Revised Draft Paper

Strategic Foresight for the Post-2015 Development Agenda

Abstract / Summary

The United Nations (UN) Commission on Science and Technology for Development (CSTD), during its 17th session held in 12-16 May 2014, selected the following as one of its two priority themes for the 2014-2015 inter-sessional period: 'Strategic Foresight for the Post-2015 Development Agenda'. As basis for the upcoming discussions on this priority theme, the present background paper is based on a global horizon scanning exercise on Science, Technology and Innovation (STI) issues for the post-2015 development agenda. In addition to analysing the future STI issues and their implications for overall development, the paper concludes with policy recommendations to be considered by national governments and other relevant stakeholders during the CSTD inter-sessional period and 18th session.

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[1] The views expressed are purely those of the authors and may not in any circumstances be regarded as stating an official position of the European Commission or any other organisation.

I. Introduction

The eight Millennium Development Goals (MDGs) – which range from halving extreme poverty to halting the spread of HIV/AIDS and providing universal primary education – have been a milestone in global and national development efforts. The framework has helped to galvanize development efforts and guide global and national development priorities. Nevertheless, the outcome document of the 2010 High-level Plenary Meeting of the General Assembly on the MDGs requested the Secretary-General to initiate thinking on a post-2015 development agenda and include recommendations in his annual report on efforts to accelerate MDG progress. The outcome of the Rio+20 Conference on Sustainable Development initiated an inclusive intergovernmental process to prepare a set of sustainable development goals (SDGs). There is broad agreement on the need for close linkages between the two processes to arrive at one global development agenda for the post-2015 period, with sustainable development at its centre (cf. UN, 2014). The Economic and Social Council will play a major role in the preparations, monitoring and implementation of a post-2015 development agenda (Ecosoc, 2013).

In UN (2012) the Task Team established by the Secretary-General outlines a vision for the post-2015 development agenda and suggests four key dimensions of inclusive economic and social development, environmental sustainability as well as peace and security (cf. Fig. 1). This vision aims to provide a more holistic guide to international and national policymaking than that provided by the MDG framework.

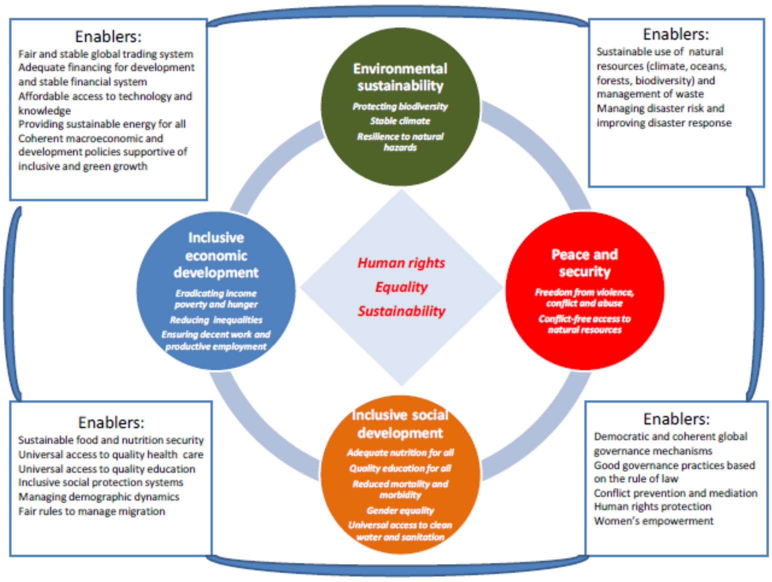

Fig. 1: Integrated framework for the post-2015 UN development agenda suggested by UN (2012).

UN CSTD (2013) frames Science, Technology and Innovation (STI) as a core issue for sustainable development. At the 17th session of the United Nations (UN) Commission on Science and Technology for Development (CSTD), a resolution requested that the CSTD should continue exploring the roles of STI in the post-2015 development agenda. For upcoming discussions within the UN-CSTD, members of the International Foresight Academy (IFA) and additional foresight experts have been invited to analyse future STI issues and their implications for overall development in this background paper. **Section 2** provides first an introduction to **horizon scanning and foresight** on STI for development. Through the meta-analysis of recent and extant foresight reports including UN reports, **key STI trends** that are likely to be relevant for development (and developing countries) in the post-2015 period have been identified and are now presented in **section 3** together with a critical assessment of their potential socioeconomic and developmental impacts. **Section 4** draws **lessons learned** for the definition of the future global development framework and **section 5** presents **conclusions and recommendations**. At the CSTD Inter-sessional Panel, representatives of the Member States will have the chance to comment and give feedback on the draft outcomes in a Foresight Café to benefit from the collective development expertise (cf. The World Café, 2008).

II. Horizon Scanning on Science, Technology and Innovation for Development

Strategic foresight is vital for any forward planning or policy activity to be able to meet future challenges proactively. Foresight enhances such thinking by gathering anticipatory intelligence from a wide range of knowledge sources in a systematic way and linking it 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). We can hold on:

- Foresight provides a number of tools to support participants (i.e. policy makers, experts and other stakeholders) to develop visions of the future and pathways towards these visions.
- It allows for debating, collective sense-making and finally shaping the future.
- Foresight is more and more perceived as a valuable policy instrument involving systematic attempts to look into longer-term future of STI and their potential impacts on society with a view of identifying the areas of scientific research and technological development likely to influence change and produce the greatest societal benefits for the future.

Carabias et al. (2012a, 2013) see strategic and technology foresight as a means to manage inclusion of different stakeholders' perspectives in providing solutions, to steer and adapt innovation systems in response to grand challenges, and to support the development of smart specialisation strategies to generate robust Science & Technology and innovation agendas in a globalised era. With FOREN (2001) we can summarize "foresight is a systematic, participatory, future intelligence gathering and medium- to long-term vision-building process aimed at present-day decisions and mobilising joint actions".

Horizon scanning is regarded as "a creative process of collective sense-making by way of collecting and synthesising observations that hold potential for the elaboration of pertinent future developments and the derivation of actionable implications for decision-making" (Könnölä et al. 2012). Technology foresight not only provides approaches and methods about scanning issues that can be measured today (i.e. trends), but also indicate 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. Here, 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 particularly sense in addressing sustainable development challenges. The analysis provided by Carabias et al. (2012b) reveals strong similarities between the future-oriented issues from the foresight approaches and the topics reflected in the sustainability indicator systems. Such comparisons can help policy-making in terms of developing a better understanding of unsustainable trends and the respective needs for correction or prevention. The findings also suggest that data collection could be enhanced to better monitor emerging issues that are currently not well covered by indicator systems. Today's sustainability indicator systems offer information on past and present states but provide limited support for understanding future developments. 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 (Carabias & Haegeman, 2013).

Foresight 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 sought to set priorities, to build networks between science and industry and, in some cases, to change their research system and administrative culture. Foresight has been used as a set of technical tools, or as a way to encourage more structured debate with wider participation leading to the shared understanding of long-term issues (Georghiou et al., 2008).

