildings whenever possible and also retrofits the roofs of existing office buildings (example adapted from Tian & Jim, 2012).

III.7 STI for sustainable transportation and mobility

Technological development in the field of sustainable transportation and mobility is expected to gain momentum in the coming years due to growing (urban) mobility demand, increasing energy prices, global economic growth and international trade as well as policy regulations for greenhouse gas emissions related to climate change. Especially the broad field of ICT technologies is expected to influence transportation towards more sustainability. An EU FP7-funded project entitled OPTIMISM used a forward-looking market analysis, including both online and other publications with a foresight perspective, in combination with an expert survey on the future relevance of identified technologies, to analyse future changes in the transportation system. According to the results of the project, the optimization of the transportation system, particularly with the use of ICTs, provides opportunities to support sustainable mobility, as described in the sections below[8].

III.7.1 Technology trends concerning the transportation system

ICT solutions in transport are key technologies supporting sustainable mobility. Telematics will optimize the transportation system with respect to infrastructure and operation with special impact on increasing efficiency of both capacity and energy efficiency:

- Especially when it comes to mobility in developing countries and urbanization in growing economies ICT supporting mass-mobility provides solutions to face related challenges. Traffic flow control and fleet management will lead to increased efficiency of traffic flow, utilization, safety and energy consumption.
- Individual motorized mobility will be improved by efficiency through vehicles information technologies, such as vehicle-to-vehicle and vehicle-to-infrastructure, in-vehicle-information, dynamic-routing and adaptive cruise control systems. Although this field of technology might not necessarily contribute to sustainability it has to be considered when implementing new transport solutions, which will have to compete with increased attractiveness of the private car.
- ICT will support the integration of vehicle and transport system technologies.
- Key technologies such as autonomous driving, compressed air car, in-vehicle and external speed-control allow for greater control of individually driven vehicles ensuring safety and optimized traffic flow, which decreases energy consumption and emissions. At the same time increased automation requires to ensure high levels of system safety in terms of technological reliability as well as security against system-attacks.
- In public transportation electronic ticketing and payment will improve services leading to a higher degree of capacity utilization.
- Smart travel cards, smartphone tickets, services and applications not only provide easy access and use of public transportation; they enable to combine different public and private services (e.g. private car sharing initiatives) – leading to seamless mobility. “Individualized public mobility” might be a consequence, providing an alternative to car use and leading to an increased share of public transportation use.

Besides ICT research and development, activities are especially found in the fields of vehicle and engine technologies, materials, infrastructure and operating technologies.

Experts in transportation were asked to rate the technologies listed for the different technologies concerning their future potential:

- **High speed trains and autonomous vehicles** were attested to be game changers in the future in the field of vehicles, while electric vehicles were most promising in engine technologies followed by hybrid and efficient fuel vehicles. Concerning sustainability these technologies might lead to improvements, hiding risks on the other side. Due to optimized transport solutions incentives to travel might increase inducing demand for mobility and thus in sum leading to less-sustainable transport conditions.
- Technologies supporting mobility based on **substitutes of fossil fuels** and decreasing greenhouse gas emissions may also serve as game changers. Electric-vehicles, as long as driven by renewable energy, hybrid or solar energy driven vehicles are promising technologies in this context.

[8] http://www.optimismtransport.eu

- **Material technology** leading to lightweight constructions has potential to support sustainable mobility providing the necessary basic materials for increased efficiency and optimized vehicles.
- Breakthroughs in implementation of **nano-solutions** in batteries or engine technologies, materials etc. would change the whole world of transportation leading to less resource intensive production, energy efficiency and thus improve sustainable mobility (Hoppe et al. 2013a).
- Technologies outside the transportation system enabling the **substitution of physical mobility** such as communication or virtualization technologies or even 3D-printing would lead to more sustainable mobility – as well as communication technologies enabling combination of modes.