Technology foresight is regarded as the most upstream element of the technology development process. It provides inputs for the formulation of technology policies and strategies that guide the development of the 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. It has increasingly been recognized worldwide as a powerful instrument for establishing common views on future development strategies among policy-making bodies, bridging the present with the future. Its unique feature stems from a wide participation of a large number of stakeholders and experts, namely, the government, science, industry and civil society. The broad aim of technology foresight is to identify emerging generic technologies likely to yield the greatest economic and social benefits (UNIDO, 2005).

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 professionalisation of the field in support of organisations at the interface of science and decision-making (Carabias & Haegeman, 2013).

Mapping Foresight Initiatives

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 (including foresight, horizon scanning, technology assessment and forecasting) 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 world (ibid.). Popper (2008a) also highlights that information technology (IT) tools are being increasingly applied to most of the foresight approaches, especially interaction- and evidence-based activities. Many applications are available now 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. In this analytical paper we have revisited the no-longer-active EFMN, iKnow and EFP databases to look into the Top 10 foresight methods using a sample of 957 cases from seven regions: North-West Europe, Southern Europe, Eastern Europe, Latin America, North America, Asia and Africa. Their frequencies are presented hereafter:

- (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

The European Foresight Monitoring Network (EFMN, 2005-09), iKnow (2008-11), and the European Foresight Platform (2009-12) were European Commission funded initiatives aimed at advancing and interconnecting knowledge generated through foresight and horizon scanning activities.

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])

The table 1 above presents the Top 10 cases per region. The results show some similarities, such as the use of *expert panels* as one of the top 3 methods across all regions, and some interesting regional features, e.g. frequent use of *key technologies* in Southern Europe and North America. Despite the similarity in the selection of some methods, these regions differ in the way methods are applied in foresight processes. Here, we adapt Keenan and Popper (2008) descriptions of the current ''status'' of foresight adoption and use in each region. In addition, Bitar (2013) provides an overview on long-term studies in Latin America.

Box: Foresight adoption and use in different world regions

Northwest Europe (511 cases from Austria, Belgium, Denmark, Finland, France, Germany, Iceland, Ireland, Luxembourg, Netherlands, Norway, Sweden, Switzerland, and United Kingdom) – There has been an explosion 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 missing from the EFMN database. 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) – It has been particularly difficult to map African foresight experiences. 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), UNIAIDS, 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.

However, 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* (dependency 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).

In spite of still having some of the mapping data available online at www.mappingforesight.eu, the interfaces and functionalities linked to the database require further work in order to achieve 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, crowd-sourced co-production of mapping knowledge. Given that foresight activities tend to involve a wide range of stakeholders, it seems reasonable to expect the active participation of foresight practitioners and users in the process of mapping foresight practices, players and outcomes. The absorptive capacity to effectively integrate foresight findings into decision-making needs to be further developed.

By scanning recent and extant foresight meta-studies and literature related to relevant sub-themes of the post-2015 development agenda, respective information that can be used to derive policy lessons will be compiled and discussed in expert panels at the upcoming CSTD Inter-sessional Panel.

III. Key trends in STI and opportunities emerging from them for development

A critical meta-analysis of relevant forward-looking reports / technology foresight studies that gather attention has been carried out for each of the following key trends in STI and development of relevance in the post-2015 context. Foresight experts from different world regions (cf. section acknowledgements in the beginning), most of them members of the International Foresight Academy, provided inputs and contributed to the development of this paper. In this way, key technology trends were identified from recent literature and their socio-economic as well as developmental impacts have been assessed.

In the following sub-sections, these key technology trends with a potential of being game-changers in the post-2015 context are being presented (incl. brief trend description, case-studies and examples) and their socio-economic and developmental impacts assessed. For the finalization of this paper, it will be important that participants to the CSTD 2014-2015 Inter-sessional Panel will take the opportunity at the Foresight Café to comment actively on the draft paper in a constructive way.

III.1 Technologies related to natural resources

As they grow, economies tend to use more resources – both renewable biological resources (cf. EEA, 2014d) and non-renewable stocks of minerals, metals and fossil fuels (addressed in this sub-section). Industrial and technological developments as well as changing consumption patterns associated with growing prosperity all contribute to this increase in demand.

While the rising living standards that drive these trends are unquestionably welcome, they create obvious 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).

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 (EEA, 2014; OECD/FAO, 2014; Sage, 2013; Bommarco et al., 2013). Within this very broad context, a few key trends – often derived from scenario development – are highlighted in the following.

III.1.1.1 Nanotechnologies

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 our ability to detect and remedy environmental deterioration (EEA, 2011). Examples include nanotechnologies for energy conversion and storage (for example dye-based solar power cells).

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 in developing countries, researchers are optimistic that the potential improvements will also soon be felt amongst developing nations (Alexandratos, N. & Bruinsma, J., 2012).

Socio-economic/developmental impacts

Developing nations can increase the competitiveness of producers in developing countries, and improve their market access (Gruére et al., 2011).

Applications of nanotechnologies in all areas will be significant tools in contributing to global issues, including food security and poverty. Nanomaterials are likely to enable development of functional building materials such as self-healing and self-cleaning concretes. Nanofilters are likely to be employed in developing regions of the world to provide potable water by 2020 (RAND, 2006).

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

As meat production is increasing due to a 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). However, meat alternatives are 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. Acceptance of alternative meats is challenging (Smil, 2014).It could have financial, health, animal welfare and environmental advantages over traditional meat (Tuomisto, Teixeira de Mattos, 2011).

III.1.1.3 IT in agricultural production

The implementation of sensors is more and more used for real-time tracking of crops, animal and machines. Automation of specific tasks by robots or microrobots, such as harvesting, picking, weeding, irrigation, etc. (Business Insider, 2014). Use of mobile phones provides access to markets, fertilizer and weather reports for farmers, as well as suppliers, retailers and policy makers (USAID, 2013b).

Socio-economic/developmental impacts

Developing countries are very agriculturally productive, but have a large potential for efficiency improvements (Godfray, Garnett, 2014). Step change improvements in productivity help to relieve the pressure of food security in developing countries. Continuous technological inputs help to maintain increases in yields (Godfray et al., 2010).

III.1.1.4 Engineering new markets

Engineering innovations to open up new opportunities, markets and methods, such as vertical farming and closed ecological systems (Business Insider, 2014). However, research and investment differs widely between emerging and developing countries which is not in line with the agricultural productivity (Sage, 2014). Intellectual property has shifted development from public to private sector.

Socio-economic/developmental impacts

New locations and potential markets buffer against climate change vulnerability in agriculture production (Sage, 2014).

High technological innovations will be diffused at different speeds when related to infrastructure provision.

III.1.1.5 Functional foods

Functional foods have optimised nutritional aims to supply dietary requirements for improving the body, decreasing risk, or even curing, disease (Bigliardi, Galati, 2013). First developed in Japan in 1991 as foods for specified health use (FOSHU) 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 (Sage, 2014).

Aging populations are looking to have an improved quality of life in their later years and functional food addresses this (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 (OECD, 2012a; UNEP, 2012; UN-WATER, 2014). 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 which consume less water, energy or capital are being explored (OECD, 2012a). Key technological trends to address these problems are presented in the following.

III.1.2.1 Decentralized and sustainable sanitation to replace open defecation

New sanitation systems in developing countries address the cost and institutional problems associated with the traditional expansion and connection to a centralized piped waste water 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 (SEI, 2012). 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 that minimize health risks and environmental impacts with low upfront costs (Katukiza et al., 2012).