III.7.2 Assessment of potential socio-economic impacts

These technological innovations, especially in the field of ICTs, will provide more convenient, seamless ways to travel. It will be possible to combine public and individual transportation more easily, leading to a more open market for mobility services, stronger user involvement like “democratisation in transportation” and new business opportunities leading to a greater variety on the supply side. For the given industries, competition will increase[9]. Such new solutions will also lead to increasing efficiency in the transport system. Meanwhile, effects concerning sustainability will depend on several factors. For instance, improved transportation and accessibility might induce additional traffic. A number of factors will also shape demand: increasing trade (also related to online activities), wealth and income development leading to more/less leisure mobility, degree of urbanization and urban sprawl as well as centralization or decentralized concentration of the economy, to name only a few. And some technology driven economic and socio-economic developments might interfere with mobility related technologies, leading to a virtualization of the working environment, changes in consumer behaviour, living habits and mobility behaviour.

On the socio-economic and economic side, technological development for transportation and sustainable mobility will cause a fundamental change. Depending upon the development and implementation of the above-mentioned technological innovation combined with trends in transportation, mobility could become more:

- Crowded, as mobility demand, partially induced by improved supply, will further increase.
- Complex, as new technologies will require skills and training to be managed.
- Exclusive, as affordability of mobility, also driven by cost for technologies will lead to social gaps.
- Vulnerable, as extreme weather events or attacks will affect the transportation system, which due to increasing complexity and ICT became more vulnerable.
- Diversity-driven, as the shift of economic growth will lead to mobility solutions tailored for the local culture; at the same time, innovative technological solutions will increase variety in mobility (see also Hoppe et al. 2014).

Not only will the transportation industry have to embrace, develop and implement new technologies, but also the population will have to adapt to the new mobility system. Ability to cope with such change is not equally distributed – neither in industries nor across different population groups. Thus, inequalities will have to be tackled as well as new risks related to increasing system complexity. The socio-economic impacts and the higher degree of technological standards will require both additional investments in infrastructure and result in higher maintenance costs.

[9] cf. EU FP7-funded project RACE2050 results http://race2050.tau.ac.il/race2050/ or Hoppe 2013b.

IV. Policy implications of key STI trends for the Post-2015 Development Agenda

IV.1 Role of international cooperation and collaboration in STI

International cooperation and collaboration in STI is recognised as being increasingly important, both in providing the basis for effective participation in the global knowledge economy, and in marshalling the resources to address major global challenges. Collaboration is a key vector of innovation-related knowledge flows[10]. R&D-active firms tend to collaborate more. While collaboration with higher education and public research institutions is mainly an important source of knowledge for large firms, it is more frequent with other market actors, particularly suppliers and clients. Suppliers play a key role as value chains become more integrated. Collaboration with foreign partners can play an important role in the innovation process by allowing firms to gain access to a broader pool of knowledge and resources at lower cost and to share risks.

The motivations for research collaboration have been identified as falling into two categories:

- Direct benefits to the S&T concerned, allowing the research to be performed or applied at a higher quality, with a broader scope, more quickly or more economically than would be the case without cooperation;
- Indirect benefits arising from the existence of the cooperation. These may accrue directly to the participants (for example through enhancement of reputation, access to further research funds) or more generally to the countries involved in terms of political economic or social benefits.

The direct benefits include: access to complementary expertise, knowledge or skills, access to unique sites, facilities or population groups, sharing costs and risks, and addressing transnational or global problems.

IV.1.1 Drivers of globalisation of STI

R&D and science and technology more generally are some among many areas from culture to markets that are becoming global. This reduces the influence of individual countries or blocs on developments both at home and abroad but also generates important benefits through specialisation, trade and competition. While STI is still strongly focused on developed countries, this pattern is weakening, as especially the large emerging economies' role in global science, technology and production continues to increase. Given that changes in the location of R&D, cooperation patterns and human capital production all have long lead times, policies need to anticipate a future where knowledge production and use is increasingly multipolar and globally networked (EC, 2012).