III.1.2.2 Energy and nutrient recovery from waste water

The energy and nutrient content of waste water has been realized and the trend is of capturing this ‘waste’ stream and recovering it for reuse. For energy production, anaerobic digestion processes of waste water and solids produces a methanol based biogas (Katukiza et al., 2012). Recently, microbial fuel cells produce electricity from the metabolism of microorganisms treating the waste water (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 larger economic development context (Cordell et al., 2011).

Infrastructure constraints for implementation, when new technology, involve renovation of current sanitation system.

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

Separation processes which remove pollution, salts, or solids from fresh or waste water 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 (Hopewell, Graham, 2014).

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 entails 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).

Technologies are developing and 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 are 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. This is why the majority of the growth will be due to developing countries (mainly in China and India, see, e.g., IEA, 2013b), while for developing ones it is widely expected to stabilize in the mid-term. 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 developed 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 developed countries, not only will efficiency improvements be overshadowed by population and economic growth, 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 (IEA, 2014). In developed countries, where a reliable electricity supply is widely guaranteed, this will be due to the widespread implementation of electric cars (e-mobility, IEA, 2013a) or heat pumps. In developing countries It will mainly be the more widespread use of ICT that enable economic and social development (IEA, 2014; WBCSD, 2011).

Socio-economic/developmental impacts

Access to new economic potential through service provision, access to broader markets, communication and information exchange (Bhattacharyya & Palit, 2014).
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

If implemented with a holistic, long term perspective: improves quality of life, access to job markets, health services, and behind it all, energy security.
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).

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 (Haselip, Nygaard, Hansen, & Ackom, 2011). However, after 2015, the climate financing may not be as readily accessible to the non-Least Developed Countries. 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, Chew, 2014) and higher energy prices.

Socio-economic/developmental impacts

Develop energy sovereignty 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). For an overview of different renewable energy technologies for developing countries see UNCTAD (2010).

Socio-economic/developmental impacts
Develop energy sovereignty. Advantages are that renewables are widely carbon neutral, can be modularly implemented, are rapidly online, and can be used to connect between regions (IRENA, 2014; Madrigal & Porter, 2013). However, their impact in different world regions depends on the local availability of renewable resources (e.g., wind and sun), which are a key determinants of the generation cost.

Box: Case Study of 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 Columbia 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, but 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 policy 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 wide spread 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 (Painuly, 2001).

Socio-economic/developmental impacts
Diversification, and thus security, of 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 will either require additional reserve capacities or demand side management measures to ensure supply adequacy (Madrigal & Porter, 2013). 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 (Grijalva & Tariq, 2011) making traditional supply chains rather resemble networks. 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.

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 present 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 their 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 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 (IRENA, 2014). Integration of energy and transport systems may be benefiting 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 (Bitar, 2013).

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 this, for example, 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 expands (Bhattacharyya & Palit, 2014).

Socio-economic/developmental impacts

Large upfront costs require long term financial viability, but small-scale and off-grid are possible for energy sovereignty in the face of institutional challenges (Bhattacharyya & Palit, 2014).In developing countries, decentralized (so-called off-grid) electricity systems are promising, although they require a form of storage or a high flexibility in demand in order to avoid costly transmission systems and minimize grid power losses over long distances (Sims et al., 2007).

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 (see Supply of Energy above: Bhattacharyya & Palit, 2014).

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

Communities in developing countries, who are particularly dependant on primary raw resources (and who, additionally, often do not have the means for producing higher valued products), are the 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 it is known that environmental consideration is only taken when socio-economic existence is stable.

Thus, as an extension from the previous point, emerging technologies that are implemented in these communities will have important impacts if the technology:

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

Separate from the direct technology, but relevant for technology investments: Carbon offset funding has many additional side benefits for developing communities, as many standards (see CDM, The Gold Standard) now require additional sustainable development measures beyond carbon. As access to financing facilities and transparent implementation continues to burden the development system, carbon financing as private investment continues to hold potential.

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 the 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 (robust evidence, high agreement). 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, p.27). 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) (limited evidence, medium agreement).

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, p.19).

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 (robust evidence, high

agreement). 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 (robust evidence, high agreement). 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 (high agreement, robust evidence). 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 (limited evidence, medium agreement) up to 2029, frequently involving modernization of existing equipment (IPCC, 2013a, p.27).
Change in annual investment flows (cf. Fig. 2) from the average baseline level over the next two decades (2010 – 2029) for mitigation scenarios that stabilize concentrations within the range of approximately 430 – 530 ppm CO2eq by 2100. Investment changes are based on a limited number of model studies and model comparisons. Total electricity generation (leftmost column) is the sum of renewables, nuclear, power plants with CCS and fossil fuel power plants without CCS. The vertical bars indicate the range between minimum and maximum estimate; the horizontal bar indicates the median. Proximity to this median value does not imply higher likelihood because of the different degree of aggregation of model results, the low number of studies available and different assumptions in the different studies considered. The numbers in the bottom row show the total number of studies in the literature used for the assessment. This underscores that investment needs are still an evolving area of research that relatively few studies have examined.

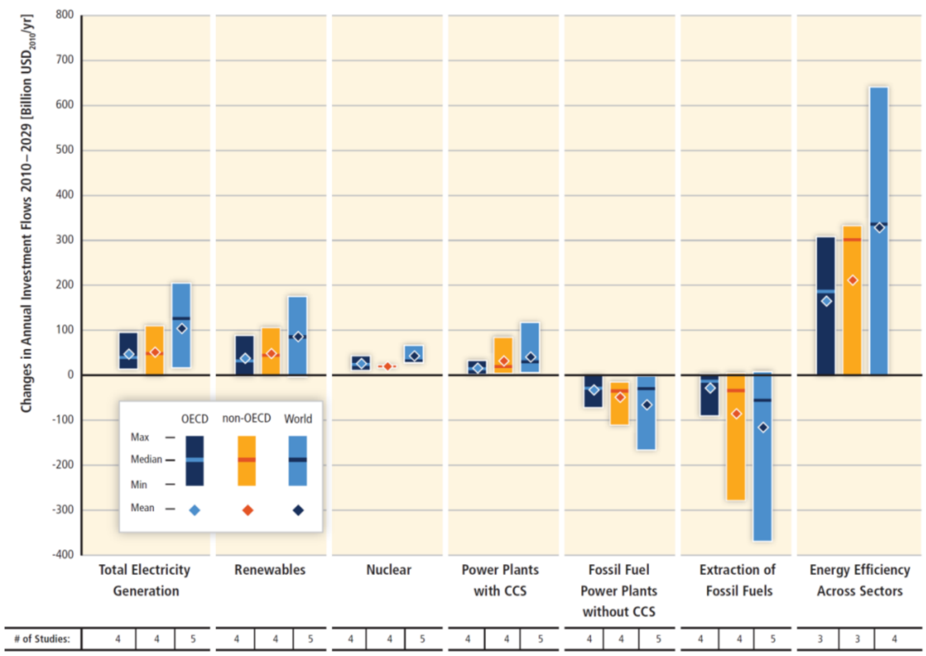

Fig. 2: Annual Investment Flows in Technological Measures estimated by IPCC (2013a, 28).

The costs of achieving nearly universal access to electricity and clean fuels for cooking and heating are projected to be between USD 72 and 95 billion per year until 2030 with minimal effects on GHG emissions (limited evidence, medium agreement). A transition away from the use of traditional biomass and the more efficient combustion of solid fuels reduce air pollutant emissions, such as sulfur dioxide (SO2), nitrogen oxides (NOx), carbon monoxide (CO), and black carbon (BC), and thus yield large health benefits (IPCC, 2013a, p.30).

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 (IPCC, 2013a, p.25).

Systemic approaches and collaborative activities across companies and sectors can reduce energy and material consumption and thus GHG emissions (robust evidence, high agreement). The application of cross-cutting 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 (robust evidence, high agreement) (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 (very high confidence). 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 in OECD (2012a) model different technology pathways to reduce emissions. These scenarios all aim at achieving the same 450 ppm emission pathway, with the same timing of emission reductions but assume 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 these 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 region is projected to follow a different mitigation strategy, predominantly relying on increasing renewable energy sources. This region 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 (nano-, bio-, ICT), advanced manufacturing

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 technological change will also affect economic sectors that have been slower to change in the past, notably energy and transport (EEA, 2011).

III.4.1 Technology trends related to converging technologies

Twelve potentially economically disruptive technologies were identified by McKinsey (2013) among them: *Mobile Internet* - Increasingly inexpensive and capable mobile computing devices and Internet connectivity; *Automation of knowledge work* - Intelligent software systems that can perform knowledge work tasks involving unstructured commands and subtle judgments; *The Internet of Things* - Networks of low-cost sensors and actuators for data collection, monitoring, decision making, and process optimization; *Cloud technology* - Use of computer hardware and software resources delivered over a network or the Internet, often as a service; *Advanced robotics* - Increasingly capable robots with enhanced senses, dexterity, and intelligence used to automate tasks or augment humans; *Autonomous and near-autonomous vehicles* - Vehicles that can navigate and operate with reduced or no human intervention; *Next-generation genomics* - Fast, low-cost gene sequencing, advanced big data analytics, and synthetic biology ("writing" DNA); *3D printing* - Additive manufacturing techniques to create objects by printing layers of material based on digital models; *Advanced materials* - Materials designed to have superior characteristics (e.g., strength, weight, conductivity) or functionality; *Advanced oil and gas exploration and recovery* - Exploration and recovery techniques that make extraction of unconventional oil and gas economical.

III.4.1.1 Biotechnology Trends and Applications to 2020

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. RAND (2006) suggests that by 2020, the following applications of biotechnology will be technically feasible:

- 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.4.1.2 Nanotechnology Trends and Applications to 2020

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. RAND (2006) suggests that the following applications of nanotechnologies will be feasible by 2020:

- 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.

III.4.1.3 Materials Trends and Applications to 2020

This multidisciplinary field 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:

- 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)

III.4.1.4 ICT Trends and Applications to 2020

The increasing availability of information and the growth of communication networks have been major factors in the globalization of the 20th century (cf. also section III.5). RAND (2006) focused in its foresight study of information and communications technology on the integrated development over the next 15 years of semiconductor materials processing and fabrication, mathematical algorithms, MEMS, nano electro mechanical systems (NEMS), smart materials, and biomaterials and biomedical devices, suggesting that the following may be feasible by 2020:

- Wireless Internet available worldwide to middle and upper classes, including developing countries and rural areas
- Wearable computers expanded to control medical devices, appliances, and entertainment systems
- Massive databases (hopefully with robust security) holding personal information such as history and log of information viewed or processed, as well as such items as medical records and genomic information
- Small and inexpensive devices storing massive data such as voice, video, and Web pages
- Increasingly improved search capabilities to locate not only text phrases but semantic phrases, pictures, and video through both meta representations and exemplars (without which the data storage would be useless)

- RFID tags to track commercial goods, consumer buying patterns, and even individual movement for security and targeted advertising
- Biometrics (e.g., fingerprints, iris scans) widely required for travel, for security access to computers and locations, and, perhaps, for commerce
- Small ubiquitous cameras and widespread sensor networks with increasingly small size and unobtrusiveness
- Hands-free machine interfaces and input devices (e.g., light scanned directly to the retina).
- Implants that connect directly to the brain and nervous system

III.4.2 Assessment of socio-economic/developmental impacts

RAND (2006) identified the following drivers and barriers to implementing technology applications: 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 nonrenewable resources, creating less hazardous waste streams, and having reduced impact on the environment.

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).

III.5 ICT for capacity-building, citizen empowerment and good governance, STEM workforce, higher education and vocations (incl. Open Labs, Better Access and Preservation of Scientific Data)

Advances in ICT have changed almost every aspect of society and economy since 1990s. It changes how people think and live, how business operate and how the government run due to increased automation, ubiquitous access to information, pervasive human networking and wider connectivity between economy (IEEE 2014, McKinsey 2014). At the same time it casts serious challenges to the society such as digital divide, breach of privacy etc. However, we are expecting more tectonic shift in socioeconomic systems due to disruptive innovations in ICT. The convergence of ICT with other technological development will lead to full utilization of its potential and results in so-called universal ICT. (cf. section III.4; McKinsey 2013, Atlantic Council 2013).

III.5.1 Technology trends related to ICT

ICT becomes smarter than ever before and competes with human even in the area where human intelligence was needed such as legal and healthcare market (Brynjolfsson 2014). Many of human tasks will be replaced by ICT as far as it is routine regardless of manual or cognitive works.

ICT becomes more pervasive in every scale of society and economy regardless of time zone and location in the world. It is just matter of time even for underdeveloped countries to enjoy full benefit of ICT. The numbers, shapes, and sizes of computing devices will increase and connectivity will grow in both locally and globally. In addition, human knowledge, intelligence and its existence are increasingly enhanced and augmented.

Future ICT needs seamless interface for connection. As connection grows rapidly and exponentially, seamless networking is essential in which transition from one network device to another should be transparent and uninterrupted.

Assigning of unique identity of things will be key challenge and will cause the security concern for government and citizens. Many forms of identities, identification and authorization method will be urgently needed as almost every object will have their own IP address in near future. Although access would be authorized based on capabilities and access tokens rather than strictly on real identity, it might be vulnerable to identity theft and to loss of privacy.

Convergence of ICT with other sector (cf. section III.4.1.4) will be accelerating in various scale and scopes. The traditional model of physical location based and face to face education is rapidly changing due to the availability of better methods for both augmented by automated and interactive learning like MOOC. Advanced robotics such as autonomous vehicles (car, drones), unmanned factory, 3D Printing would cause disruptive transformation in whole industrial landscape permanently.

Governance on ICT continues to be key concerns to each stakeholder. The new form of governance is needed to take full advantage of advances in ICT for betterment of healthcare, education, science, security etc. The gap between the developed and underdeveloped would continue to increase due to bad governance and policy which is no good even for the developed country due to the disruption in global connectivity.