The internationalisation of STI occurs through a variety of processes, including:

- Through public or private research institutes or universities, through the international mobility of S&T students and researchers and international collaboration among S&T researchers.
- By firms that develop R&D activities internationally, at home and abroad. The R&D done at home uses inputs from abroad, through the recruiting of foreign S&T employees and building on existing knowledge located abroad. The R&D done abroad enables use of locally available S&T human resources and sourcing of locally available know-how. In addition, firms are exploiting their innovations on world markets, through licensing their technologies abroad or selling their innovations on foreign markets.
- International collaboration in S&T, where partners (firms and research institutes) from more than one country jointly research and develop technological know-how and innovations.

The on-going globalisation and internationalisation of STI is affected by a number of drivers:

[10] The 2011 General Electric Global Innovation Barometer indicates that forty per cent of all innovation in the next decade is expected to be driven by collaboration across institutional and national boundaries (GE, 2011).

- The globalisation of the world economy drives firms to increasingly access scientific sources outside their local boundaries.
- Students and researchers are increasingly mobile. As a consequence, scientific institutions and firms are competing for talent in a global labour market.
- The ICT/Internet revolution has reduced the cost of international communication and boosted international exchange in science. These trends are amplified by reductions in real transport costs of the last few decades.
- ICTs and the Internet have also fostered new ways of gathering knowledge, leading to innovative international knowledge transfer models in the fields of fundamental research.
- The research agenda is increasingly focused on issues that have a global dimension, such as climate change, energy, safety and pandemics.
- Policymakers are increasingly focusing attention on international S&T cooperation and funding programmes to stimulate internationalisation of higher education and research. This includes many governments from emerging economies, which have come to view STI as integral to economic growth and development. To that end, they have taken steps to develop their S&T infrastructures and expand their higher education systems. This has brought a great expansion of the world's S&T activities and a shift toward developing Asia, where most of the rapid growth has occurred.
- Costs of and access to infrastructure lead to stronger incentives to cooperate and share resources across boundaries.
- Increased specialisation of knowledge production results in excellence being spread across the world and hence makes it vital to identify and access it, wherever it is.
- Scientific knowledge is being produced with greater speed and impact, creating incentives to avoid duplication.

IV.1.2 Meeting global challenges through international cooperation in STI

Global challenges are not new, but have increased in urgency and scope. STI can play an important role in addressing them. Despite the ongoing globalisation of STI and evident benefits of collaboration, STI cooperation efforts at the international level can be hard to achieve in practice. Addressing such complex issues call for effective governance mechanisms. Good governance practices have been identified from a study of major global STI collaborative schemes (OECD, 2012b). These include the following:

- The institutional framework for priority setting should be flexible.
- Flexible funding and spending mechanisms help ensure stability.
- Knowledge sharing and IP management require a tailored approach.
- Outreach is indispensable for putting STI into practice (technology transfer).
- International collaboration needs to include countries with weaker STI capacities, because these countries may be the most affected by certain global challenges.

Important policy lessons that have been drawn are:

- The need for high level coordination.
- The governance structure must be a learning system tailored to the needs of the specific collaboration and allow for active and responsive adaptation.
- It must establish and maintain linkages between local, regional, national and international levels to avoid duplication and maintain transparency between stakeholders.
- Outreach from the research community to other stakeholders should be a priority.
- Knowledge sharing and IP provisions should be adapted to each stage of the collaboration life cycle.
- Capacity building is an essential component.

Such lessons certainly apply in the specific context of cooperation on strategic foresight. Given the need to prepare their workforce to disruptive technology trends, developing countries may benefit from new educational approaches to adapt their STEM workforce. One example is provided through the concept of Massively Online Open Courses.

IV.2 Implications of technology foresight for the Post-2015 Development Agenda

The horizon scanning exercise and foresight research conducted for this paper produced a broad and vibrant range of new technologies under the chosen themes. Wide differences exist between the implementation capacity, investment cost and long-term impact of each technology. Furthermore, policymakers are confronted with the question of context and relevance when evaluating these technologies.