III.5.1.1 Massively Online Open Courses (MOOC)

Massively Online Open Courses (MOOC) are free, high-quality, university-level course content that can be provided to anyone with internet access (international scale). Low-income countries can utilize full potential of MOOC for building and enhancing of human capacity. The leading universities, especially in US are actively engaging in MOOCs for brand enhancement, pedagogic experimentation, recruitment and business model innovation though it is sliding Into the trough (Gartner 2014, BIS 2013). The impact would be tremendous due to its potential to reach millions of students with no cost. However, it may be not easy task which it seems to fail in living up to original promise (The Economist, June 24, 2014). It needs to changes in educational structure and design that could cause collapse of traditional college and faculty system though not all of them will suffer. Currently less than 8% of applicant completes the course and assessment and authentication are still challenges. There is no clear sustainable business model.

Socio-economic/developmental impacts

Used to enhancing capacity building for low-income countries, for the job seeker (IEEE Computer Society 2014; MIT 2012).

III.5.1.2 Big Data and Analytics

It is about collecting and sharing of exponentially grown data and extracts the insight through analysis due to advancement of Internet and cheap storage cost. 40 zetta bytes of data will be created by 2020. It will help discover hidden insights, improve decisions, by enriching information for decision makers and automate business processes. According to Hype cycle by Gartner, big data has just passed the top of the Hype Cycle, and moving toward the 'Trough of Disillusionment'. However there are several barriers for full exploitation of big data potential. For example, volume itself isn't the only thing to deal with. The variety of Information may hinder the data integration. Management of large datasets (HW & SW), validation, interpretation through analytics and conflict in privacy is not to be underestimated.

Socio-economic/developmental impacts

Retailing, healthcare, security etc. Remote sensing and other big data approaches have great potential for assessing long-term sustainable development progress (IEEE Computer Society 2014, McKinsey 2013, McKinsey 2011, MIT 2014a, UN 2014, US White House 2014a, US White House 2014b)

III.5.1.3 Internet of Things (IoT)

IoT is a network of low-cost sensors and actuators for data collection, monitoring, decision making, and process optimization, providing ubiquitous interconnectivity. It will be major disruption in logistics/supply chain management through automation and reduce wastes through just-in-time delivery are expected. According to McKinsey (2013), there will be 300% increase in connected machine-to-machine devices over past 4 years. In 2025, one trillion things could be connected to the Internet across industries such as manufacturing, health care, and mining (McKinsey 2013). However, in addition to technical difficulty in data collection/analytics, regulation on privacy is a big concern as same in big data.

Socio-economic/developmental impacts

Major disruption in Logistics/supply chain management through automation. Reducing waste through just-in-time delivery (IEEE Computer Society 2014, MIT 2014b).

III.5.1.4 Cloud Computing

Cloud computing is distributed data center transitioned from centralized mainframes to clients networked. Any computer applications or services could be delivered with minimal or no local software or processing power required. Currently in 18 months, the server performance per dollar is doubled. Global users of cloud-based email services like Gmail, Yahoo, and Hotmail will reach to 2 billion and 80% North American institutions will host or be planning to host critical applications on the cloud by 2025 (McKinsey 2013).

The cloud technology will provide platform for the explosive growth of Internet-based services, from search to streaming media to offline storage of personal data (photos, books, music), as well as the background processing capabilities that enable mobile Internet devices to do things like respond to spoken commands to ask for directions. The cloud can also improve the economics of IT for companies and governments, as well as provide greater flexibility and responsiveness. Finally, the cloud can enable entirely new business models, including all kinds of pay-as-you-go service models.

Huge change is expected in economic dynamics through exponential growth in Internet based services such as searching, media streaming, social network service. It also provides the great flexibility in company and government responsibility.

Socio-economic/developmental impacts

Economic dynamics in social network service are expected to change (IEEE Computer Society 2014, MIT 2011).

III.5.1.5 Robots

There is a new kind of robot due to advancements in machine vision, artificial intelligence, machine-to-machine communication, sensors, actuators and materials. The medical robot can be used for delivery, telemedicine and robotic surgery. Autonomous and near autonomous car and drone are expected to totally change the transportation system. If Baxter in manufacturing is used as a main source of labor, the impact will be tremendous. However, regulations to will be a key issue to promote the adoption of technologies.

Socio-economic/developmental impacts
If robots are used as a main source of labour, the impact will be tremendous; Advances in relevant technology; Regulations; Customers' acceptance (IEEE Computer Society 2014, McKinsey 2013).

III.5.1.6 High-Performance Computing (HPC)
In 1965, Gordon E. Moore, co-founder of Intel described the future trend that the number of transistors in a dense integrated circuit doubles approximately every two years and it came true. Fast and big calculation due to advances in HW, SW and tools will change everything that needs big computational calculations with high speed and big data. However scaling within power limits will depend on device/component such as MEMS, photonics etc. that may cause the serious challenge in green computing. Hardware and software will be other challenges.

Socio-economic/developmental impacts
Changes everything that needs big computational calculations with high speed and big data (IEEE Computer Society 2014).

III.5.1.7 Quantum Computing (QC)
QC utilizes quantum mechanical phenomena to execute our computations that fundamentally change our approach to computing and algorithm. The larger impact is bigger than that of transistor but it needs fundamental research.

Socio-economic/developmental impacts
Artificial intelligence aimed at creating computing systems that can learn from data (IEEE Computer Society 2014).

III.5.1.8 Natural User Interfaces
It is important to have interaction in a natural way using speech, gestures, and intelligence, and interface with computers to boost-up the efficiency and productivity in gaming, shopping, IT service where creative and comfortable interaction is needed. For example, Siri and Kinect have changed the way for the human to interact with computer by replacing traditional keyboards. However the legacy of old programming of UI hinder the full adoption of natural user interface. Future direction of technical advances will be toward more predictive, anticipatory, and adaptive, contextual awareness.

Socio-economic/developmental impacts
Technical advances being predictive, anticipatory, and adaptive, contextual awareness (IEEE Computer Society 2014).

III.5.1.9 Nanomaterial, nanodevice (MEMS) & nanoparticle
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 device and components to run IC product and process.

Socio-economic/developmental impacts
Healthcare; Manufacturing – high performance with small and low energy consumption; Replace current all storage/memory; Nonvolatile memory influencing big data accessibility and portability (IEEE Computer Society 2014, McKinsey 2013).

III.5.2 Assessment of potential socio-economic impact

Capacity-building:
"Massively Online Open Courses (MOOC)" could lead to wide range of educational/vocational innovation through large-scale online participation that operates via the creation of networks. There are already several MOOC sites operating. For example, "Coursera" (www.coursera.org/about/community) has 22,232,448 enrollments from students across 571 courses, representing 190 countries. Though there are still controversial on the effectiveness and future potential of MOOC, it seems quite certain that the developing countries are one of most beneficiaries.

Citizen empowerment:
ICT could facilitates a shift of paradigm of participation in policy making, with a more open research process sharing good and bad experiences through digital media and collaboration efforts. The collective intelligence and new collaborative knowledge creation leads into emergence of new disciplines and connections to policy alternatives (UN CSTD 2014).

Good governance:
The recent ICT innovations such as big/open data and analytics from various social media lead to more information and knowledge exchange as well as enhanced connectivity, openness and transparency on all levels. Citizens today are more aware of their rights, have better access to information on public services and consequently have higher expectations of service levels, especially as they become accustomed to private sector organisations providing customisation and other benefits (EC DG Communication networks 2013).

Higher education:
ICT will also continue to transform work, enabling more agile workflows and reducing costs. The idea of a fixed physical workplace will change as new technologies allow remote working with realistic experiences.

Vocations (incl. Open Labs, Better Access and Preservation of Scientific Data):
There is little doubt that these practices are beneficial for firms as well as for workers, yet many workplaces in Europe (in both the private and public sectors) resist change (Beblavy et al., 2012), mostly because of implementation costs, an unclear regulatory framework or a lack of skills.

III.6 STI for global health and security

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.6.1 New technologies are 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. Examples of such applications include targeted drug therapies and increasingly accurate diagnostic and surgical methods using biological materials and processes (EC, 2010).

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).

In order for resource-limited countries to benefit from disruptive innovations based on advances in healthcare, Hizel et al. (2014) present a novel funding framework based on citizen science, crowd funding and angel philanthropy for a new health informatics and biotechnology disruptive innovation ecosystem 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.

Case for healthcare trend: 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.6.2 Resource technologies (technologies ensuring the security of vital resources) will be on the rise

Necessary resources to meet the demand of a growing world population for food, water and energy are under increasing pressures such as lack of supply, volatile prices and distorting effects of climate change. Examples of such technologies include precision agriculture, water irrigation techniques, solar energy, etc. (NIC, 2012). For example, 70% of global fresh water withdrawals are used for agriculture (up to 90% in developing economies) but inefficiencies in water use are high, esp. in traditional irrigation. 55% of the world’s population is expected to be dependent on food imports by 2030 as a result of insufficient domestic water (WEF Initiative; Boden et al., 2010).

Socio-economic/developmental impacts

Developing countries may benefit from early adoption of new resource technologies.

Poor countries will be affected disproportionately by the effects of climate change, water scarcity and lack of food at affordable prices (Boden et al., 2010), increasing the risks of increasing illness and death rates in developing countries (IPPC, 2007) due to malnutrition, injury due to extreme weather events, diarrhoeal diseases, increased frequency of cardio-respiratory and other diseases. Developing countries may therefore benefit from taking a lead in developing and adopting next-generation resource technologies (NIC, 2012).

Case for resource trend: Since years SolarAid is aiming at eradicating the kerosene lamp from Africa by 2020 and replacing them by solar lamps. The solar lights do not only save money (for the kerosene) and CO_2 emissions (331 thousand tonnes saved in the lifetime of the project), but also reduce health problems such as coughing, chest problems, eye irritation and illness due to indoor toxic fumes. Improved health links back to income, education and well-being (SolarAid Impact Report, 2014).

III.6.3 Global rise of use of mobile technologies

According to Pew Research Center (2014) and the World Bank, internet and mobile technologies have become part of daily life in many parts of the world. The internet penetration is still rather limited in developing countries, but once people do gain access to the internet, they quickly begin to integrate it into their lives. A significant part of those who use it, tend to use it on a daily basis (PewResearchCenter, 2014; World Bank, 2013).

Socio-economic/developmental impacts

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 to big parts in the world, esp. developing countries (add references). 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 (Wattegama, 2007; UN-APCICT/ESCAP, 2009), and now seems to get renewed attention.

Small mobiles (and other ICT applications) can make big changes in agriculture: 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 (www.e-agriculture.org). In the Asia-Pacific region also tablet computers with low-cost architecture that can be connected to cell phone networks have become very popular (FAO, 2013; www.ictinagriculture.org; www.e-agriculture.org, 29/10/2014). 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.

Mobile technology for disease prevention and personalised medicine in developing countries: 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). The degree to which limited-resource countries will benefit from such shift may well depend on specific funding frameworks that particularly focus on developing countries (see Hizel et al. (2014) and technological trend 1).

Case for mobile technology trend: 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.7 Urbanization and habitat

Urban areas host a continuously growing share of the global population. Thus, creating urban living spaces that allow for adequate qualities of life, including opportunities for economic and social development, is a key challenge for urban development. In particular, according to UN Habitat (2013: 9) the major challenges for future urban planning are:

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

The following selection of key technological trends concerning urbanization refers to these challenges of the 21st Century. Technological development and new, emerging technologies may at the same time be a key driver of these challenges and also produce new strategies to address them. Moreover, cities are places, where many trends converge and manifest. In particular, trends concerning urbanization are strongly interlinked with other trend areas that are discussed in this report, such as mobility, use of natural resources or energy (cf. for example in Bitar, 2013).

III.7.1 Technologies as enablers for most of demographic, socio-economic, and political developments in cities

Demographic, socio-economic, and political developments in urban areas are based on emerging technological developments. 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. 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 motors of economic development, (iii) an increasing segregation and privatization of public spaces, and (iv) a growing (in)dependency of urban from rural areas.

III.7.2 Strong growth of urban and suburban population

The rise in global urban population remains a continuing trend. The economies of Asia, Latin America and particularly Africa, are catching up in their industrial development which is about to be completed in North-America, Europe or Japan (cf. Fig. 4).

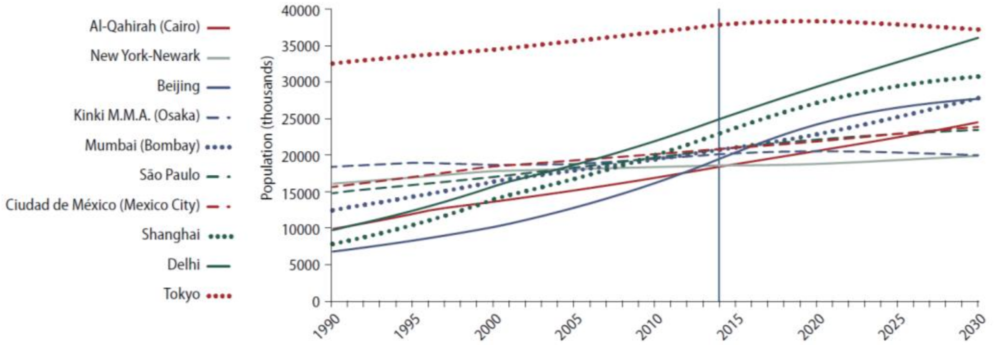

Fig. 4: The ten largest urban agglomerations in 2014 show varied growth patterns (UN-Department of Economic and Social Affairs World Urbanization Prospects, 2014: 14).

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, this growth does not happens synchronously in cities around the globe. In many regions, medium-sized cities are expected to grow faster than Megacities (over 10 Mio. Inhabitants) (Cohen, 2006: 73-75; EEA, 2014: 11).
One particularly strong trend is that of an extension of cities' areas: efforts to promote a reurbanization of core cities is unlikely to compensate for the trend towards sub-urbanization (Keil 2013, see also section 8.4.).

Main enabling technologies
There exist a range of technologies that enable and support the trend of continued urban population growth. All of them have in common 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 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, google street view or mobile crowd sourcing.

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

- Overall, if people are more concentrated in 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 (Seto, Parnell, & Elmqvist, 2013).
- 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.