One of the main lessons derived from the analysis of technology trends in Section III is the evidence provided on the *increasing role of converging technologies*, as discussed in the sections on biotechnology, nanotechnology, and advanced manufacturing. *ICTs are key drivers of such convergence, and increasingly omnipresent under various socio-economic topics* including food production, mobility, urbanization, energy supply and health, which is why they are not mentioned in a separate section. A more widespread use of ICT will allow for a much more efficient management of society. This applies to a variety of issues, ranging from farming to energy supply.

Developing countries can tap into the potential created by such trends and benefit from previous experiences of countries that have already undergone high levels of technological integration, without having to go through the learning curve from scratch. For example, they can already benefit from 'nano' as a common theme, as it is already known that nanotechnology has a multi-topic role in food, health and environmental quality in support of the SDGs and overall development.

It is important to note that such technological convergence cannot produce positive developmental outcomes on its own. On one hand, ICTs and electrification create more targeted technologies that address specific, small and niche problems at the individual levels, such as in agriculture, healthcare and good governance. On the other, the increased variety that results does not necessarily imply that inequalities are overcome, and in several cases it was seen that *inequality was further expanded* (e.g. mobility, urbanization). Likewise, technologies need to be complemented with behavioural change and incentives to have a significant impact. For example, emissions can be substantially lowered through changes in consumption patterns (e.g., mobility demand and mode, energy use in households, choice of longer-lasting products) and dietary change and reduction in food wastes. A number of options including monetary and non-monetary incentives as well as information measures may facilitate behavioural changes apart from technological measures (IPCC 2013a, 21).

As part of the research conducted for this Issues Paper, the implications of the key technology trends identified in Section III on the seventeen draft SDGs were analysed (OWG, 2014; UN, 2014). Each of the identified key trends and associated opportunities were evaluated according to how strongly they would contribute to achieving the SDGs. Not surprisingly, *the identified key STI trends support the SDGs related to their thematic fields the strongest*. For instance, trends of technologies with regards to natural resources show the strongest support towards the SDGs related to environmental sustainability. The weakest support is achieved in relation to SDGs where the acceleration and integration of technological change that could lead to long-term support is not clearly associated, such as those encompassing "end poverty" or "achieve gender equality" (cf. Table 2).

More effort is required to develop sustainable development models that are capable of minimizing, if not resolving trade-offs across the different dimensions of sustainable development or different policy objectives (UN, 2014). Energy, water and food security, land use issues, development policy, and climate policy continue to be addressed in fragmented way. Sustainable development highlights the need for integrated approaches to finding solutions that are commensurate with the challenge of achieving economic, social and environmental goals that are often interlinked. Hence implementing the post-2015 development agenda will require greater coherence between policy communities involved in development co-operation, sustainable development and climate change. Improving co-ordination and ensuring complementarities and synergies among existing processes, such as between the Sustainable Development Goals, the climate change agenda, the G20 and the Global Partnership for Effective Development Co-operation, as well as the involvement of key stakeholders will be critical for success. *International collaboration in STI, but also inter- and transdisciplinarity in addressing complex societal challenges, should be a key ingredient of the Post-2015 Development Agenda.*

V. Recommendations for policymakers and conclusion

The global horizon scanning exercise on STI issues for the post-2015 development agenda conducted for this paper has once more confirmed that "foresight and STI policy are closely interlinked". While foresight has so far been applied mainly in developed countries, other countries have also been discovering the potential of foresight for STI policy, especially during the last decade (cf. Section II). Meanwhile, foresight studies also face some challenges in terms of fulfilling their potential contribution to the shaping and future orientation of STI policy. Foresight studies are largely based on expert knowledge that stems from a scientific or engineering background. Foresight can identify promising STI fields based on expert knowledge, but cannot overcome the uncertainty of achieving success in meeting urgent societal challenges in a given time. Foresight is of a long-term nature, which can be a drawback due to the strong expectation of an immediate return on investment from the financial resources invested in such studies and science in general.