Case study ICT services in urban areas: Online system for handling civic affairs in Seoul (example cited from EEA, 2014: 19)
Seoul's executive leadership has sought to encourage more citizen input into metropolitan city management (they enabled for civil society and non-profit organisations to request audits of agencies, encourage their direct participation in controlling corruption and even offering financial inducements towards this aim. City officials made excellent use of Korea's very high rate of internet dissemination to craft an online system for handling civic affairs. They encouraged direct citizen representation in the decision-making process through various committees and 30% of these committees' members are required to be women.

III.7.3 Cities as economic 'motors'
Cities are the places of markets and innovation. They are on the forefront of economic wealth creation, as most innovation and paid employment tends to be located in urban areas (EEA, 2014 b: 14). Therefore the urbanization process normally acts as a motor of economic development. The economic welfare generated in cities (Pearce Neal et al, 2012; UN Habitat, 2012; EEA, 2014b: 14) 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 skilled working force, 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
ICT (followed by improved communication networks, increased productivity, improvements in energy, health and education sectors and by tertiarization) and the 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 collocation of multiple companies, economic growth is the consequence of these enabling technologies.

Socio-economic/development 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 profit, and may therefore help to eliminate extreme poverty. This will increase access to information and adequate education upgraded by ICT-infrastructure.
However, the downsides are

- Growing inequality, as rich will profit more from economic growth relatively to the poor (cf. below section III.8.4 Increase of segregation). With increasing incomes, the majority of habitants allow themselves more luxury in terms of housing (example: raising energy-demand), combined with e 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 (Keil, 2013).

III.7.4 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 (Koskela, 2000). The phenomenon in cities, especially in poor and emerging countries is well explored and 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.

Socio-economic/development 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 due to globalization processes.
Against the broad narrative of rising living standards associated with urbanisation, the rapid growth of slums described above represents a serious concern. Slum inhabitants often endure squalid living conditions and high crime rates. The lack of access to basic services is also associated with increased risks of infectious disease (EEA, 2014b: 14).

III.7.5 Growing (in)dependency of urban from rural areas

Some emerging technologies concerning raising efficiency of consumption of resources are promising to leave the long tradition of the dependency of city by their surrounding rural areas behind us. Solar or wind energy can be partly produced inside urban areas. Improved thermal insulation of buildings reduces the influx of fossil fuels.
The supply of urban areas with good and resources becomes 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 dependency of the urban areas from the surrounding rural ones is decreasing,

the dependencies from global markets is increasing (Elmqvist, Redman, Barthel, & Costanza, 2013).

Main enabling technologies
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 multistoried platforms (e.g. construction and building technologies), can reduce the inflow of food from rural areas and add some independency for the urban population.

Socio-economic/development impacts
Additive manufacturing 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 urban areas to city centers.
As the spread of urban areas results in a lack of space for food production, small-scale peri-urban market gardening can make up for shortages of healthy, fresh food and generate employment. Peri-urban farms can even reuse urban wastewater for irrigation purposes. Production of fruit and vegetables in private, small farms ("Market gardening") close to cities can be less costly than supplies from rural areas due to lower transport costs. It can also help contain urban sprawl by creating urban green belts. Mozambique demonstrates the best example for successful market gardening in Africa. The Government created so-called "green zones" by organizing horticulture cooperatives in the capital city Maputo and other major cities. They play a key economic role through healthy small-scale production and supply of fresh vegetables, the creation of employment opportunities and use of urban wastewater for irrigation purposes (FAO, 2012:71–73; UN, Report of the Secretary-General, 2013: 11).

Case study on utilizing ecosystem services in urban areas: Sky gardens in Hong Kong (example adapted from Tian & Jim, 2012)
Green spaces in cities are desirable for a number of reasons: They are not just nice to look at but also fulfil 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. Between 2007 and 2012 they over 100 sky gardens on new and over 60 on new government buildings could be realized.

III.8 STI for sustainable transportation and mobility

Technological development in the field of sustainable transportation and mobility is expected to increase in dynamic 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. According to the results of the EU FP7-funded project OPTIMISM the optimization of the transportation system by information and communication technology provides opportunities to support sustainable mobility as described in the following technology trends (http://www.optimismtransport.eu/). A forward looking market analysis is underlying this including both online and other publications with foresight perspective – combined with an expert survey on the future relevance of identified technologies.

III.8.1 Technology trends concerning the transportation system

IC solutions in transport are key technologies supporting sustainable mobility; telematics will optimize the transportation system with respect to infrastructure and operation with especial 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 (cf. Fig. 3).

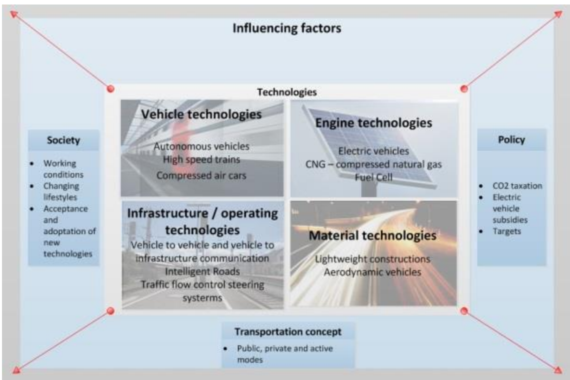

Fig. 3: Innovative technology fields in transportation as result of a forward looking market analysis according to OPTIMISM (Hoppe et al. 2013a).

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 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.
- 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.

Described technological innovations, especially in the field of ICT will provide more convenient, seamless ways to travel. Public and individual transportation will be combinable 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 (cf. EU FP7-funded project RACE2050 results http://race2050.tau.ac.il/race2050/ or Hoppe 2013b).

New solutions will lead to increasing efficiency in the transport system. Effects concerning sustainability will depend on several factors:

- Improved transportation and accessibility might induce additional traffic.
- Impact factors will 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.
- Other technology driven economic and socio-economic developments might interfere with mobility related technologies, e.g. leading to a virtualization of the working environment, changes in consumer behaviour, living habits and mobility behaviour.

III.8.2 Assessment of potential socio-economic impacts

On socio-economic and economic side, technological development in transportation and for sustainable mobility will cause a fundamental change. According to the development and implementation of described technological innovation combined with trends in transportation, mobility will become more:

- Crowded, as mobility demand, partially induced by technology improved supply, will further increase.
- Complex, as new technologies will require skills and learning to use.
- 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 Asian culture; the same is true for innovative technological solutions, which will increase variety in mobility (see also Hoppe et al. 2014).

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

III.9 Role of international cooperation and collaboration in STI, inter- and transdisciplinarity to address complex challenges, globalization, multipolar world

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 (cf. UN, 2014).

The OECD STI Scoreboard summarises the situation along the following lines: Collaboration is a key vector of innovation-related knowledge flows. R&D active firms tend to collaborate more. Collaboration with higher education and public research institutions is mainly an important source of knowledge for large firms. Collaboration 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 (OECD, 2013).

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 motivations for research collaboration have been identified as “falling into two categories: (1) 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; (2) 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.” (Geoghiou, 1998)

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.

III.9.1 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. STI is still strongly focused on the ‘Triad’ countries overall. However, this pattern is weakening fast, 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:

- 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.
- ICT and 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 focussed on issues that have a global dimension, such as climate change, energy, safety and pandemics.
- Policy makers 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, who 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 globally results in excellence being located more diversely 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.

III.9.2 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. However STI cooperative efforts at the international level can be hard to achieve. Addressing such complex issues call for effective governance mechanisms (OECD, 2012b).

Good governance practices have been identified from a study of major global STI collaborative schemes. These include:

- 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.

Box: International Foresight Academy (http://ifa.cgee.org.br/, 10.11.2014)

The recently created International Foresight Academy is the first organisation to bind together foresight activities around the globe and from contrasting 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.

IV. Lessons learned for the definition of the future global development framework

The horizon scanning exercise and foresight research produced a broad and vibrant range of new technologies in the chosen themes. Wide differences exist between the implementation capacity, investment cost and long-term impact of each technology, and this is then a question of context and relevance for the local decision-maker. As ICT continues to penetrate various socio-economic topics as a point of converging technologies, including food production, mobility, urbanization, energy supply and health, the potential is very high that the developing world is exposed to and takes up a very high level of technological integration, thus benefitting from previous experiences of other world regions. There is certainly a high potential in the relationship that exists between electrification and access to new technologies based on electricity, as the economic opportunities and access to new markets have a wider and longer social impact. On one hand ICT 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. However, 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). Finally, 'nano' can also be taken as a common theme, as nanotechnology had a multi-topic role in food, health and environmental quality. Evidence is provided for the increasing role of converging technologies, at the head ICT and nanotechnology, in support of SDGs and overall development.

Each individual sub-section shortly addressed the contexts and capacities where these technologies can most efficiently take root. 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.

Implications of the key trends for harnessing Science, Technology and Innovation (STI) for overall development in a sustainable way are summarized in the following Table 2, i.e. linking the main technology trends identified in section III with the SDGs (OWG, 2014; UN, 2014), and therefore indicating elements for a post-2015 development agenda.

Key trends in STI related to / SDG	III.1 Natural Resources	III.2 Energy Systems	III.3 Climate Change	III.4 Converging Technologies	III.5 ICT for capacity-building	III.6 Health and Security	III.7 Transport and Mobility	III.8 Urbanization	III.9 Internat. Collaboration. in STI
1. End poverty	weak	weak		weak		weak		weak	weak
2. End hunger	strong					weak	weak		weak
3. Ensure healthy lives	weak	weak	weak	weak	weak	strong	weak	weak	weak
4. Ensure lifelong learning		weak		weak	strong	weak		weak	weak
5. Achieve gender equality		weak			weak	weak		weak	weak
6. Ensure availability of water	strong	weak	weak	weak				weak	weak
7. Ensure access to energy	strong	strong	weak	weak	weak		weak	strong	weak
8. Promote economic growth	weak	strong		weak	weak	weak	strong	strong	weak
9. Build resilient infrastructure	weak	weak	strong	weak	weak				weak
10. Reduce inequality		weak			weak				strong
11. Make cities inclusive, safe		weak			strong	strong	weak	strong	weak
12. Sust. consumption / production		weak	weak	strong	weak				weak
13. Combat climate change impact	strong	strong	strong	weak	weak		weak		strong
14. Sustainably use the seas	strong		weak				weak		weak
15. Sustainably use the land	strong	weak	weak				weak	weak	weak
16. Promote peaceful societies					weak	strong			strong
17. Global partnership for SD			weak		weak	weak	weak	weak	strong

Table 2: Estimation of how each of the identified key trends and associated opportunities help towards achieving the different SDG (● strong support, ● weak support, ○ ambivalent/neutral)

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 covering the key dimension “environmental sustainability” highlighted in Fig. 1. Obviously, the roles of international collaboration in STI but also of inter- and transdisciplinarity addressing complex societal challenges support in a stronger or weaker way all SDGs. 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 to minimize if not resolve trade-offs across the different dimensions of sustainable development or different policy objectives (UN, 2014).

However, the global horizon scanning exercise on STI issues for the post-2015 development agenda has once more confirmed that “foresight and STI policy are closely interlinked” (Gokhberg and Sokolov in Meissner et al., 2013). While foresight has so far been applied mainly in developed countries to a large extent for significant time transition, other countries are discovering the potentials of foresight for STI policy only for the last decade (cf. section II). The doubtless potential of foresight studies’ contribution to the shaping and future orientation of STI policy is challenged in several ways. Foresight studies are to a large share based on expert knowledge which stems from scientific or engineering background. Having said this, it becomes obvious that foresight might identify promising STI fields but still cannot overcome the uncertainty of achieving success in meeting urgent societal challenges in a given time. Foresight is of a long term nature but there is a strong presence of the immediate proof of return on these financial resources invested into science.

Currently, foresight studies are used for detecting future challenges towards society, 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. Future studies and analysis are gaining momentum in both developed and emerging countries. 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 (Boden et al., 2010). There is a latent need to position UN Commissions within adaptive and dynamic global institutions in order to achieve global governance structures capable of addressing global and common challenges.

V. Conclusions and recommendations

Technology foresight not only provides approaches and methods about scanning issues that can be measured today (i.e. trends), but also indicate 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. Here, the main added value is to show that different, interlinked policy and technology fields must be aligned to enable policy to tackle current and future challenges. Among other fields, strategic foresight makes particularly sense in addressing sustainable development challenges. Today's sustainability indicator systems offer information on past and present states but provide limited support for understanding future developments. Combining sustainability monitoring with anticipatory activities could therefore enhance policy support in developing more adaptive and anticipatory approaches to better orient societal and technological change towards sustainable development (Carabias & Haegeman, 2013; Destatte, 2010).

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. And technological capabilities in developing countries need to be substantially strengthened if they are to partake actively of the major technological transformations that lie ahead (UN, 2014).

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 decision (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.

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.

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).

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.

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 (OECD, 2014).

The technology foresights in this report can be further used as a starting point for additional foresight studies to look at specific contextual implications and 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 key topics within the SDGs where a high potential is seen based on the results and discussion of this report.

In this context, to consider undertaking Strategic Foresight initiatives on global and regional challenges at regular intervals is critical to building a common understanding of current situations and to translating it into common visions of the world's future to be jointly pursued and therefore enhancing the awareness of such technology trends on their path towards attaining the SDGs. To build a continuous and shared approach to understand the present, to look at different future possibilities and to shape a direction to follow, coupled with an evaluation of what has or has not been achieved from time to time to correct deviations and to continually adapt to new situations would help to give evidence for taking action by policymakers (Boden et al., 2010). Foresight could anticipate the need for STI action and change the course of existing action, thus contributing to an ongoing renewal of the approach to sustainable development by emphasizing its systemic and holistic aspects (Carabias et al., 2012b), and in that way strengthening the definition of future global development framework and related roadmaps.

While the trend towards institutionalisation of foresight may appear obvious, it is 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 (cf. section III.9.2), as informal but nevertheless stable settings which 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).

In this respect, the UN-CSTD's potential role in catalyzing such collaboration initiatives for conducting further technology foresight exercises at international and Member State levels will be crucial. Moreover, the Member States are encouraged to consider the use of strategic and technology foresight as a means to manage inclusion of different stakeholders' perspectives in providing solutions, 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. Foresight experts all over the world are committed to provide support in the implementation of respective 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. The UN-CSTD promotes collaboration between scientific communities and other relevant stakeholders to think, debate and shape future developments.

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