V.1. Technology foresight and sustainable development

Technology foresight not only provides approaches and methods about scanning issues that can be measured today (i.e. trends), but also indicates to policy-making those future issues or wild cards that are not yet considered in policy design but must be tackled today if we are to develop our societies in a sustainable way. The main added value is to show that different, interlinked policy fields must be aligned to enable policy to tackle current and future challenges. Among other fields, strategic foresight makes particular sense in addressing sustainable development challenges. There are strong similarities between future-oriented issues from the foresight approaches and the topics reflected in sustainability indicator systems (Carabias et al. 2012b). *Using technology foresight as an input to sustainability monitoring systems can help policy-making in terms of developing a better understanding of unsustainable trends.* The respective needs for correction or prevention can be identified by collecting data to better monitor emerging issues that are currently not well covered by indicator systems. Combining sustainability monitoring with anticipatory activities could therefore enhance policy support in developing more adaptive and anticipatory approaches to better orient societal change towards sustainable development.

While technology can be expected to further develop and advance at a fast pace, the societal impact of technological trends will fall short of those of socio-economic ones, such as population dynamics and economic growth in developing countries, or shifts in global power structures. This is why *technological trends should never be analyzed in an isolated way, but always in the context of these wider, socio-economic trends*. On the contrary, integrative approaches striving for technically but also socio-economically innovative and sustainable solutions are required to catalyse development, such as for instance to reduce energy consumption, to promote the use of renewable energy, and to cut CO_2 emissions. In addition, knowledge generation has to go hand in hand with knowledge and technology transfer to finally enable the implementation of innovative actions along the SDGs. Technology transfer is happening too slowly to tackle the big sustainable development challenges. Technological capabilities in developing countries need to be substantially strengthened if they are to actively take part in the major technological transformations that lie ahead (UN, 2014).

V.2. Technology foresight and investment

Many of the discussed trends are closely linked to infrastructure development (e.g. electricity grids, transport infrastructure or ICT) that has long lifetimes of several decades. This is why today's decisions (e.g. on urban development) have a high long-term impact. In particular in a development context, investments that will relieve many people's budgets (such as in efficient public water or electricity supply systems) may be much better spent than the currently widespread subsidies of fuels, water and food that are in place in many countries.

Each individual sub-section in Section III shortly addressed the conditions under which these technologies can most suitably flourish. Looking at a broader perspective of overall policy measures, it is clear that *fostering an innovative private sector* will activate the embedding of ICT, nanotechnology, etc. into more established business sectors, as most of these technologies are based on a convergence of research and business, as well as new approaches for private sector implementation.

V.3. Technology foresight and innovation policy

Currently, foresight studies are used for detecting future societal challenges, the assessment of potential technological developments and the identification of gaps and needs for immediate, mid-term and long-term measures. However, *foresight studies also have the potential of being used for the anticipation of potential policy measure impacts and the identification of the next generation of innovation policy related measures.* Here a new field for applying foresight studies is likely to arise in the near future. Governments and companies usually react to changes by trying to adapt rather than being able to manage them properly, let alone being able to anticipate and welcome change. Multiple factors influence the ways in which the future will evolve and existing institutions have not yet been able to develop a fully systemic view of current and possible future situations to be prepared to properly shape the future. CSTD member States could build a continuous and shared approach to steer and adapt innovation systems in response to societal challenges, and to strive towards the achievement of SDGs through the development of robust STI agendas, including periodic evaluation of what has or has not been achieved. Such evaluations are indispensable to inform policymakers so that they can correct deviations and continually adapt to new situations.

V.4. International cooperation on technology foresight

The technology foresight in this report can be used as a starting point for additional foresight studies that look at specific contextual implications, for example to identify whether other technologies exist for more precise applications or whether synergies may arise from the combined approach of STI trends. This can be achieved through smaller working groups for specific topics linked to the SDGs where a high potential is seen based on the results and discussion of this report. *In this context, CSTD member States could consider undertaking Strategic Foresight initiatives on global and regional challenges at regular intervals*, by including different stakeholders' perspectives in providing solutions, to enhance their awareness of technology trends that may have an impact on their future development plans, particularly in terms of attaining the SDGs.

While a clear trend is observable towards institutionalisation of foresight, it is also important to understand the advantages and disadvantages of different organisational models for addressing future societal challenges. The implementation of individual strategic foresight projects or programmes of a limited duration and with targeted objectives provides an alternative model to the dedicated in-house Foresight Units, which can provide continuous input to their embedding or mother organisations. Different combinations of elements of these ideal-type models are possible, including (international) foresight networks, such as the International Foresight Academy, as informal but nevertheless stable settings that can bundle or coordinate resources and competencies. Ultimately, the appropriate model of Strategic Foresight (i.e. external foresight services, setting-up of dedicated Foresight units, and foresight networks) will strongly depend on the wider institutional and organisational environment in which foresight is to be embedded, be it in the private or the public sector (cf. Weber et al., 2012; Bitar, 2013).

Box 5. International Foresight Academy

The recently created International Foresight Academy is the first organisation to bind together foresight activities around the globe and from a wide range of cultural and political contexts. Foresight activities vary with regard to their functions in political priority-setting and strategy formulation of modern democracies. Many foresight practitioners value the possibility granted by foresight exercises to bring topics on the political agenda that need to be discussed with broad public involvement (http://ifa.cgee.org.br/, 10.11.2014).

In this respect, the CSTD's potential role in catalyzing such collaboration initiatives for conducting further technology foresight exercises at international and Member State levels will be crucial. The CSTD could promote collaboration between scientific communities, including the global foresight community, and other relevant stakeholders to think, debate and shape future developments using strategic foresight methodologies. Foresight experts all over the world are committed to provide support in the implementation of initiatives such as technology foresight collaborations in developing countries, to advise on the approach and methodologies to be used and how to transform insights from technology foresight exercises into policy actions.

Finally, CSTD member States could cooperate towards establishing a 'fully-fledged mapping system'. For example, there is a need to add more interactivity to the mapping process, i.e. a move from the simple dissemination of mapping results to a more collaborative, possibly crowd-sourced co-production of mapping knowledge. Given that foresight activities tend to involve a wide range of stakeholders, the active participation of foresight practitioners and users in the process of mapping foresight practices, players and outcomes will be beneficial. In this context, the absorptive capacity to effectively integrate foresight findings into policy-making would need to be further developed.

Appendix I. Questions for discussion

1. With regard to the technology trends covered in Section III of the Issues Paper, do you agree with them, including their impact assessments? How relevant are these STI trends for your country? Would you propose other key trends that are more suitable for your specific national and regional context?

2. How can technology foresight be used to inform the Post-2015 Development Agenda on a regular basis and how can it contribute to the implementation of the Agenda?

3. How can findings of technology foresight exercises be used for more informed policy action and future investment decisions (particularly in the context of critical infrastructure needed for sustainable development and attaining the SDGs)?

4. How can the STEM workforce be prepared for the converging, disruptive technologies of the future?

5. Have foresight studies been conducted in your country before? What methodologies have been used? What are some of the good practices and lessons learned?

6. What are the key issues regarding institutional capacity and the requirements for undertaking such activities on a regular basis?

7. Which foresight models are more suitable for your national context? (for example, choosing between establishing dedicated in-house foresight units or undertaking limited-duration/sectoral foresight projects)

8. How can foresight studies contribute to a better understanding of societal challenges?

9. How can the private sector be involved in national foresight studies?

10. What in your view are some of the potential collaboration opportunities -- in the private or public sectors, involving multi-stakeholders -- between countries and regions that face similar development challenges?

11. What role can the CSTD play in catalysing foresight collaboration initiatives?

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